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STUDY OF LH_2 FUELED SUBSONIC PASSENGER TRANSPORT AIRCRAFT

by G. D. Brewer & R. E. Morris

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16. ABSTRACT

This extension of a previous study to investigate the potential of using liquid hydrogen as fuel in subsonic transport aircraft, was performed to explore an expanded matrix of passenger aircraft sizes. Aircraft capable of carrying 130 passengers 2,780 km (1500 n.mi.); 200 passengers 5,560 km (3000 n.mi.); and 400 passengers on a 9,265 km (5000 n.mi.) radius mission, were designed parametrically. Both liquid hydrogen and conventionally fueled versions were generated for each payload/range in order that comparisons could be made. Aircraft in each mission category were compared on the basis of weight, size, cost, energy utilization, and noise.

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FOREWORD

This is the final report of work performed as an addendum to a previously completed study of hydrogen fueled subsonic transport aircraft (Reference 1). This work was performed under Modification No. 4 of Contract NAS 1-12972 for NASA - Langley Research Center. The report is documentation of the substance of work performed during the period 20 June through 20 December, 1975.

The study was performed within the Advanced Design Division of the Science and Technology Organization at Lockheed - California Company, Burbank, California. G. Daniel Brewer was study manager and Robert E. Morris was project engineer. Other participants were

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All computations were performed in U.S. Customary units and then converted to S.I. units.

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NOMENCLATURE

AR	=	Aspect Ratio
ATA	=	Air Transport Association
b	=	Wing Span
BPR	=	Bypass Ratio
Btu	=	British Thermal Unit
C_v	=	Velocity Coefficient
CPR	=	Compressor Pressure Ratio
DOC	=	Direct Operating Cost
DTAM	=	Deviation from std. ambient Temperature
FAR	=	Federal Air Regulation
F_N	=	Net Thrust
FPR	=	Fan Pressure Ratio
GH_2	=	Gaseous Hydrogen
HP	=	High Pressure
Jet A	=	Conventional Hydrocarbon Fuel

NOMENCLATURE (Continued)

KEAS	=	Knots Equivalent Airspeed
L/D	=	Lift-to-Drag Ratio
LH_2	=	Liquid Hydrogen
LP	=	Low Pressure
M	=	Mach Number
MAC	=	Mean Aerodynamic Chord
OPR	=	Overall Pressure Ratio
Pax.	=	Passenger
Sw	=	Wing Reference Area
SFC	=	Specific Fuel Consumption
SLS	=	Sea Level Static
T/W	=	Thrust to Weight Ratio
TIT	=	Turbine Inlet Temperature
t_c	=	Wing Thickness Ratio
$\bar{V}$	=	Tail Volume Coefficient
Vapp	=	Landing Approach Velocity

NOMENCLATURE (Continued)

Vo	=	Flight Velocity
Vr	=	Takeoff Rotate Velocity
V_2	=	Takeoff Safety Speed
Vs	=	Stall Velocity
$W_a \frac{\sqrt{\theta_{T_2}}}{\delta_{P_2}}$	=	Engine Corrected Airflow
W_g	=	Gross Weight
W_{pod}	=	Engine Pod Weight
W/S	=	Wing Loading (weight/wing area)
δ_{P_2}	=	Delta P_2 = P_{T_2} PSIA/14.7
θ_{T_2}	=	Theta T_2 = T_{T_2} °K/288.2

STUDY OF LH_2 FUELED SUBSONIC PASSENGER TRANSPORT AIRCRAFT

G. D. Brewer and R. E. Morris
Lockheed-California Company

SUMMARY

The work reported herein is supplemental to an original study performed for NASA - Langley Research Center in 1974 (Reference 1). In that study two different LH_2 passenger aircraft designs were established, one of which carried the fuel within the fuselage in tanks located both forward and aft of the passenger compartment; the other, in tanks mounted on short pylons above the wing at about midspan. Versions of these internal and external tank LH_2 airplane designs were configured to carry 400 passengers two different ranges: 5560 km (3000 n.mi.) and 10,190 km (5500 n.mi.).

The present study extended the scope of missions considered for the LH_2 fueled aircraft as follows:

130 passengers	2780 km	(1500 n.mi.)
200 passengers	5560 km	(3000 n.mi.)
400 passengers	9265 km	(5000 n.mi.) radius

As noted, the longer range mission was specified as a radius. The aircraft was designed to fly 9265 km, land, and return to point of origin without refueling, carrying full design payload both directions and providing for specified reserve fuel for both landings.

Both internal tank and external tank LH_2 designs were defined for the short and medium range missions. Only the internal tank concept was considered for the long range requirement. For all three missions, equivalent designs of conventionally fueled aircraft were identified to provide a basis for comparison and evaluation.

One of the objectives of the work was to determine if the external tank LH_2 design concept would begin to show design advantages, or at least design equivalence, with the internal tank concept at the low fuel load missions. It apparently does not. Even for the short range mission the external tank design was clearly not competitive. This stems from the dual, but imcompatible, needs to design the external tanks with a high fineness ratio for aerodynamic acceptability on the one hand, but with a low surface-to-volume ratio on the other to achieve low heat leak with minimum insulation thickness and weight. On small aircraft the external tanks account for an increasing percentage of total aircraft drag.

A summary of selected data for the preferred, internal tank LH_2 aircraft and for the corresponding Jet A fueled designs for all three of the subject missions is presented in the table on page 3.

One of the objectives of the study was to determine if a crossover point could be predicted, i.e., a design mission requiring such a small amount of Jet A fuel that an equivalent LH_2 fueled aircraft would offer no advantage. The short range mission of this study appears to be at or near that crossover point. The internal tank LH_2 aircraft and the corresponding Jet A design are virtual standoffs. Since the LH_2 aircraft designed for the longer range, larger payload missions do show advantage over corresponding aircraft, it is presumed that for a mission requiring even less energy than the short range mission of this study, the Jet A airplane would be preferred.

As in the previous study, the results show that use of LH_2 fuel provides significant advantages in long range aircraft. The more energy required to perform the mission, the greater the advantage to be gained by using a high energy fuel. The long range LH_2 aircraft of this study are lighter; require smaller wing area and shorter span but larger, longer fuselages; use smaller engines; can operate from shorter runways; and use 25 percent less energy to perform the mission. Further, the LH_2 airplane would cost less both to develop and to produce. A differential of $1.00 more per GJ ($1.05/10^6 Btu) can be paid for LH_2, relative to a current price

S.I. Units

		Short Range [130 Passengers 2780 km]		Medium Range [200 Passengers 5560 km]		Long Range [400 Passengers 9265 km radius]	
		LH_2	Jet A	LH_2	Jet A	LH_2	Jet A
Gross Weight	kg	44,600	49,300	81,400	58,400	266,400	450,200
Total Fuel Wt.	kg	3,360	8,940	9,480	27,720	68,500	238,000
Operating Empty Wt.	kg	28,300	27,400	51,900	50,700	158,100	172,600
Thrust/Weight	N/kg	3.43	3.43	3.33	2.75	2.65	1.96
Number of Engines	-	2	2	4	4	4	4
Thrust per Engine	N	75,600	84,100	66,700	68,100	175,300	221,100
Wing Area	m^2	84.7	86.3	148.8	154.6	466	662
Span	m	29.3	30.8	37.5	38.7	68.3	85.3
Fuselage Length	m	42.7	34.4	52.7	44.2	77.4	68.6
FAR T.O. Distance	m	2,410	2,430	1,640	2,432	2,106	3,650
Price per Aircraft	$\$10^6$	7.85	7.51	13.95	13.33	38.90	40.0
Noise							
Sideline	EPNdB	86	86	86	86	94	93
Flyover	EPNdB	79	79	82	86	93	100
Energy Utilization	$\frac{kJ}{Seat\ km}$	763	734	631	876	950	1,210

U.S. Customary Units

		Short Range [130 Passengers 1500 n.mi.]		Medium Range [200 Passengers 3000 n.mi.]		Long Range [400 Passengers 5000 n.mi. radius]	
		LH_2	Jet A	LH_2	Jet A	LH_2	Jet A
Gross Weight	lb	98,300	108,700	179,500	216,900	587,400	992,500
Total Fuel Wt.	lb	7,400	19,700	20,900	61,100	150,900	524,000
Operating Empty Wt.	lb	62,300	60,400	114,500	111,800	348,500	380,500
Thrust/Weight	-	0.35	0.35	0.34	0.28	0.27	0.20
Number of Engines	-	2	2	4	4	4	4
Thrust per Engine	lb	17,000	18,900	15,000	15,300	39,400	49,600
Wing Area	ft^2	912	929	1,602	1,664	5,020	7,125
Span	ft	96	101	123	127	224	280
Fuselage Length	ft	140	113	173	145	254	225
FAR T.O. Distance	ft	7,890	7,970	5,380	7,980	6,910	11,970
Price per Aircraft	$\$10^6$	7.85	7.51	13.95	13.33	38.90	40.00
Noise							
Sideline	EPNdB	86	86	86	86	94	93
Flyover	EPNdB	79	79	82	86	93	100
Energy Utilization	$\frac{Btu}{Seat\ n.mi.}$	1,340	1,290	1,460	1,540	1,670	2,120

for Jet A, and still have equal direct operating cost. The LH_2 design is 6 EPNdB quieter in flyover noise, but slightly noisier in sideline and approach compared to the Jet A counterpart.

Advantages for the LH_2 aircraft not reassessed in this supplementary study, but which nevertheless pertain, are the significant reduction in noxious exhaust products reported in Reference 1, and the fact that aircraft designed for initial operation in 1990-1995 will have normal service life long after Jet A - type fuel is expected to become increasingly unavailable and expensive around the world.

1. INTRODUCTION

This work is an addendum to a study performed in 1974 for NASA-Langley Research Center to evaluate the feasibility, practicability, and desirability of using liquid hydrogen (LH_2) as fuel in subsonic transport aircraft. NASA CR-132558 and 132559 (Reference 1), dated January 1975, are the Summary and Final reports, respectively, of the original study. That work involved investigation of both passenger and cargo type aircraft. The passenger vehicles were all capable of carrying 400 passengers plus appropriate cargo for a total of 36,300 kg (88,000 lb) of payload. Aircraft designed for two ranges, 5560 km (3000 n.mi.) and 10,190 km (5500 n.mi.) and for cruise speeds of Mach 0.80, 0.85, and 0.90 were evaluated. In addition, aircraft capable of carrying 600 and 800 passengers were also investigated for both ranges but for only Mach 0.85 cruise speed. Cargo aircraft capable of carrying 56,700 kg (125,000 lb) and 113,400 kg (250,000 lb) were designed for ranges of 5560 km (3000 n.mi.) and 10,190 km (5500 n.mi.), respectively. All cargo aircraft were designed for Mach 0.85 cruise speed.

In the present study, the payload and range spectrum of the passenger aircraft was enlarged to involve aircraft of the following capability, all designed to cruise at Mach 0.85:

	Passengers	Range	
		km	(n.mi.)
Short range mission	130	2780	(1500)
Medium range mission	200	5560	(3000)
Long range mission	400	9265 radius	(5000) radius

For the short and medium range missions, LH_2 fueled aircraft using both internal and external tank design concepts illustrated by the artist's rendering in Figure 1, taken from Reference 1, were parametrically evaluated.

The long range mission was different in that the range requirement was stated as an unrefueled radius capability. The aircraft was intended to fly

Figure 1. Illus ration of External and Internal Tank LH_2 Aircraft

9265 km (5000 n.mi.), land, and then return to the point of origin unrefueled with full payload and with full allowances for reserve fuel for both landings. For this mission, only the internal tank design of LH_2 fueled aircraft was investigated.

For all missions, as in the case of the original study, reference aircraft using conventional (Jet A) fuel were designed to the same guidelines and technology to provide a basis for valid comparison.

All aircraft incorporate such advanced technology concepts as are forecast to be available for designs which might be ready for initial operational use in 1990-1995.

Since the subject work is a "follow-on" to an earlier study and uses the basic LH_2 airplane design concepts developed and described in Reference 1, only revisions and modifications to the designs and the results derived therefrom are reported in full in this report. The reader interested in the background leading to derivation of the original airplane design concepts should refer to NASA CR-132559 (Reference 1).

2. TECHNICAL APPROACH

This investigation expanded the matrix of passenger aircraft missions which were studied under the original contract (Reference 1). The complete list of aircraft evaluated herein is shown in Table I.

As noted, the long range aircraft were designed to fly 9256 km (5000 n.mi.) carrying full allowance for reserve fuel (per ATA international definition), land, takeoff without refueling, fly 9265 km (5000 n.mi.) and land with final reseves calculated on the basis of the airplane weight at the end of cruise for the second leg.

TABLE I. AIRCRAFT DESIGNS REQUIRED

Aircraft Number	Passenger Load	Range km	Range (n.mi.)	Fuel	Configuration
Short Range					
1	130	2780	(1500)	LH_2	Internal Tank
2	130	2780	(1500)	LH_2	External Tank
3	130	2780	(1500)	Jet A	Conventional
Medium Range					
4	200	5560	(3000)	LH_2	Internal Tank
5	200	5560	(3000)	LH_2	External Tank
6	200	5560	(3000)	Jet A	Conventional
Long Range					
7	400	9265 radius	(5000) radius	LH_2	Internal Tank
8	400	9265 radius	(5000) radius	Jet A	Conventional

Guidelines used in the present study were the same as those which served as a basis for the work in the original study (Reference 1) with the exception that the short and medium range aircraft used reserve fuel quantities as defined by the ATA for domestic flights. The long range aircraft continued to use the ATA international reserve definition. The same differences in basis for calculating direct operating costs applied; the short and medium range aircraft were treated as domestic flights per the 1967 ATA equations, while the long range aircraft were treated as international carriers. For convenience, Table II presents the complete list of updated guidelines which were used in the present study. It should be noted that the allowable runway length for the long range aircraft was extended to 3600 m (12,000 ft). The basis for this revision is discussed in Section 6.

The technical approach employed was essentially the same as that described in Reference 1 for the original study. Preliminary sizing and conceptual design studies established baseline sizes, weights, and configurations for each of the eight aircraft. The resulting preliminary configuration drawings were then used as a basis for assessment of

- stability and control requirements
- structural and weight relationships
- drag characteristics
- propulsion requirements
- tank insulation requirements

as required for the various aircraft.

The results of these analyses, plus the preliminary sizing data, provided input to the ASSET (Advanced System Synthesis Evaluation Technique) computer program for parametric determination of preferred vehicle design characteristics. The performance capability, weight, and cost of aircraft designs derived for each of the specified set of requirements were determined by detail analysis of the carpet-type Autoplots produced from ASSET printout data. The criterion used as an ultimate basis for selecting

TABLE II. BASIC GUIDELINES

Fuel: Liquid Hydrogen (assumed available at airport for this study)

Initial Operational Capability: 1990-95

Advanced Aircraft Technologies:

- Supercritical aerodynamics
- Composite materials
- Active controls
- Terminal area features

Advanced Engines: Contractor-derived performance for both LH_2 and Jet A fueled turbofans

Noise Goal: 5.18 km^2 (2 mi^2) area for 90 EPNdB contour (sum of takeoff + approach)

Emission Limit Goals:

● Ground Idle	CO	14 gm/kg fuel burned
	UHC	2 gm/kg fuel burned
● Takeoff Power	NO_x	13 gm/kg fuel burned
	Smoke	SAE 1179 Number 25

Landing and Takeoff: 32.2°C (90°F) day, 304.8 m (1000 ft) altitude.
2410 m (8000 ft) runway for short and medium range aircraft.
3660 m (12,000 ft) runway for long range aircraft.

Fuel Reserves: ATA guidelines (Reference 2)

- Use domestic definition for short and medium range aircraft
- Use international definition for long range aircraft

Direct Operating Cost:

- Utilization: Short Range - 3300 hrs/yr
  Medium Range - 3600 hrs/yr
  Long Range - 7000 hrs/yr
- 1967 ATA equations

  international basis for long range aircraft.

  domestic basis for short and medium range aircraft.
- 1973 Dollars
- 350 aircraft production base
- Baseline fuel costs

  LH_2 = \$2.85/GJ (\$3/10^6 Btu = 15.48¢/lb)

  Jet A = \$1.90/GJ (2/10^6 Btu = 24.8¢/gal = 3.68¢/lb) preferred vehicle design characteristics was minimum direct operating cost (DOC). Final design three-view general and interior arrangement drawings of each of the eight aircraft were then made to reflect the results of the analysis. Noise levels for preferred LH_2 aircraft and the Jet A counterpart for each mission were then determined.

The characteristics of the eight aircraft were compared to the extent possible. Since this study was simply an evaluation of a matrix of aircraft designed to perform specified payload/range combinations, and was not planned specifically as a study to determine performance trands, there was little which could be concluded by comparing aircraft of the various missions. Comparisons were basically limited to evaluating internal tank versus external tank LH_2 designs within each of the three range categories, and then comparing the preferred LH_2 design with the corresponding Jet A airplane. The only exception to this was an opportunity to establish a three-point curve and thus provide a basis for comparison between range categories involving the 400 passenger aircraft. Aircraft from the long range mission of the present study were correlated with final design 400 passenger aircraft of the original study (Reference 1). In order to make this comparison valid the conventional oneway range capability of the aircraft from the current study were determined, as contrasted with their mission radius capability.

3. TECHNOLOGY MODIFICATIONS

3.1 Propulsion

The high bypass ratio turbofan engine data developed for the original LH_2 subsonic aircraft study (Reference 1) were based on predictions of component efficiencies and weight for advanced (1985-1990) state-of-the-art technology. The baseline engine size for that study was set at 155.7 kN (35,000 lb) for the sea level static (SLS) design point. This was achieved with a 1.51 fan pressure ratio (FPR) and a 35.0 overall pressure ratio (OPR). The engine data used was estimated to be scaleable to approximately 70 percent of the base engine size without changes in component efficiencies or overall cruise specific fuel consumption (SFC).

The same engine data were used in the present study, within limits of scale. For a description of the basis for derivation of the point design engine cycle parameters, and for a tabulation of the engine design and performance characteristics, see Section 3.2, starting on Page 30, Reference 1.

In addition to the baseline engine, the current study required that engine data be developed for smaller aircraft which would otherwise require scaling the baseline engines to approximately 35-45 percent. Such scaling would obviously result in some degradation of component efficiencies and, therefore, overall engine performance. This is basically due to the effects of reducing the size of the high pressure (HP) module of the engine. Specifically, the problem is related to the ratio of the HP compressor and turbine blade tip clearances to the blade height becoming relatively large compared to the baseline engine size - thereby making the originally assumed HP rotor presssure ratios and component efficiencies very difficult to achieve.

Because of this size (efficiency) problem, a new baseline engine cycle was defined for the smaller aircraft. It was sized to produce 53.4 kN (12,000 lb) thrust (SLS) and has a more moderate overall pressure ratio of 25.0, achieved with the same 1.51 FPR and a 16.67 compressor pressure ratio (CPR). The average pressure rise per axial stage would be approximately the same (1.37) as the large engine, however, only nine axial stages are required to achieve the lower compressor pressure ratio. The estimated polytropic efficiency for the design point HP compressor of such a configuration is 90 percent (decreased from 92 percent), and the estimated turbine adiabatic efficiency is 89.5 percent (decreased from 91 percent) to account for size effects at the lower design pressure ratio.

The small engine design point cycle characteristics are presented in Table III for both the LH_2 and Jet A fueled engines. Some weight and dimensional characteristics of a typical installation of the 53.4 kN (12,000 lb) thrust size engine are shown in Tables IV and V. Table IV presents the wing pod weight buildup and Table V defines the nacelle dimensions. Nacelle scaling, resulting from small engine thrust perturbations, are referenced to the 53.4 kN (12,000 lb) thrust size and scaled with the equations provided in Table V.

The reduction in overall engine pressure ratio from 35.0 to 25.0 results in a 4.5 percent increase in cruise specific fuel consumption (SFC) and the decrease in HP component efficiency increases the SFC an additional 1.5 percent. Therefore, the total cruise SFC increase for both the LH_2 and Jet A fueled engines is approximately 6 percent, relative to the large thrust engine. A typical cruise SFC comparison for the LH_2 fueled engines is shown in Figure 2. All rated power thrust levels were scaled directly by the thrust change.

3.2 Hydrogen Tankage

The wide range of sizes of aircraft investigated in this study necessitated a review of the work done on hydrogen tankage in the previous contract (Reference 1). In particular, the smaller aircraft were examined with regard to tank, insulation, and cover weights as the tanks (internal and external)

TABLE III. SMALL ENGINE DESIGN POINT DATA, SEA LEVEL STATIC - STANDARD DAY

	Hydrogen Fueled		Jet A Fueled	
I. Base Size Engine				
Installed Net Thrust	53.4 kN	(12,000 lb)	53.4 kN	(12,000 lb)
Installed S.F.C.	0.098 kg/hr/daN	(0.100 lb/hr/lb)	0.292 kg/hr/daN	(0.298 lb/hr/lb)
Turbine Inlet Temperature	1416°C	(3040°R)	1416°C	(3040°R)
Bypass Ratio		12.8		10.8
Overall Pressure Ratio		25.0		25.0
Jet Exhaust Velocity	254.5 m/sec	(835 ft/sec) (V_j PRI & V_j duct matched @ SLS)	254.5 m/s	(835 ft/sec)
II. Fan Design				
Stages		1		1
Airflow - $W_a \sqrt{\theta_{T_2}}/\delta_{P_2}$	212 kg/sec	(468 lb/sec)	212 kg/sec	(466 lb/sec)
Pressure Ratio		1.51		1.51
Polytropic Efficiency		91%		91%
Diameter	1.26	(149.6 in.)	1.26 m	(149.6 in.)
Tip Velocity	249 m/sec	(817 ft/sec)	249 m/sec	(817 ft/sec)
Fan Face Mach No.		0.56		0.56
Hub/Tip Ratio		0.36		0.36
III. Compressor Design				
Compressor Pressure Ratio		16.7		16.7
Polytropic Efficiency		90.0%		90.0%
Airflow	15.2 kg/sec	(33.4 lb/sec)	17.8 kg/sec	(39.3 lb/sec)
IV. Combustor				
Efficiency		100%		100%
Total Pressure Loss		4.5%		4.5%
V. High Pressure Turbine				
Pressure Ratio		3.2		3.8
Stages		2		2
Adiabatic Efficiency		89.5%		88.5%
Cooling Air		0		5%
VI. Low Pressure Turbine				
Pressure Ratio		6.5		5.4
Stages		4		4
Adiabatic Efficiency		91%		91%
Cooling Air		0		0
VII. Nozzle Design				
Configuration		Coplanar, fixed convergent nozzle		Same
Performance - (Vel. Coef.)				
A. Primary C_v		0.995		0.995
B. Fan C_v		0.995		0.995
VIII. Acoustic Treatment				
A. Inlet	Variable geometry throat – Throat Mach = 0.8 during takeoff and approach, inlet wall treatment			Same
B. Exhaust – 1. Fan Duct	All treatment on both core engine and outer wall, one treated duct ring			Same
2. Primary	Wall treatment			Same
IX. Nacelle Geometry				
Maximum Diameter	1.26 m	(62 in.)		
Overall Length	4.22 m	(166 in.)		
Inlet Highlight Diameter	1.28 m	(51 in.)		Same
Inlet Throat Diameter	1.17 m	(46 in.)		
Cruise Throat Mach Number		0.73		

TABLE IV. SMALL ENGINE PROPULSION SYSTEM WEIGHT

Base Thrust = 53.4 kN (12,000 lb) (SLS, Installed)

TIT = 1416°C (3040°R), OPR = 25.0

Fan Pressure Ratio = 1.51

Item	kg	lb
Bare Engine	839.2	1850
Accessories and Gear Box	74.8	165
Inlet, Variable Geometry	156.5	345
Mounting Brackets and Pylon Splitter Fairing	31.8	70
Nacelle	154.2	340
Gas Generator Cowl and Tail Pipe	79.4	175
Fan Duct Acoustic Ring	43.1	95
Thrust Reverser	97.5	215
Total Pod Weight (per Engine)	1476.5	3255

TABLE V. SMALL ENGINE NACELLE DESIGN CHARACTERISTICS

Base Thrust = 53.4 kN (12,000 lb) (SLS, Installed)

Fan Hub/Tip Ratio	= 0.35
Fan Tip Diameter	= 1.26m (49.6 in.)
Max Nacelle Diameter	= 1.58m (62.2 in.)
Max Nacelle Length	= 4.22m (166.1 in.)

NACELLE SCALING DATA

$$\text{WT. POD} = \text{WT}_{\text{POD(REF)}} \left(\frac{F_{N_{SLS}}}{F_{N_{SLS\,(REF)}}} \right)^{1.07}$$

$$\text{DIA.} = \text{DIA}_{\text{(REF)}} \left(\frac{F_{N_{SLS}}}{F_{N_{SLS\,(REF)}}} \right)^{0.50}$$

$$\text{LENGTH} = \text{LENGTH}_{\text{(REF)}} \left(\frac{F_{N_{SLS}}}{F_{N_{SLS\,(REF)}}} \right)^{0.45}$$

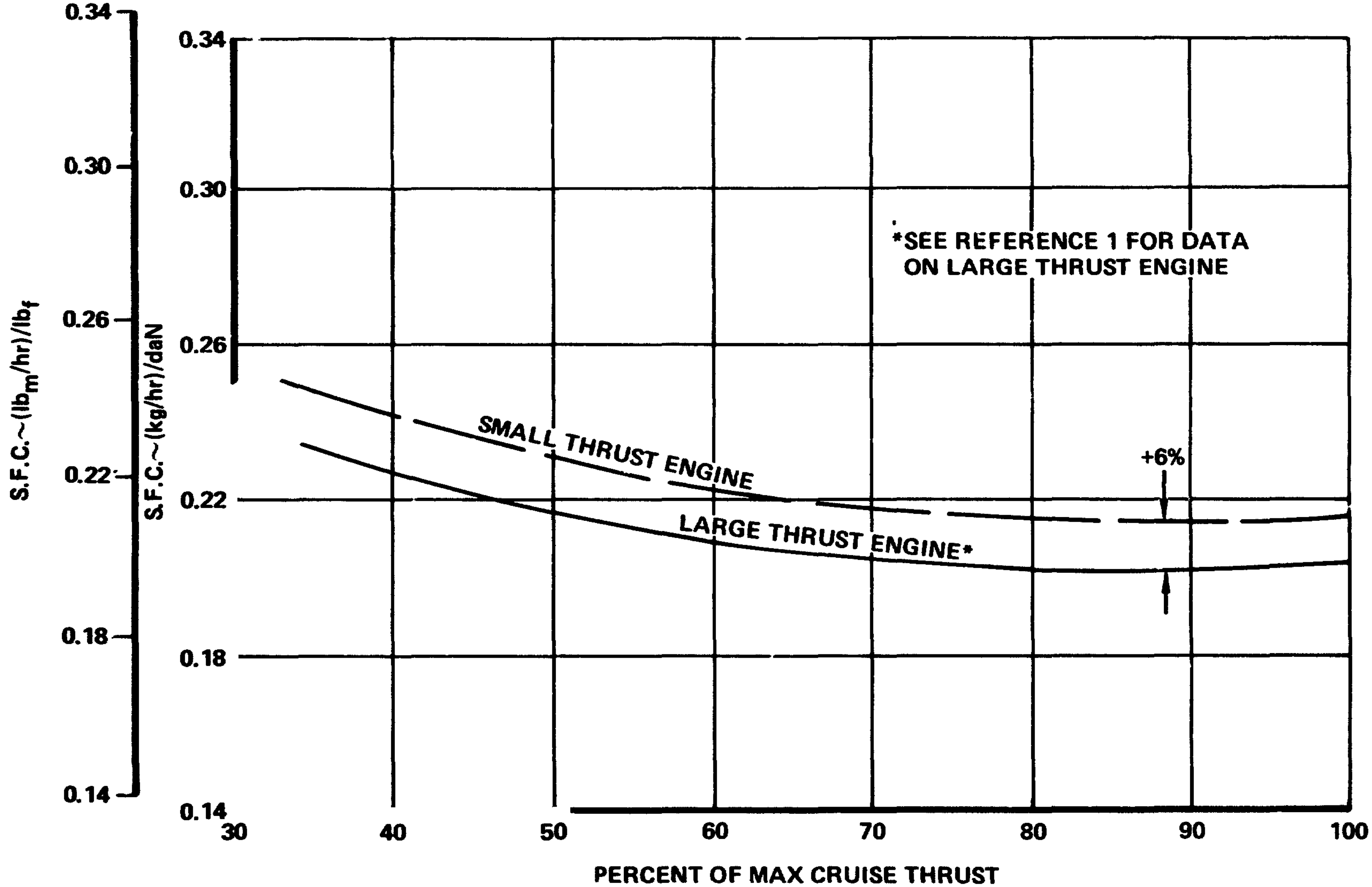


Figure 2. Installed Cruise SFC Versus Percent Maximum Rated Thrust 10,668 m (35,000 ft), Mach 0.85, Standard Day (LH_2 Fueled Engines)

became smaller. A preliminary analysis was made to examine trends based on the following assumptions:

- Range of gross weights: 45,360 to 181,440 kg (100,000 to 400,000 lb)
- 3780 km (1,500 n.mi.) range
- Constant fuel fractions
- External tank length-to-diameter ratio (l/d) = 6.5
- Constant wing loading of 527 kg/m^2 (108 lb/ft^2)

It was further assumed that the percent boil-off remained constant. This required an increase in insulation thickness as the ratio of tank wetted area-to-volume increased since boil-off is approximately proportional to this ratio. Figure 3 shows the results of this investigation and indicates that:

1. The external tank has a higher ratio of wetted area-to-volume than the internal tank.
2. This results in the much higher ratio of insulation and cover weight fractions as indicated. (Note, tank weight not included).
3. The effect of the addition of the tank wetted areas on the aircraft L/D is shown at the top of the figure compared to a clean (no tank) configuration. The internal tank aircraft L/D decreases 4.1 percent while the external tank L/D reduction is 15.8 percent over the gross weight range from 45,360 to 181,440 kg (100,000 to 400,000 lb).

These results show that the insulation thickness and weight must be adjusted as the size of the tanks decreases. This was done in providing the input data to ASSET for the parametric aircraft study. The results also indicate that the external tank aircraft will suffer more severe weight and aerodynamic penalties relative to the internal tank design as the aircraft size is decreased.

3.3 Weight Allowances

The aircraft designs which were considered in the present study represent a wide range of passenger requirements. This necessitated adjustment of those items of equipment associated with providing services to passengers. The

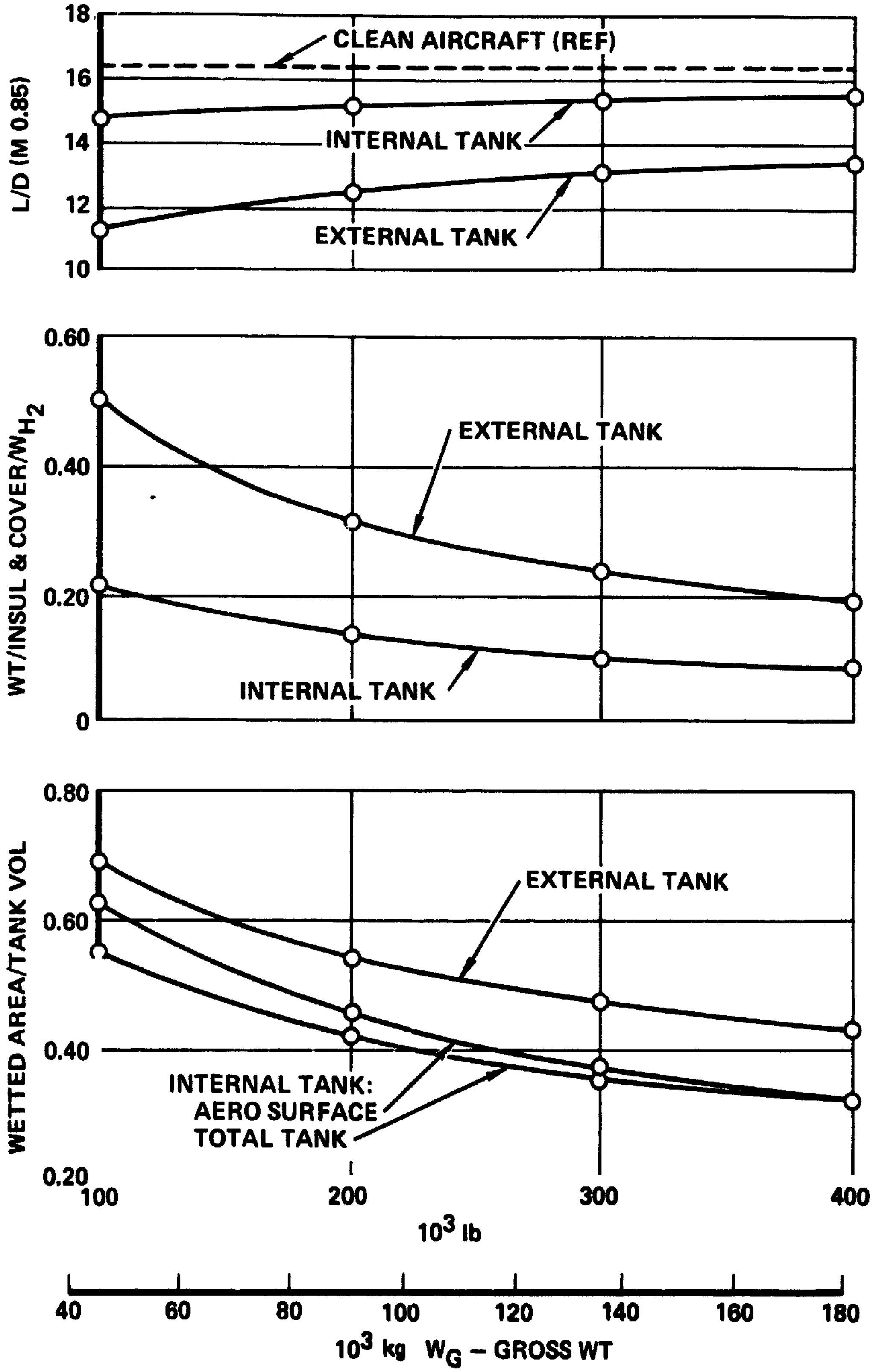


Figure 3. Results of Analysis of Hydrogen Tanks

adjustment is basically a function of the number of passengers carried, and the design range. As previously defined, the short range aircraft carry 130 passengers 2780 km (1500 n.mi.), the medium range aircraft carry 200 passengers 5560 km (3000 n.mi.), and the long range aircraft carry 400 passengers 9265 km (5000 n.mi.) each way, out and back. Table VI shows values which were used for these items which required such adjustment.

There was also a small adjustment in the weight of escape slide/rafts as a result of the fact the LH_2 aircraft designed for the long range mission is double decked. Its conventionally fueled counterpart is not, all 400 passengers are carried on a single deck. Accordingly, as shown on the table, the weight of escape slide/rafts provided for the LH_2 airplane is 810 kg (1786 lb) while that for the Jet A design is 623 kg (1374 lb).

Other weight changes to the short range aircraft include addition of air stairs (2) and deletion of certain navigation and communication equipment not required for short, over-land flight.

TABLE VI. PASSENGER SERVICE EQUIPMENT

	Short Range	Medium Range	Long Range
Escape Slide/Rafts kg (lb)	160 (353)	203 (448)	810 (1786)-LH_2 623 (1374)-Jet A
Food Allowance/Pass. kg (lb)	3.74 (8.24)	4.65 (10.24)	6.91 (15.24)
Water Allowance/Pass. kg (lb)	0.73 (1.6)	0.91 (2.0)	1.42 (3.12)
Pass. Serv. Equip./ Pass. kg (lb)	0.95 (2.1)	1.27 (2.8)	1.81 (4.0)
Cargo Containers-Total kg (lb)	0.0	1470 (3240)	1960 (4320)
Serving Carts-Total kg (lb)	330 (726.)	494 (1090)	989 (2180)
No. of Cabin Attendents	4.0	5.0	8.0
No. of Lavatories	3.0	4.0	7.0

4. SHORT RANGE AIRCRAFT

4.1 Design Requirements

The short range aircraft are designed to meet the following requirements and constraints:

- 2780 km (1500 nmi) design range
- 130 passengers plus baggage and cargo for a total payload of 12,970 kg (28,600 lb)
- Maximum FAR takeoff field length of 2438 m (8000 ft)
- Minimum initial cruise altitude of 10,360 m (34,000 ft)
- Reserve fuel per ATA domestic regulations.
- Maximum approach speed of 69.4 m/s (135 KEAS) for aircraft weight corresponding to end of design range

4.2 Configuration Selection

Because of the small size and range of the aircraft, extended over-water operation was not envisioned and a two-engined configuration was selected. This requires an engine-out second segment climb gradient of at least 2.4 percent during takeoff.

The short range two-engined aircraft, in contrast to the medium and long range version which were investigated in the original study (Reference 1), offered the most possibilities for variations in configuration. Some of the variations investigated were:

1. Aft mounted engines as shown in Figure 4 for the internal tank hydrogen fuel version and in Figure 5 for the external. This is a viable configuration for the internal tank aircraft but presents some aerodynamic, and structural dynamic problems in the external tank version.

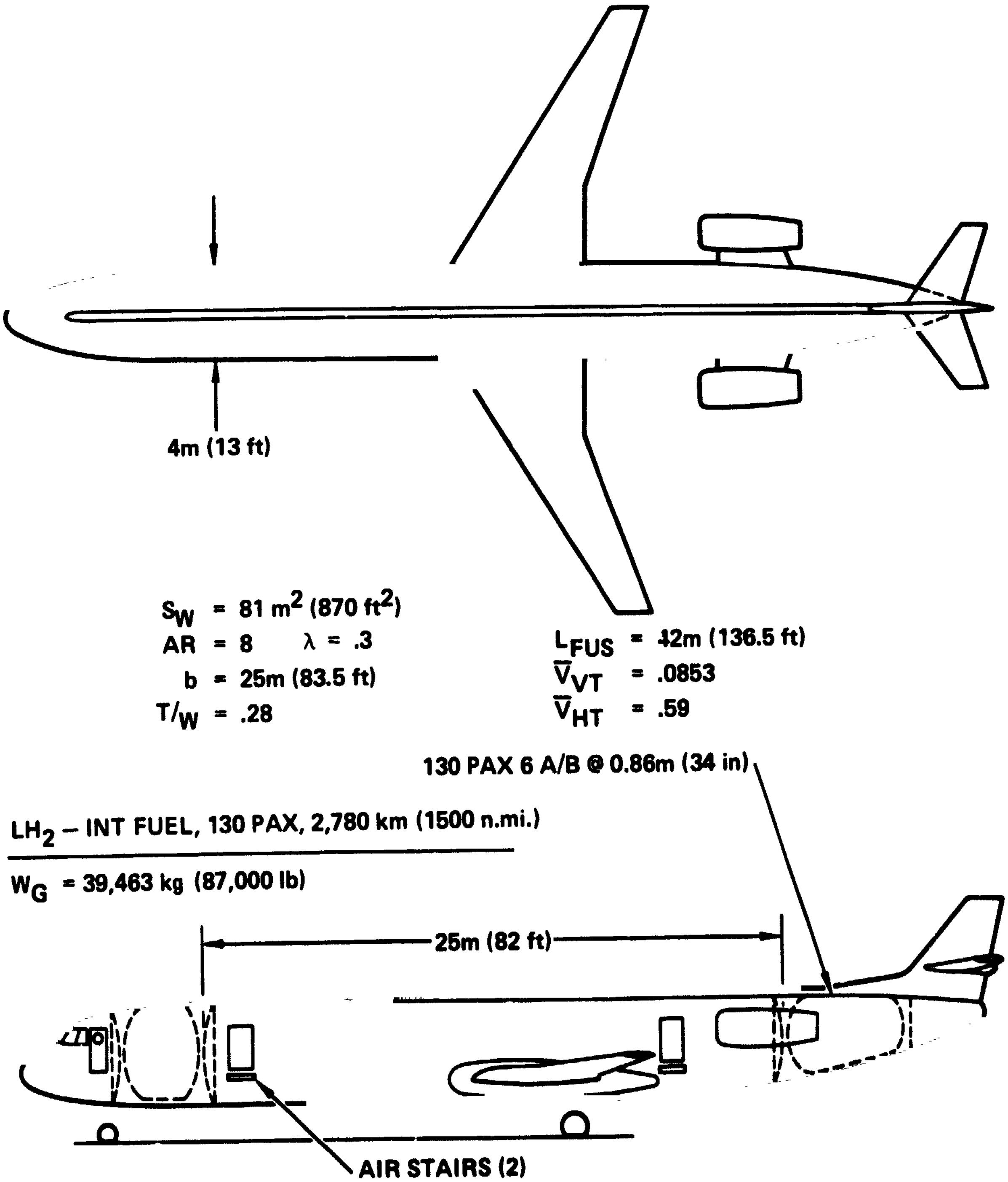


Figure 4. Candidate Configuration - Internal Tanks, Aft Mounted Engines

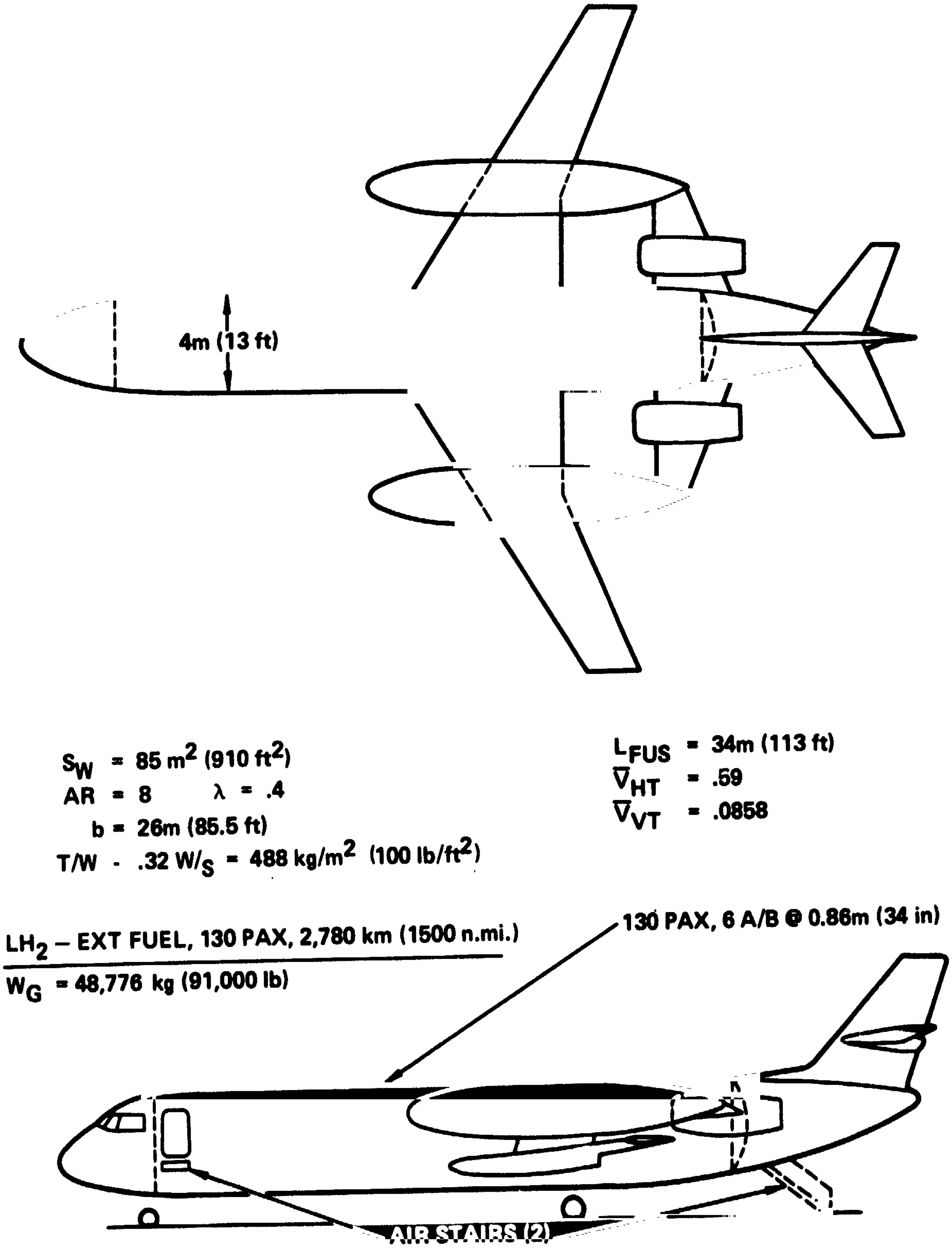


Figure 5. Candidate Configuration - External Tanks, Aft Mounted Engines

2. A high-winged configuration with underwing mounted engines for both internal and external tanks. This configuration presented no advantage over the low wing aircraft and had the problem of landing gear location and storage and also vulnerability of the internal fuel tanks to a wheels-up landing due to having no heavy wing box for protection as is the case with low winged aircraft. Another disadvantage is the passenger cabin exposure to an engine burst due to absence of the wing box.

3. A version of the aft-engined internal tank hydrogen fuel aircraft in which all fuel is carried in a single aft tank was also considered. This arrangement has the advantage of placing all fuel and propulsion in a package aft of the passengers. The obvious disadvantage with this concept is the excessive c.g. travel, estimated at 75 percent of MAC. This requires a horizontal tail approximately twice as large as is the case when the fuel is located fore and aft. Other disadvantages are the exposure of the tank to damage, and structural weight penalties due to the cantilevered tank and tail junction.

The concept chosen for analysis was a conventional low-winged design with under-wing mounted engines as described in the following sections. This configuration allows for maximum flexibility in going from the internal to the external hydrogen tanks and is adaptable to the Jet A version as well. This insures a high degree of commonality between all the designs for comparison purposes.

4.3 LH_2 Internal Tank Airplane (Aircraft No. 1)

The parametric study was conducted using the ASSET vehicle synthesis program described in Section 4.3, Reference 1. In the previous study, a comprehensive investigation was made to determine the influence of wing geometry (thickness ratio, taper ratio, and sweep) on vehicle performance. Those characteristics found to be optimum for Mach 0.85 cruise were retained for this study. The primary consideration in the present work was selection of wing aspect ratio as described below.

4.3.1 Aspect Ratio Selection. - From a matrix of some 64 aircraft generated by the vehicle synthesis program, i.e., 16 aircraft for each of four candidate aspect ratios (8,10,12, and 14) one aircraft which met all the performance constraints was selected for each aspect ratio. The variation of the selection criteria; DOC, gross weight, price, and block fuel for these point design aircraft is presented in Figure 6 as a function of aspect ratio. This figure indicates that if the selection criteria were minimum airplane purchase price and gross weight an aspect ration of 8 would be chosen. If minimum block fuel were desired, it would be 14. Since minimum DOC was specified as the ultimate selection criterion to be used in event of conflict, an aspect ratio of 10 was selected. Following this choice, all synthesis program input data was reviewed, revised where required, and the final point design aircraft was generated. This method of selecting the final configuration was used for each of the study aircraft.

Since two-engined aircraft are critical with regard to field length and climb gradient with one engine out, a subroutine of ASSET was used to determine the optimum takeoff flap setting and overspeed (V_2/V_S) ratio to meet these constraints with any given combination of thrust-to-weight, aspect ratio, and wing loading.

4.3.2 Configuration Description. -- A general arrangement drawing of the LH_2 internal tank, Mach 0.85, 2280 km (1500 n.mi.), 130 passenger aircraft is shown in Figure 7. The passenger compartment is located in the central section of the fuselage. Liquid hydrogen fuel tanks are located fore and aft of the passenger compartment. They occupy the full available cross section of the fuselage, except for provision for protective, crushable structure around the bottom areas. No provision was made for a passageway through or around the forward tank to permit movement between flight station and passenger compartment. The flight station is provided with separate lavatory and galley facilities.

Passenger accommodations, shown in Figure 8, use 6 abreast seating and seat spacing of 0.8 m (34 in.). The arrangement provides doors, lavatory and galley facilities in accordance with requirements of FAR 25 and current wide-body standards. Air stairs are provided at both portside doors. All cargo is contained in the pressurized fuselage below the cabin floor where space is provided for cargo containers and for loose cargo. Further details of the design are as follows:

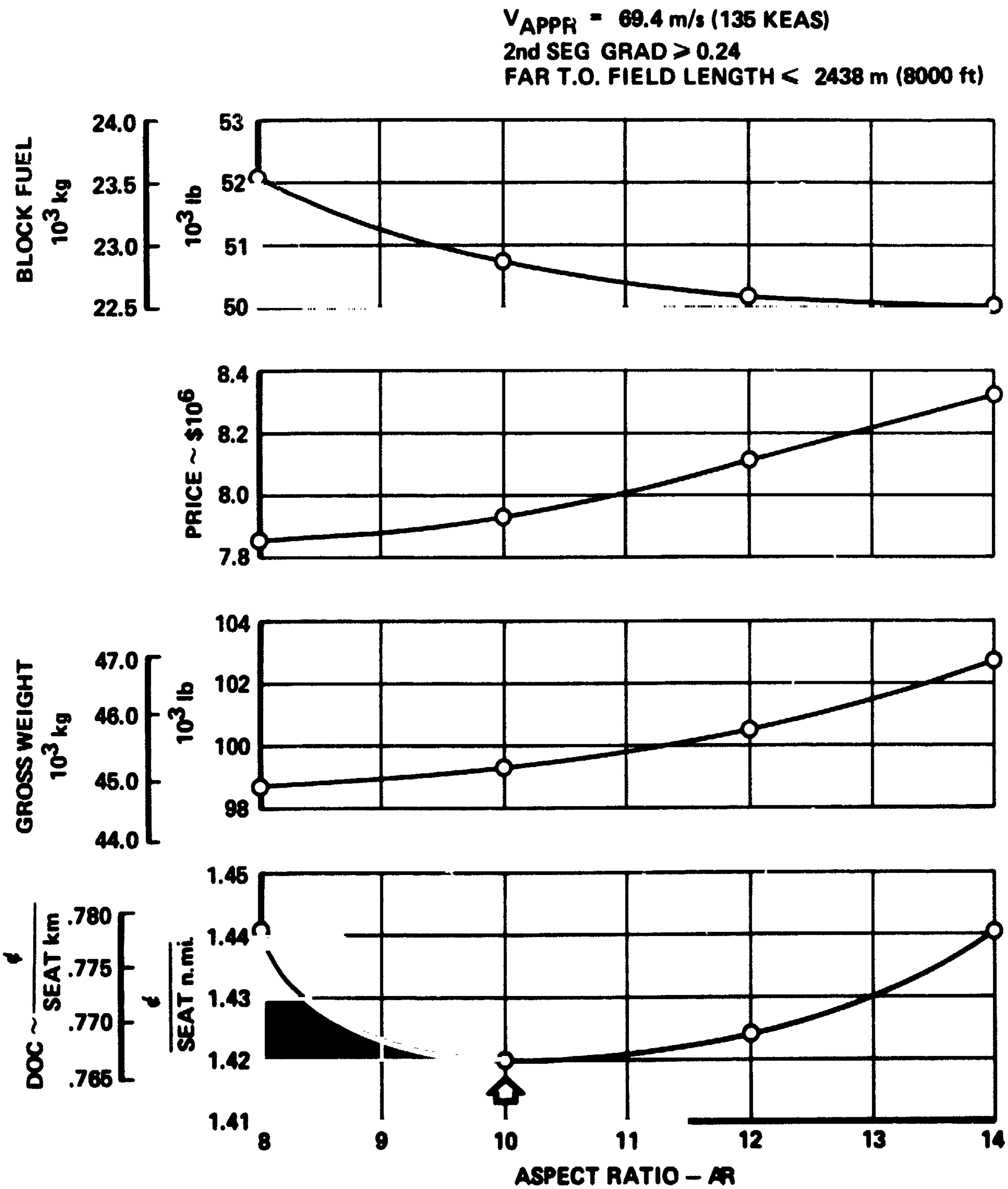


Figure 6. Aspect Ratio Selection - Aircraft No. 1

Wing: The wing has an aspect ratio of 10, thickness ratio of 10 percent and a sweep angle of 30°. The high lift devices include 15 percent leading edge slats and 35 percent double-slotted flaps, as shown. This high lift system is typical for all study configurations. Spoilers are used in flight for direct lift control, and for landing ground run deceleration. Conventional ailerons are fitted outboard of the flaps.

Landing gear: The landing gear consists of two two-wheel main gears mounted aft of the rear spar. They retract inward into the fuselage. The space between the retracted gear contains the hydraulic service center. The forward gear has two-wheels mounted on a strut which retracts forward under the pilot's compartment.

Hydrogen tank and systems: The hydrogen tank structural concept selected for purposes of this study is the integral type described in Reference 1, Section 3.1.2. All aircraft structural loads in addition to the fuel dynamic and pressure loads are taken by the tank shell. Loads are transferred from the vehicle structure to the tank at both ends by low heat-leak boron-reinforced fiberglass tubes arranged in an interconnect truss structure. Eight inches of closed-cell plastic foam insulation e.g., Rohacel 41S, covers the tank, in accordance with the scaling relationship discussed in Section 3.2. The foam insulation is then wrapped by a vapor shield (Kapton) to prevent cryopumping in event a crack develops in the foam insulation. A fiberglass reinforced composite layer covers the entire tank section to provide a smooth aerodynamic surface, and protection from physical damage.

The tank is thus generally protected from mechanical damage by the foam insulation and its fiberglass cover. Further special protection from foreign object damage and damage from aircraft maneuvers such as overrotation or tail scrape is provided on the bottom of the tank, as shown in Figure 7, by an energy absorbing, aluminum honeycomb structure supported from the tank bottom. Protection is also provided by this structure for plumbing, electrical, and control systems which would be routed adjacent to the tank.

The tank and mounting is designed for both inflight structural and fatigue loads (fail saife considerations) and to withstand the emergency crash load requirements of FAR 25 with full fuel load.

4.3.3 Vehicle Data. - All weight, performance, and cost data are presented in Section 4.6.

CHARACTERISTICS	WING	HORIZ. TAIL	VERT. TAIL
AREA M^2 (SQ FT)	84.68 (911.5)	8.73 (94)	8.36 (90)
ASPECT RATIO	10	4.5	1.6
SPAN M (FT)	23.11 (35.5)	6.28 (20.6)	3.66 (12.0)
ROOT CHORD M (IN)	4.49 (176.3)	2.14 (84.4)	3.52 (138.5)
TIP CHORD M (IN)	1.34 (52.88)	0.64 (25.3)	1.05 (41.5)
TAPER RATIO	0.3	0.3	0.3
MAC M (IN)	3.13 (125.64)	1.53 (60.1)	2.51 (98.7)
SWEEP RAD. (DEG)	0.524 (30)	0.524 (30)	0.524 (30)
T/C ROOT (%)	10	9	9
T/C TIP (%)	10	9	9

DESIGN GROSS WT. - 44,563 KG. (98,257 LB.)

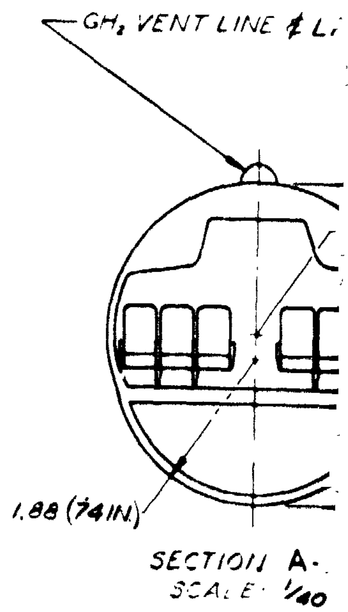
POWER PLANT - (2) TURBOFANS

INSTALLED THRUST EA.) - 75,383 N. (16,943 LB)

PASSENGERS - 130

FUEL (LH_2) - 3,463 KG. (7,634 LB.)

RANGE - 2,780 KM. (1,500 N.M.)



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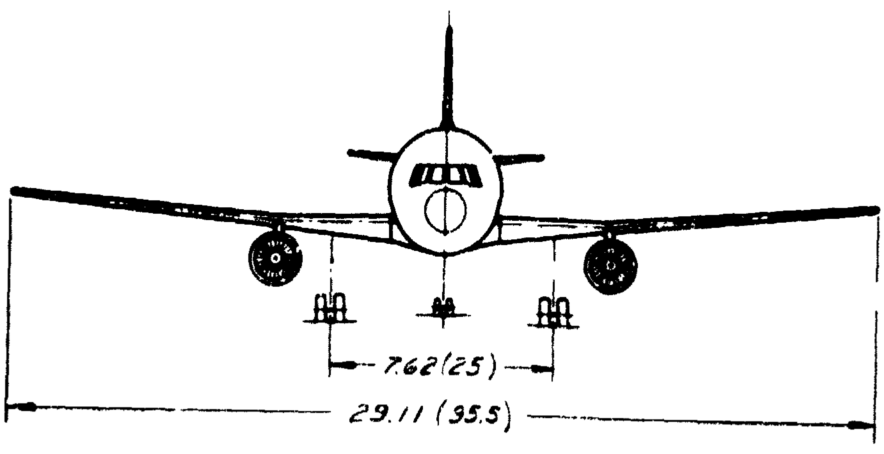

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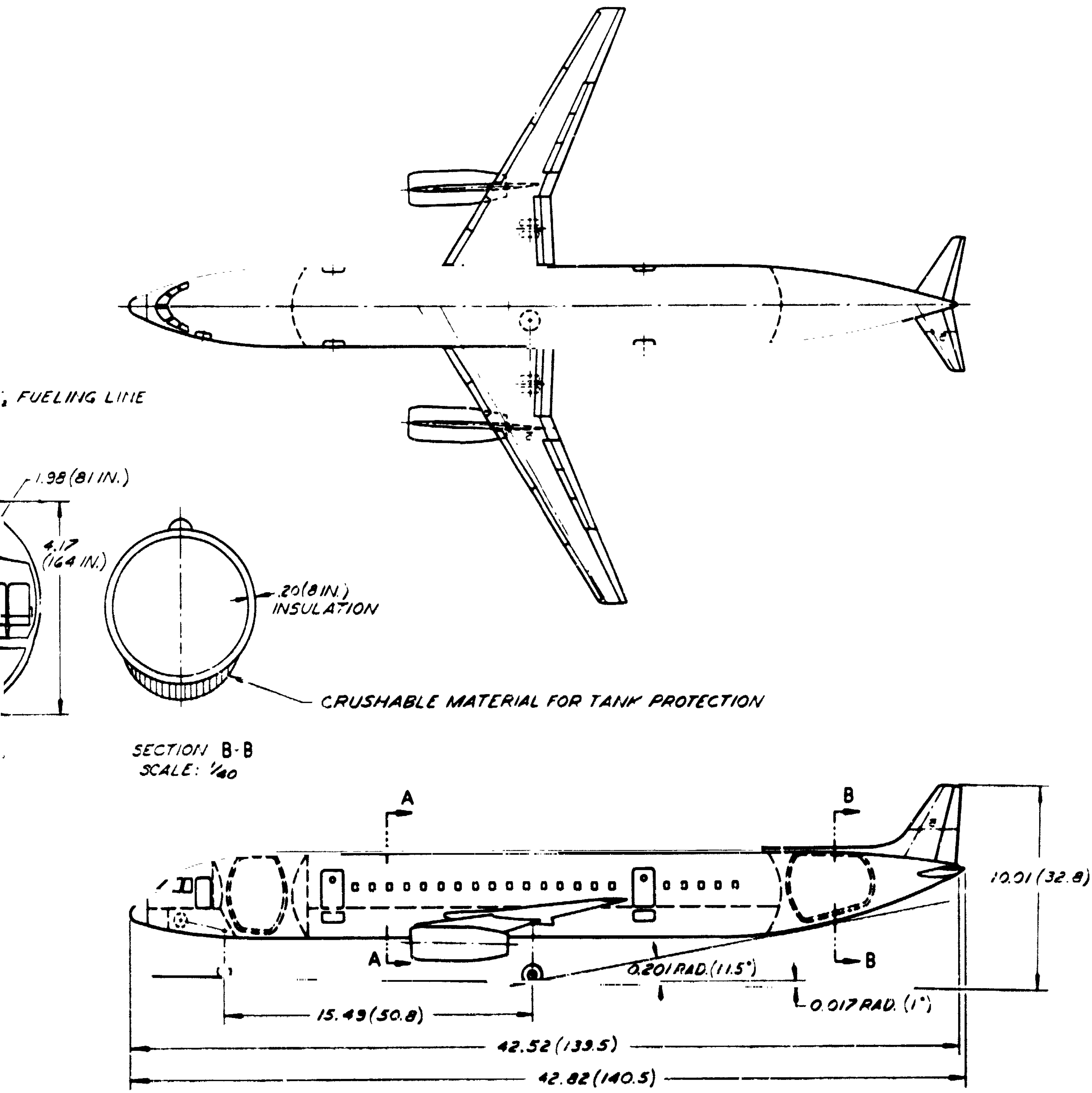

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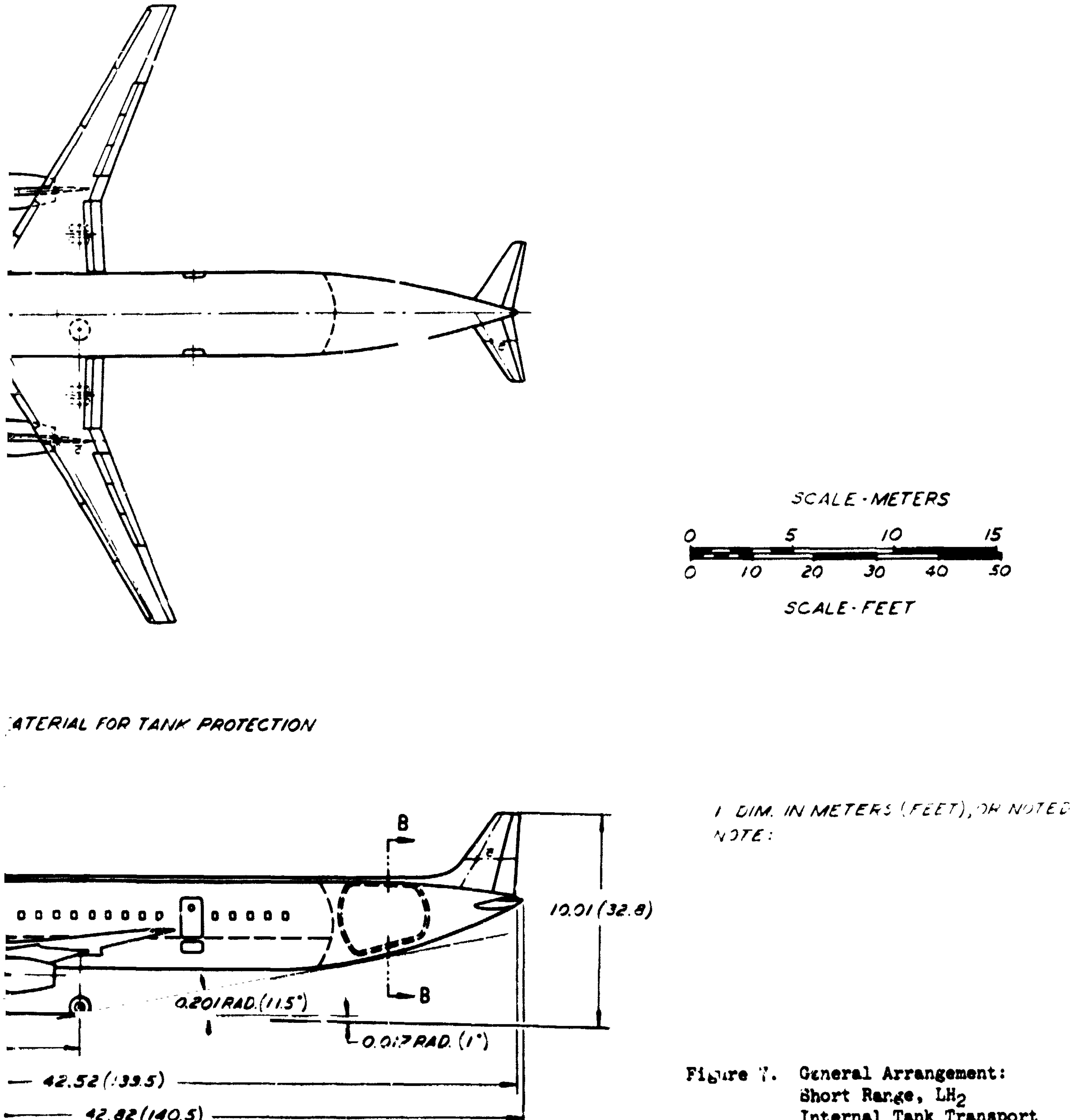
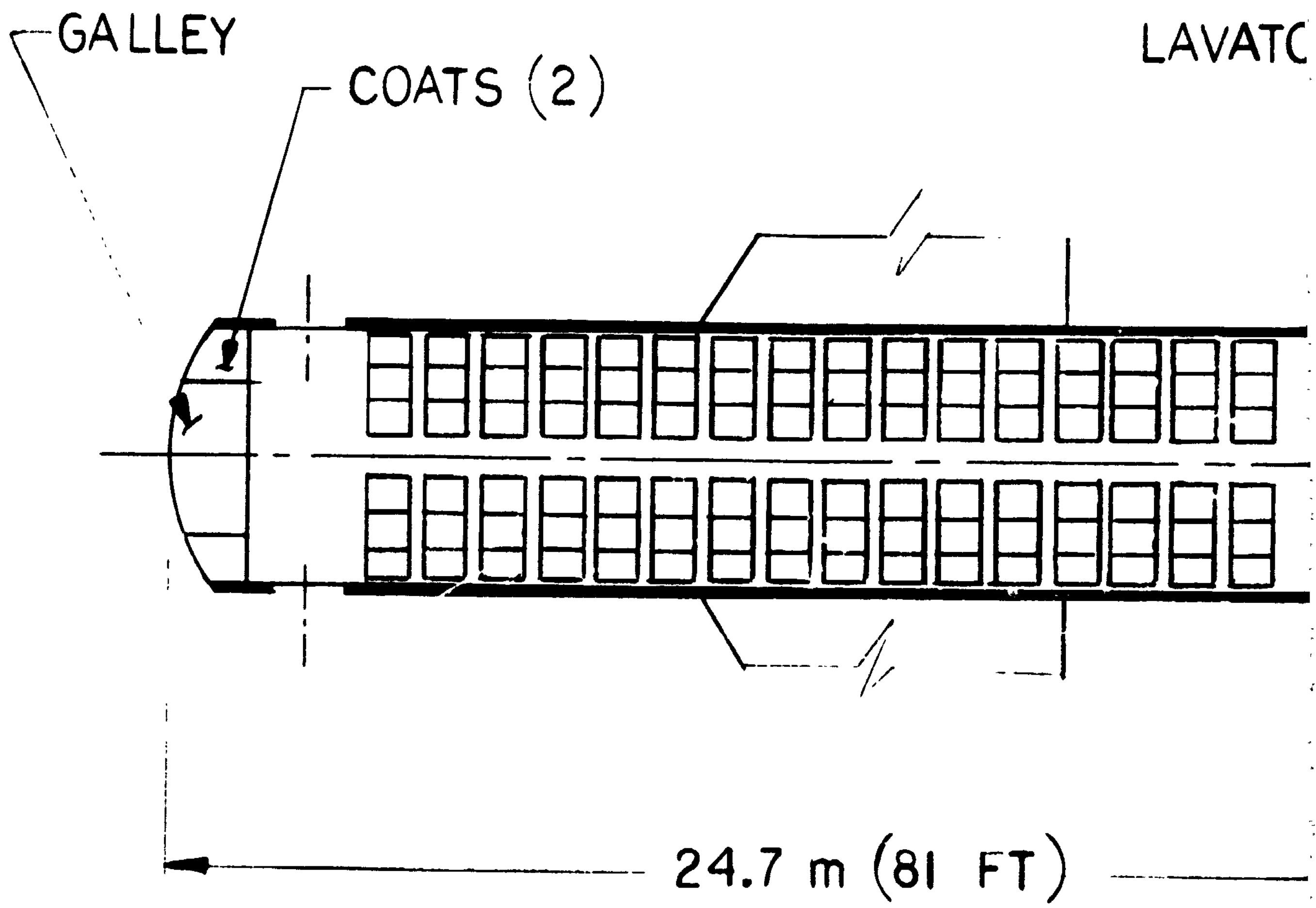


Figure 7. General Arrangement: Short Range, LH_2 Internal Tank Transport



130 PAX, 6 A/B, .86 m (34 IN) SPACING

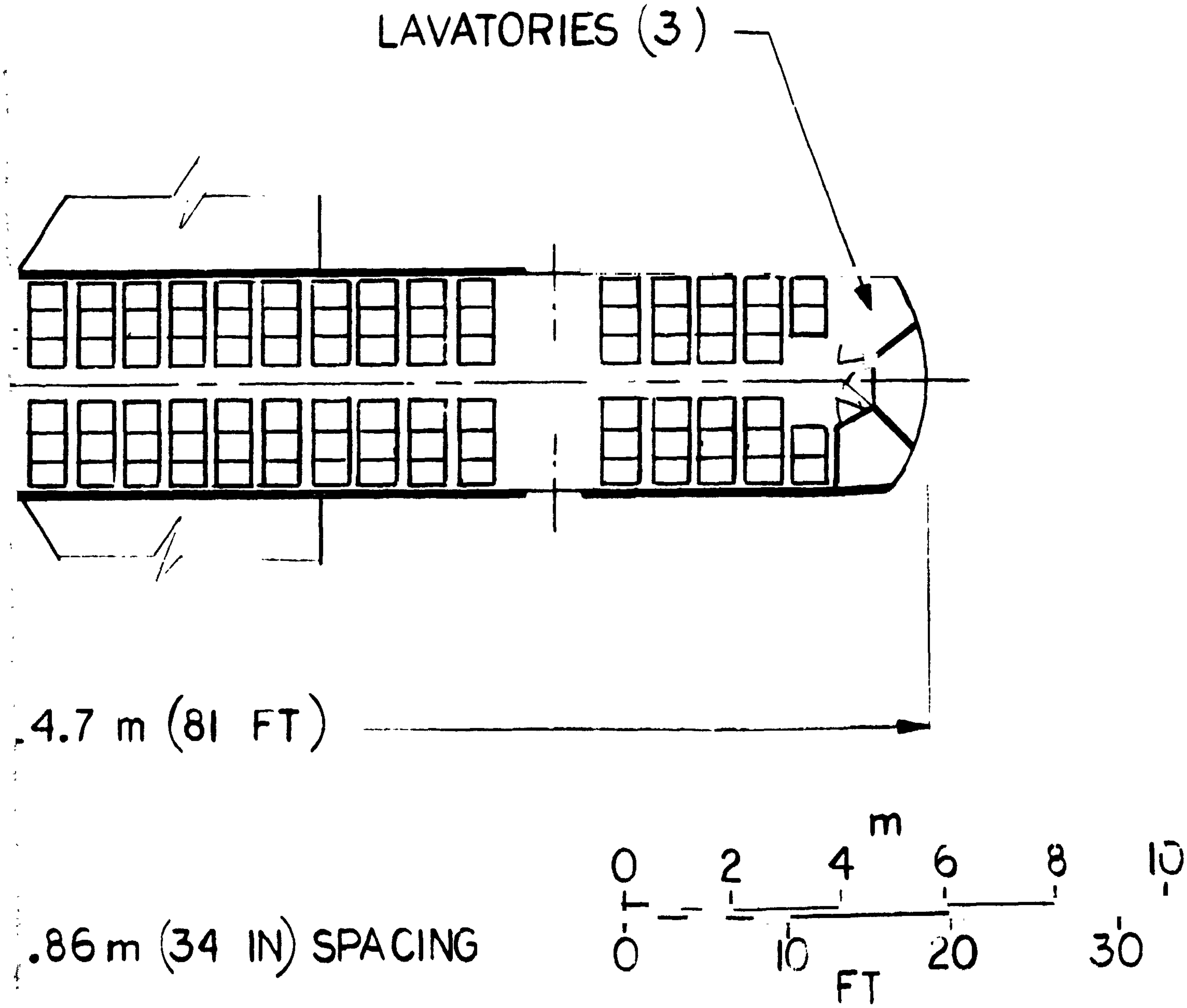


Figure 8. Interior Arrangement:
130 Pax Aircraft

FOLDOUT FRAME 2

4.4 LH_2 External Tank Airplane (Aircraft No. 2)

4.4.1 Aspect Ratio Selection. - The procedure for selecting aircraft characteristics from the parametric matrix generated by use of ASSET is the same as that described in Section 4.3.1 for the internal tank configuration. Figure 9 shows the effect of the various selection criteria on choice of aspect ratio. Based on minimum DOC, an aspect ratio of 9.5 was selected for the final point design aircraft.

4.4.2 Configuration Description. - The most obvious feature of the external tank LH_2 aircraft design shown in Figure 10 is of course the large wing-mounted tanks. Their physical size prevents mounting below the wing. To reduce drag to an acceptable level the tank is supported on a plyon with a height of approximately one-third the tank diameter. The tank is of integral construction covered with eight inches of closed-cell plastic foam insulation protected by a vapor proof barrier film and an external fiberglass reinforced composite cover.

The fuselage length of this aircraft has been reduced compared to the internal tank version by removal of the hydrogen fuel tanks. Six abreast seating is provided with a 0.86 m (34 in.) seat pitch for 130 passengers. Cargo volume, lavatory, and galley facilities are equivalent to those on the internal tank aircraft.

The tank arrangement of this aircraft simplifies the fuel system arrangement since only one engine crossfeed line and refuel line are carried across the aircraft fuselage in the wing box.

Air stairs are provided at both entry doors on the left hand side of the aircraft.

4.4.3 Vehicle Data. - All weight, performance, and cost data for this aircraft are presented in Section 4.6.

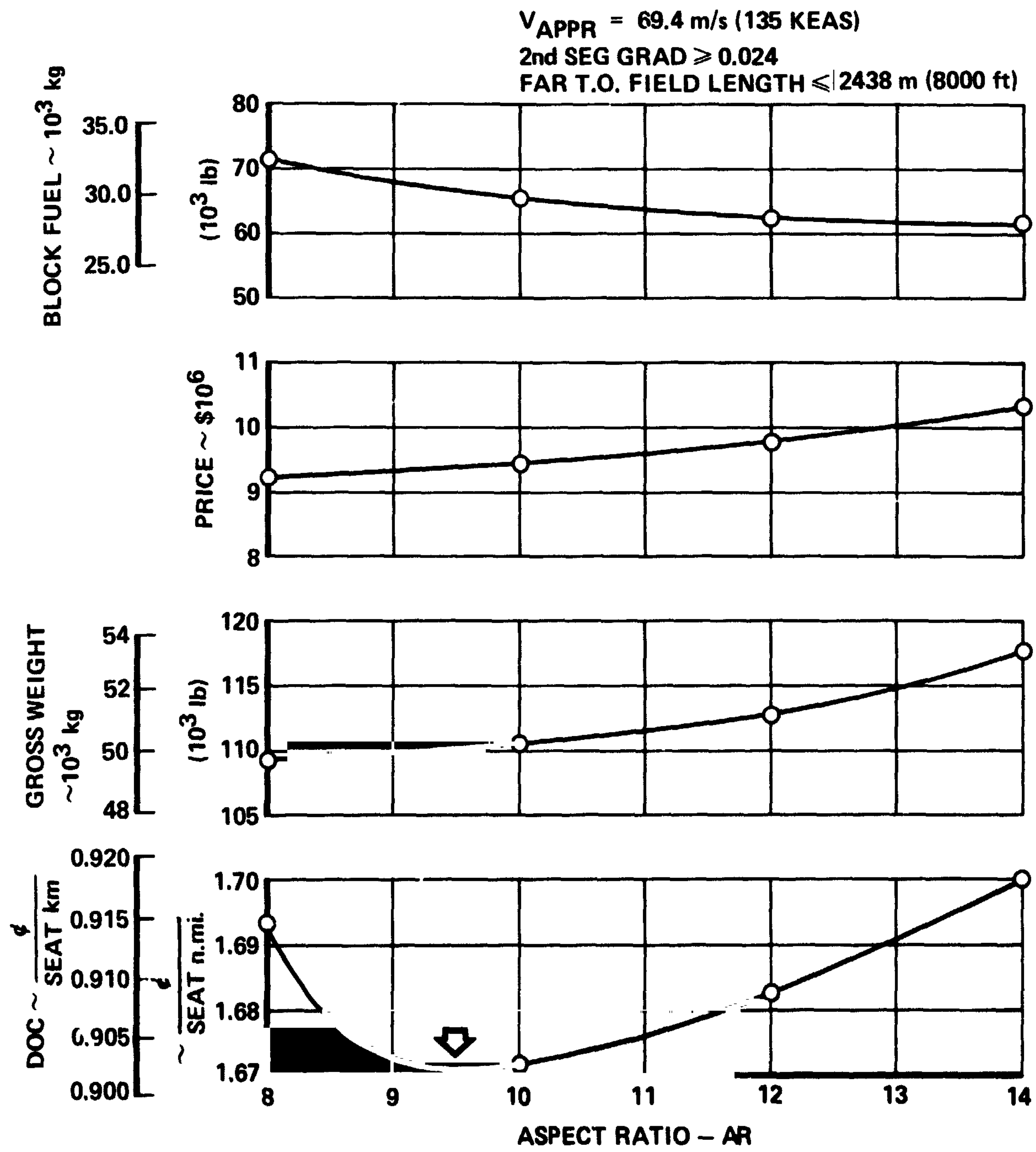


Figure 9. Aspect Ratio Selection - ircraft No. 2

CHARACTERISTICS	WING	HORIZ. TAIL	VERT. TAIL
AREA M^2 (SQ FT)	94.54 (1017.6)	15.16 (163.2)	12.89 (138.8)
ASPECT RATIO	9.5	4.5	1.6
SPAN M (FT)	29.97 (98.3)	8.26 (27.1)	4.54 (14.9)
ROOT CHORD M (IN)	4.51 (177.4)	2.82 (111.1)	4.37 (172.0)
TIP CHORD M (IN)	1.80 (71.0)	0.85 (33.3)	1.31 (51.6)
TAPER RATIO	0.4	0.3	0.3
MAC M (IN)	3.35 (131.5)	2.01 (79.2)	3.11 (122.6)
SWEEP RAD. (DEG)	0.524 (30)	0.524 (30)	0.524 (30)
T/C ROOT (%)	10	9	9
T/C TIP (%)	10	9	9

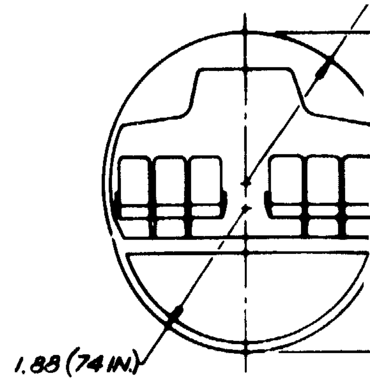
DESIGN GROSS WT. - 49,851 KG. (109,901 LB.)

POWER PLANT - (2) TURBOFANS
INSTALLED THRUST (EA.) - 109.986 N. (24,727 LB.)

PASSENGERS - 130

FUEL (LH_2) - 4,361 KG. (9,615 LB.)

RANGE - 2,780 KM. (1,500 N.M.)



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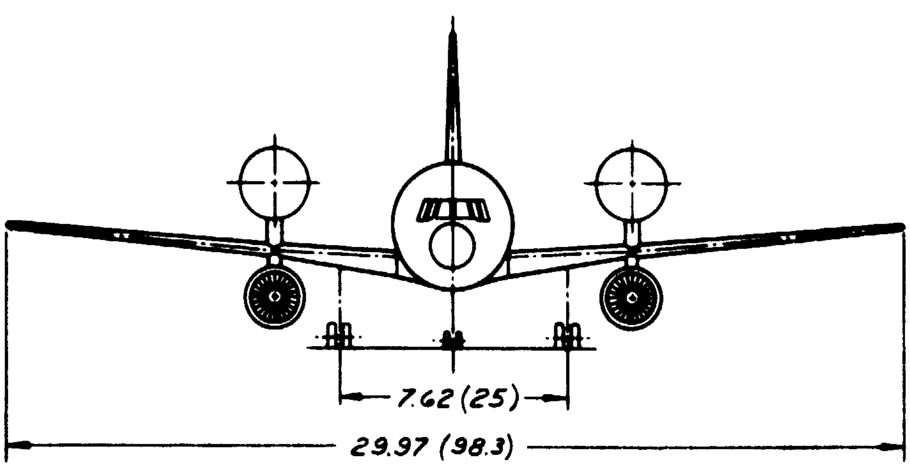

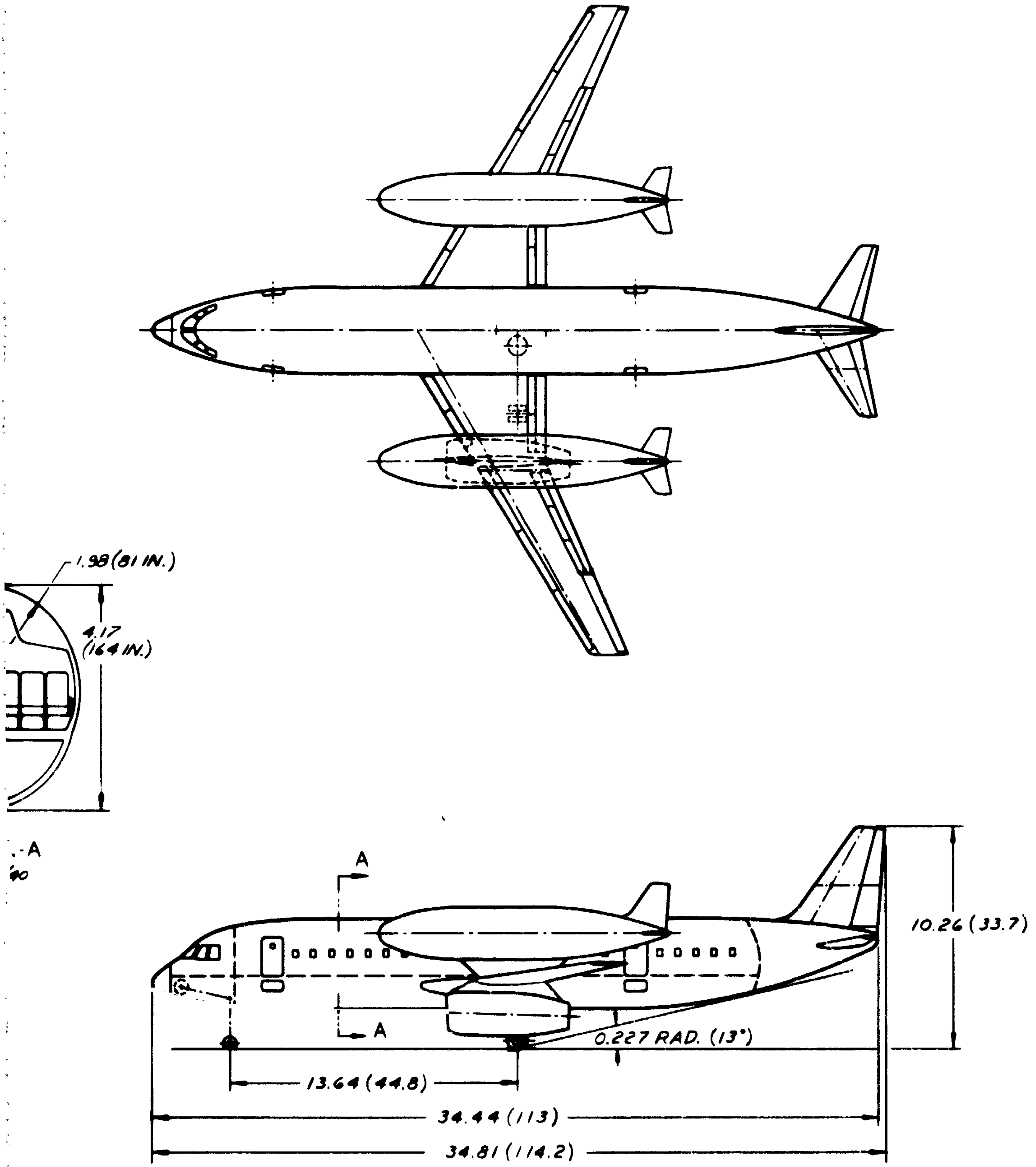

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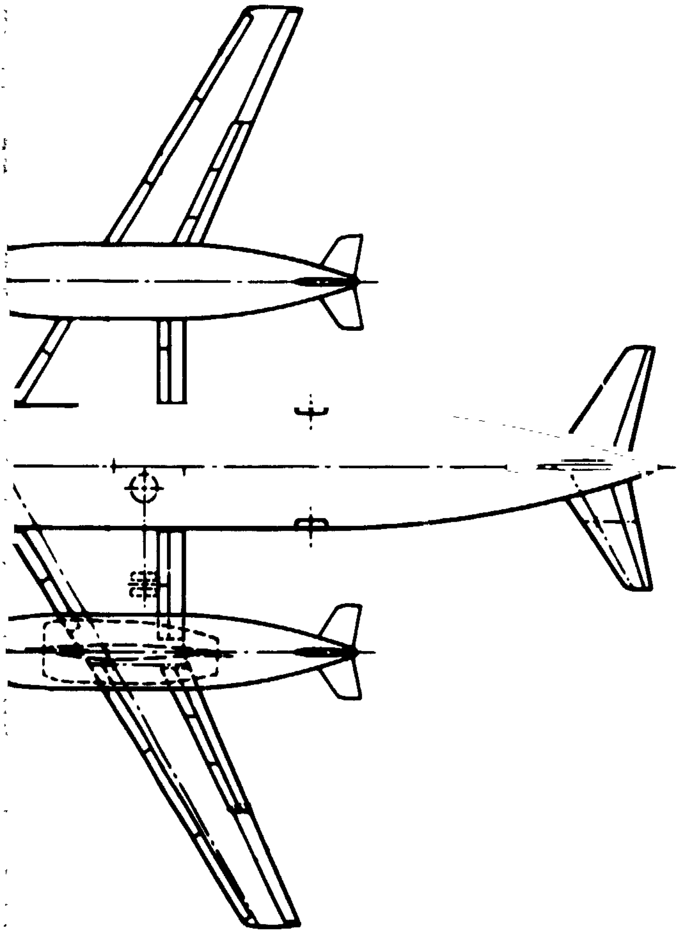

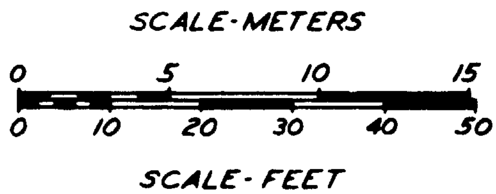

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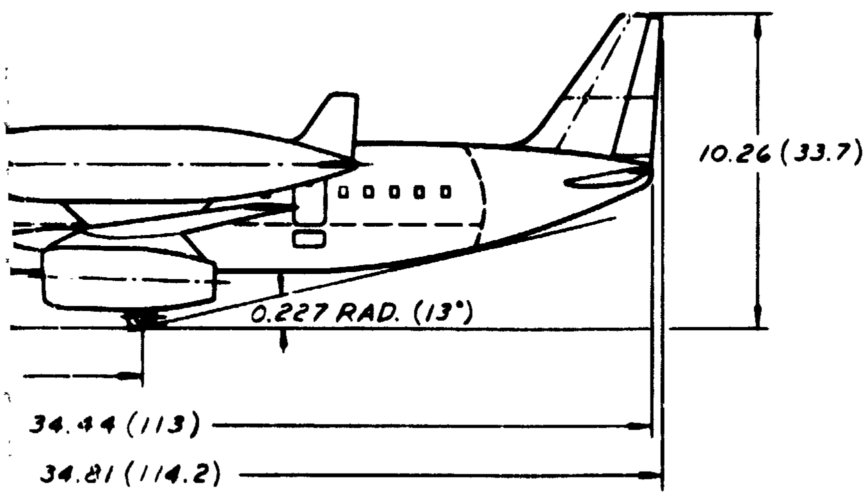


Figure 10. General Arrangement: Short Range, LH_2 External Tank Transport

4.5 Jet A Airplane (Aircraft No. 3)

4.5.1 Aspect Ratio Selection. - Figure 11 shows the various selection criteria versus aspect ratio and indicates a choice of 11 to provide minimum DOC.

4.5.2 Configuration Description. - The general arrangement of the Jet A fueled aircraft is shown in Figure 12. The fuselage and interior arrangement is the same as that of the external tank hydrogen aircraft described in Section 4.4. All fuel is contained in the wing box structure resulting in some load relief for this wing compared to the internal tank hydrogen design. Air stairs are provided on both left hand entry doors.

4.5.3 Vehicle Data. - All weight, performance, and cost data for this aircraft are presented in Section 4.6.

4.6 Comparison of Short Range Aircraft

Table VII presents a summary of the characteristics of the three short range aircraft. These are the final point designs meeting all performance constraints and selected on the basis of minimum DOC. For convenience in comparing the designs, ratios of the more significant values are shown.

Comparison of the external to the internal tank LH_2 aircraft designs shows that in spite of the short range involved, and therefore a relatively small fuel load, the drag of the external tanks resulted in a lift/drag ratio 15 percent poorer for that aircraft design compared to the internal tank aircraft. This is due to the rapid increase of external tank wetted area (and weight) compared to the internal tank, as discussed in Section 3.2. The lower L/D in turn, requires more cruise thrust and results in use of larger engines.

Use of larger engines accounts for the shorter takeoff distance and the higher initial cruise altitude of the external tank design. However, the combination of lower L/D and larger engines causes a significant penalty in fuel weight, aircraft price, and DOC. These disadvantages led to selection of the

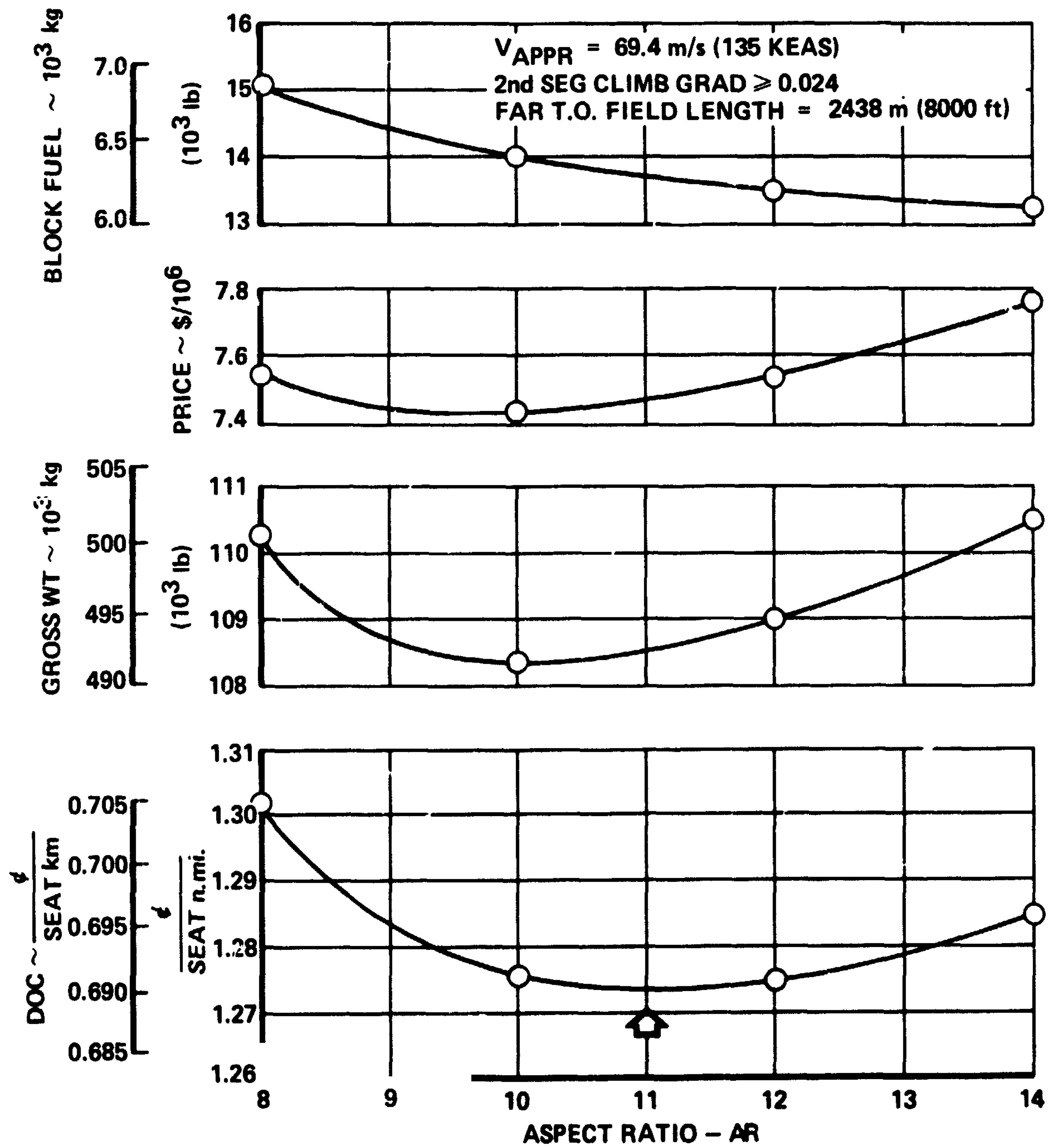


Figure 11. Aspect Ratio Selection - Aircraft No. 3

CHARACTERISTICS	WING	HORIZ. TAIL	VERT. TAIL
AREA M^2 (SQ FT)	86.3(928.7)	12.3(132.1)	11.6(125.4)
ASPECT RATIO	11	4.5	1.6
SPAN M (FT)	30.81(101.1)	7.43(24.4)	4.32(14.2)
ROOT CHORD M(IN)	4.31(169.6)	2.54(99.9)	4.14(162.9)
TIP CHORD M(IN)	1.29(50.9)	0.76(30.0)	1.24(48.9)
TAPER RATIO	0.3	0.3	0.3
MAC M (IN)	3.07(120.9)	1.81(71.2)	2.95(116.1)
SWEEP RAD. (DEG)	0.524(30)	0.524(30)	0.524(30)
T/C ROOT (%)	10	9	9
T/C TIP (%)	10	9	9

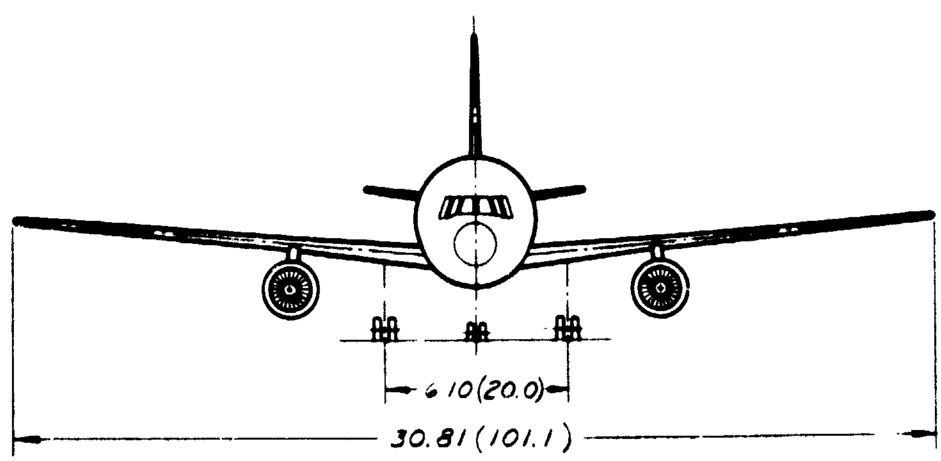
DESIGN GROSS WT. - 49,287 KG. (108,657 LB.)

POWER PLANT - (2) TURBOFANS
INSTALLED THRUST (EA) - 84,094 N. (18,906 LB.)

PASSENGERS - 130

FUEL (JET A) - 8,938 KG (19,704 LB.)

RANGE - 2,780 KM. (1,500 N.M.)



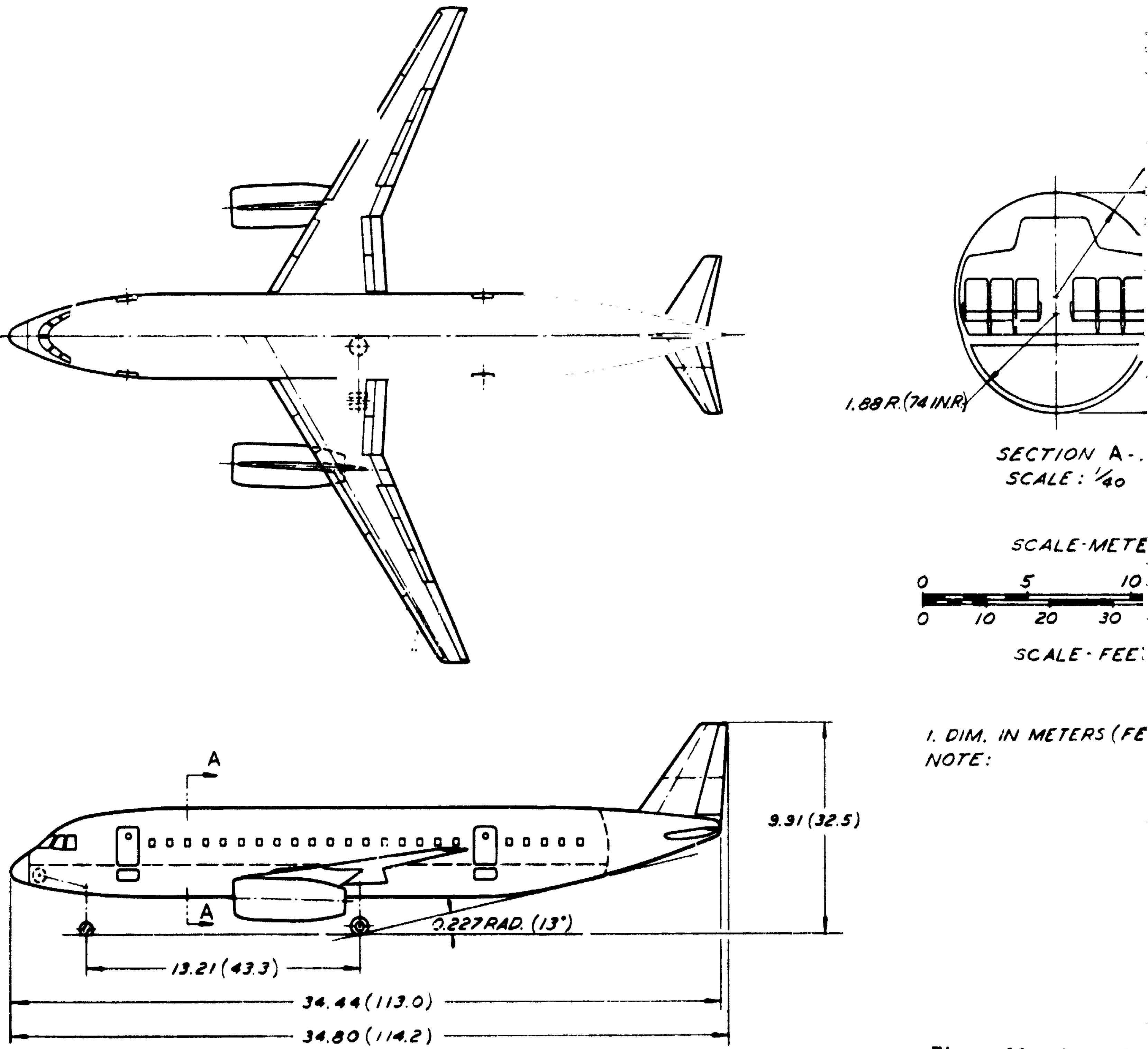


Figure 12. General
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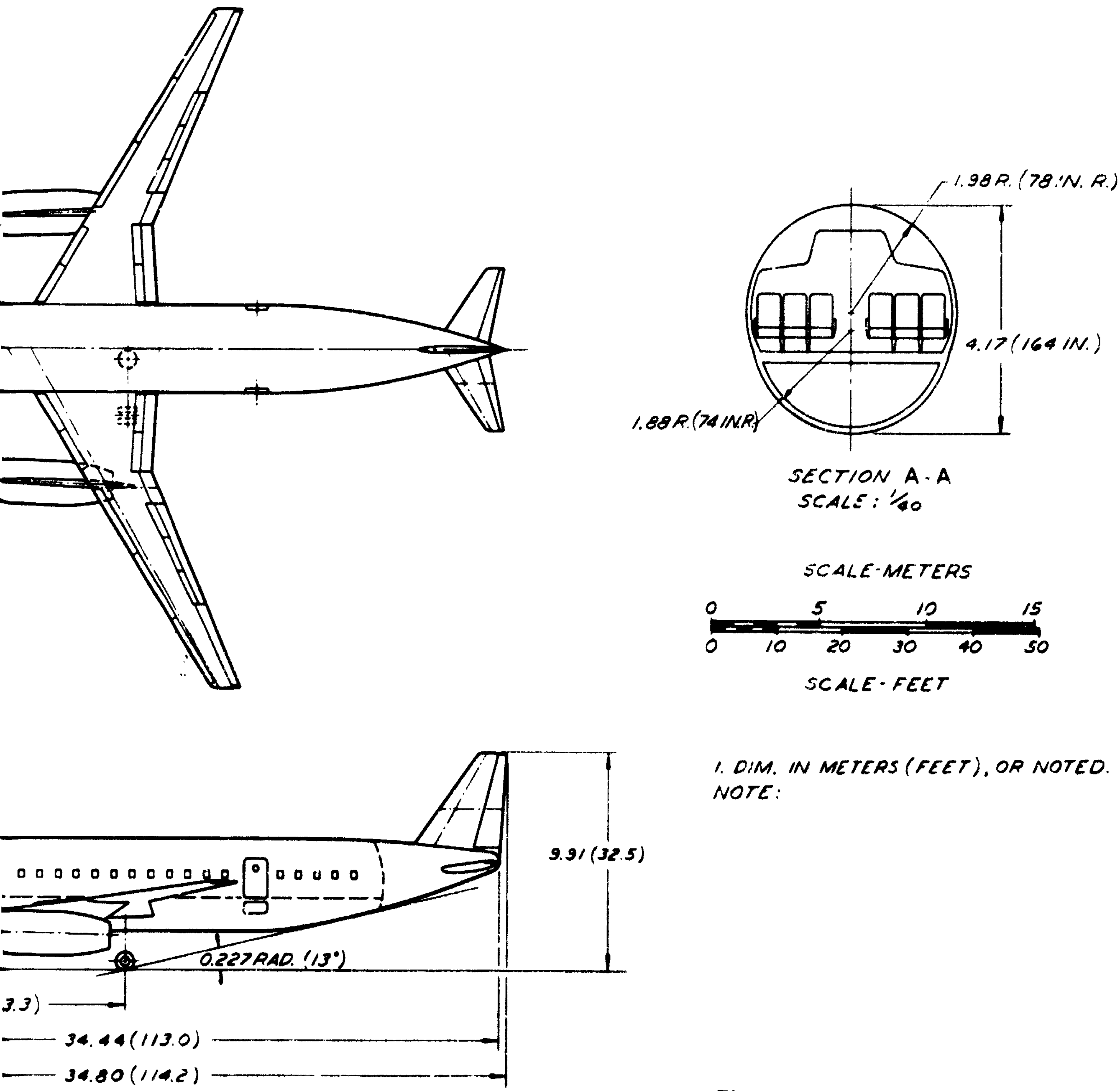


Figure 12. General Arrangement: Short Range, Jet A Fuel Transport

TABLE VII. COMPARISON OF FINAL DESIGN SHORT RANGE AIRCRAFT

(S.I. UNITS)

(2780 km Range – 130 Pax. - Mach 0.85)

Payload = 12,973 kg

		Aircraft No. 1 (Int LH_2)	Aircraft No. 2 (Ext LH_2)	Ratio (Ext / Int)	Aircraft No. 3 (Jet A)	Ratio (Jet A / Int LH_2)
Gross Weight	kg	44,570	49,850	1.118	49,290	1.11
Total Fuel	kg	3,340	4,380	1.31	8,940	2.68
Block Fuel	kg	2,296	3,015	1.31	6,190	2.70
Operating Empty Wt	kg	28,260	32,520	1.15	27,380	0.97
Empty Wt	kg	26,290	30,520	1.16	25,460	0.97
Aspect Ratio		10	9.5		11	
Wing Area	m^2	85	94.5	1.11	86.3	1.02
Sweep	degrees	30	30		30	
Span	m	29.1	30.0	1.03	30.8	1.06
Fus. Length	m	42.5	34.4	0.81	34.4	0.81
L/D – Cruise		13.9	11.7	0.846	16.3	1.18
SFC – Cruise	$\frac{kg}{hr}$ /daN	0.215	0.215		0.629	2.93
Initial Cruise Altitude	m	10,970	11,580		12,190	
Wing Loading	kg/m^2	526.3	527.3		571.2	
Thrust/Weight	N/kg	3.38	4.41	1.3	3.41	1.0
No. Engines		2	2		2	
Thrust Per Engine	N	75,390	109,990	1.46	84,090	1.12
FAR T.O. Distance	m	2,403	1,420	0.59	2,429	1.02
FAR Ldg. Distance	m	1,748	1,753		1,754	
2nd Seg Climb Grad. (Eng. Out)		0.0276	0.0583	2.11	0.0365	1.32
Approach Speed	m/s	69	69		69	
Weight Fractions	percent					
Fuel		7.5	8.8		18.1	
Payload		29.1	26.0		26.3	
Structure		28.3	27.6		26.1	
Propulsion (Includes Fuel System)		12.8	17.6		9.2	
Equipment and Operating Items		22.3	20.0		20.3	
Price	$\$10^6$	7.85	9.34	1.19	7.51	0.95
DOC	¢/seat km	0.763[1]	0.901[1]	1.18	0.689[2]	0.90
Energy Utilization	kJ/seat km	762	1001	1.32	733	0.96

[1] DOC based on LH_2 cost = \$2.85/GJ

[2] DOC based on Jet A cost = \$1.90/GJ

TABLE VII. COMPARISON OF FINAL DESIGN SHORT RANGE AIRCRAFT

(U.S. CUSTOMARY UNITS)

(1500 n.mi. Range - 130 Pax. - Mach 0.85)

Payload = 28,600 lb

		Aircraft No. 1 (Int LH_2)	Aircraft No. 2 (Ext LH_2)	Ratio $\left(\frac{Ext}{Int}\right)$	Aircraft No. 3 (Jet A)	Ratio $\left(\frac{Jet\ A}{Int\ LH_2}\right)$
Gross Weight	lb	98,280	109,900	1.118	108,660	1.11
Total Fuel	lb	7,364	9,616	1.31	19,704	2.68
Block Fuel	lb	5,060	6,647	1.31	13,645	2.70
Operating Empty Wt	lb	62,290	71,690	1.15	60,350	0.97
Empty Wt	lb	57,970	67,270	1.16	56,130	0.97
Aspect Ratio		10	9.5		11	
Wing Area	ft^2	911.5	1,018	1.12	928.7	1.02
Sweep	deg	30	30		30	
Span	ft	95.5	98.3	1.03	101.1	1.06
Fus. Length	ft	139.5	113.0	0.81	113.0	0.81
L/D – Cruise		13.9	11.7	0.846	16.3	1.18
SFC – Cruise	$\frac{lb}{hr\ lb}$	0.211	0.211		0.618	2.93
Initial Cruise Altitude	ft	36,000	38,000		40,000	
Wing Loading	lb/ft^2	107.8	108.0		117.0	
Thrust/Weight		0.345	0.450	1.3	0.348	1.0
No. Engines		2	2		2	
Thrust Per Engine	lb	16,950	24,730	1.46	18,9[illegible]0	1.12
FAR T.O. Distance	ft	7,885	4,[illegible]0	0.59	7,970	1.02
FAR Ldg. Distance	ft	5,728	5,752		5,754	
2nd Seg Climb Grad. (Eng. Out)		0.0276	0.0583	2.11	0.0365	1.32
Approach Speed	KEAS	136	136		136	
Weight Fractions	percent					
Fuel		7.5	8.8		18.1	
Payload		29.1	26.0		26.3	
Structure		28.3	27.6		26.1	
Propulsion (Includes Fuel System)		12.8	17.6		9.2	
Equipment and Operating Items		22.3	20.0		20.3	
Price	$\$10^6$	7.85	9.34	1.19	7.51	0.95
DOC	$\frac{¢}{seat\ n.mi.}$	1.413[1]	1.669[1]	1.18	1.276[2]	0.90
Energy Utilization	$\frac{Btu}{seat\ n.mi.}$	1,339	1,759	1.32	1,288	0.96

[1]DOC based on LH_2 cost = $\$3/10^6$ Btu

[2]DOC based on Jet A cost = $\$2/10^6$ Btu = 24.8 /gal

internal tank design for comparison with the Jet A fueled airplane. For a description of the complete rationale leading to selection of internal tank over external tank designs, see Section 4.6 of the final report of the original study (Reference 1).

As might be expected from the low fuel fraction involved in this small payload, short-range mission, the advantage of using hydrogen fuel is largely mitigated by the penalties involved, i.e., tank, insulation wight, and drag increase due to more wetted area. The factor of 2.93 advantage in specific fuel consumption offered by the LH_2 fueled design, operating on the small fuel weight involved, is not sufficient to overcome the 18 percent disadvantage in L/D. Table VII shows almost equal empty weights for the internal tank LH_2 (Aircraft No. 1) and Jet A (Aircraft No. 3) designs and only an 11 percent higher gross weight for the Jet A fueled design. The purchase price of Aircraft No. 3 is lower by 4 percent and energy used in perfroming the mission is lower by 4 percent.

Table VIII presents a breakdown of costs for the three aircraft. Note that DOC is calculated on the basis of the prescribed fuel costs. Figure 13 shows the DOC versus the fuel cost in \$/GJ (\$/10^6 Btu) across the lower edge, and for Jet A fuel in ¢/gallon at the top. It indicates the high DOC of the external tank LH_2 and almost equal DOC's for the internal LH_2 and the Jet A aircraft for the same fuel price. In other words, for these aircraft LH_2 cannot cost more than Jet A for equal DOC's.

Selected pages of ASSET computer printouts for the internal tank LH_2, external tank LH_2, and Jet A point design aircraft are reproduced in Appendix A-1, A-2 and A-3, respectively.

4.6.1 Noise. - A comparison of noise generated by the two aircraft is presented numerically in Table IX and graphically in Figure 14. The analysis was made using the takeoff and approach paths generated for the respective aircraft in the ASSET program, and using engine parameters and procedures described in Section 4.8.2 of the final report of the previous study (Reference 1).

TABLE VIII. COST COMPARISON OF FINAL DESIGN SHORT RANGE AIRCRAFT

2,780 km (1500 n.mi.) - 130 Pax. - M 0.85

	Aircraft No. 1 (Int. LH_2)	Aircraft No. 2 (Ext. LH_2)	Aircraft No. 3 (Jet A)
Development $\$10^6$			
Airframe	21.62	27.47	23.68
Engine (Amortized in prod. cost)	0	0	0
TOTAL	21.62	27.47	23.68
Production $\$10^6$			
Airframe Cost	5.482	6.222	5.210
Engine (including R&D)	1.530	2.113	1.340
Avionics	0.220	0.220	0.220
R&D Amortization (Airframe)	0.618	0.785	0.677
TOTAL Aircraft Price	7.850	9.340	7.507
Direct Operating Cost $\frac{\$}{km}$ $\left(\frac{\$}{n.mi.}\right)$			
Crew	0.228 (0.422)	0.227 (0.420)	0.228 (0.423)
Maintenance			
Airframe Labor (Including Burden)	0.072 (0.134)	0.078 (0.145)	0.070 (0.129)
Engine Labor (Including Burden)	0.029 (0.053)	0.035 (0.064)	0.045 (0.084)
Airframe Material	0.037 (0.069)	0.043 (0.079)	0.036 (0.067)
Engine Material	0.037 (0.069)	0.051 (0.095)	0.051 (0.095)
Fuel* and Oil $\frac{\$}{km}$ $\left(\frac{\$}{n.mi.}\right)$	0.296 (0.549)	0.389 (0.721)	0.185 (0.342)
Insurance	0.060 (0.111)	0.071 (0.132)	0.058 (0.107)
Depreciation	0.232 (0.430)	0.278 (0.514)	0.222 (0.412)
TOTAL DOC	0.992 (1.837)	1.17 (2.170)	0.896 (1.659)
TOTAL Unit DOC $\frac{¢}{seat\ km}$ $\left(\frac{¢}{seat\ n.mi.}\right)$	0.763 (1.413)	0.901 (1.670)	0.689 (1.276)

*Fuel Cost:

Jet A = \$1.90/GJ (\$2/10^6 Btu = 24.8¢/gal = 3.68¢/lb)

LH_2 = \$2.85/GJ (\$3/10^6 Btu - 15.48¢/lb)

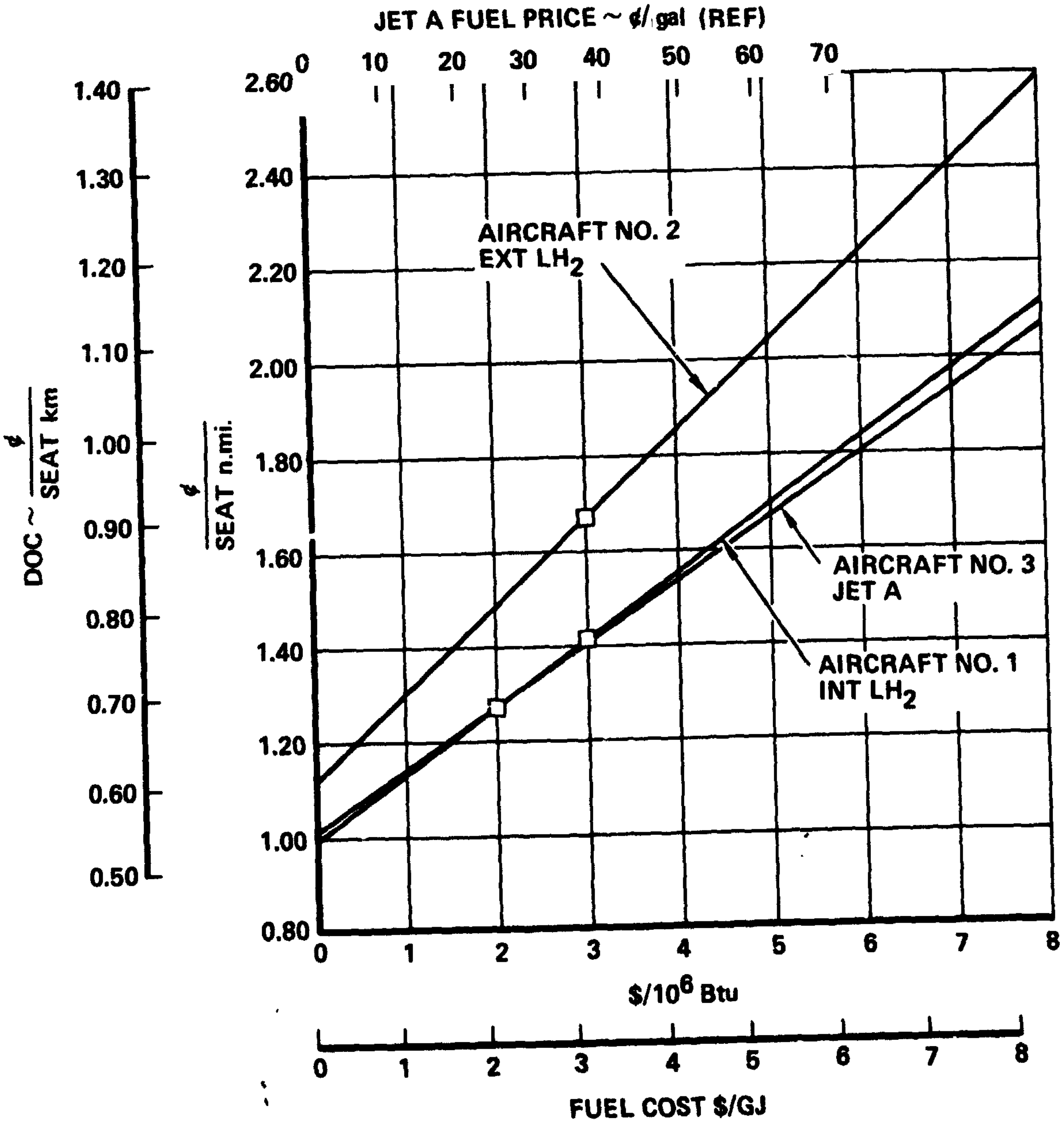


Figure 13. DOC Versus Fuel Cost - 1500 n.mi., 130 Pax Aircraft

TABLE IX. NOISE EVALUATION - SHORT RANGE AIRCRAFT

Airplane No.		1		3
Number of Engines		2		2
Fuel		LH_2		Jet A
Gross Weight kg (lb.)	44,570	(98,260)	49,288	(108,660)
FAR 36 Flyover Level (EPNdB)		79.2		79.2
Limit Per NPRM 75-37		87.6		88.2
FAR 36 Sideline Level (EPNdB)		85.5		85.7
Limit Per NPRM 75-37		93.7		94.0
FAR 36 Approach Level (EPNdB)		91.1		90.3
Limit Per NPRM 75-37		98.8		99.1
Enclosed "Footprint" Contour Area	km^2	$st.mi.^2$	km^2	$st.mi.^2$
80 EPNdB - Takeoff	8.03	3.10	7.56	2.92
- Approach	6.32	2.44	5.36	2.07
- Total	14.35	5.54	12.92	4.99
90 EPNdB - Takeoff	1.92	0.74	1.94	0.75
- Approach	.47	0.18	.36	0.14
- Total	2.39	0.92	2.30	0.89

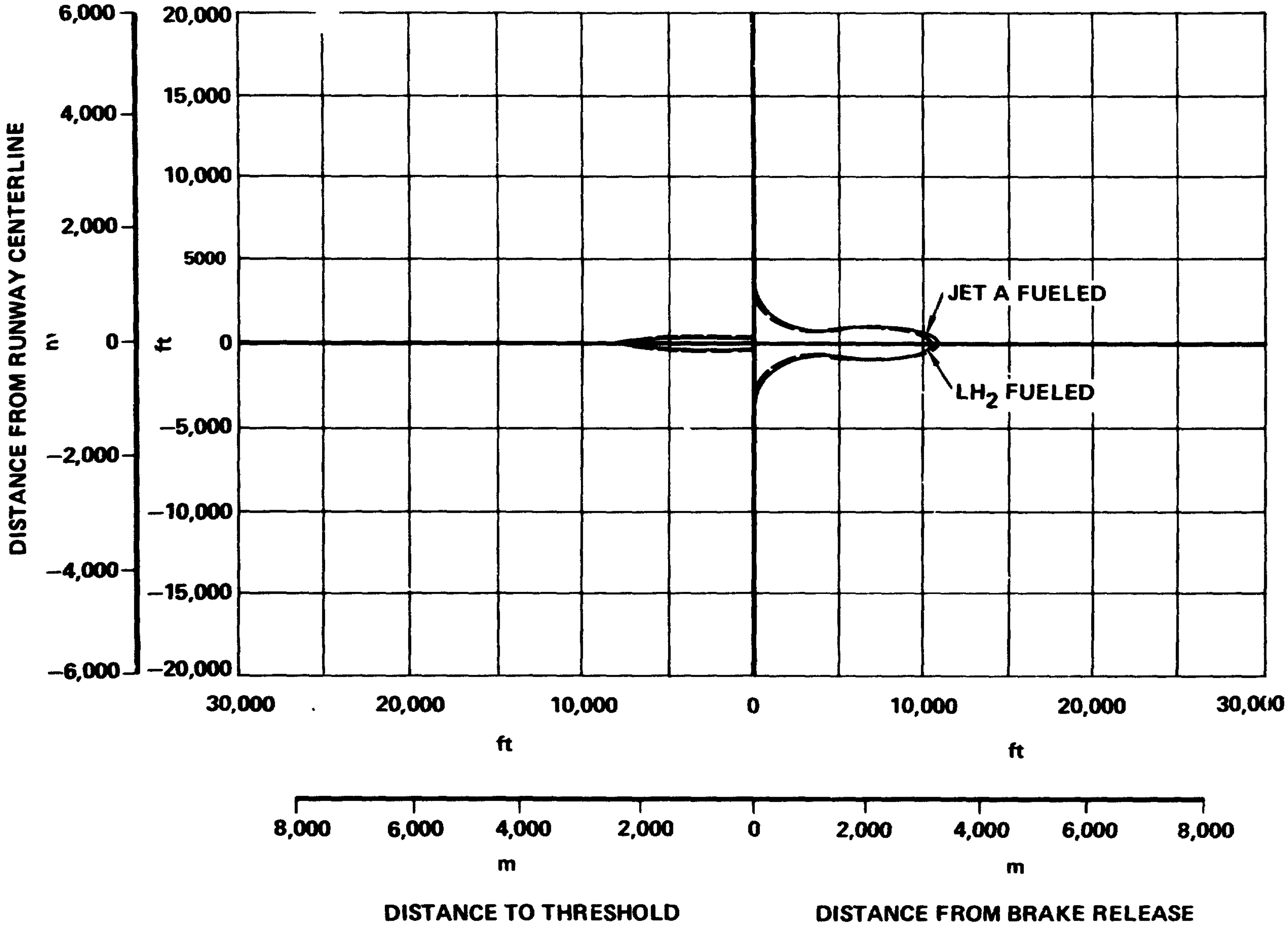


Figure 14. 90 EPNdB Contour Comparison - Short Range Aircraft

Noise limits which are listed in the table for comparison with the values calculated for the subject aircraft are calculated according to the recently published Notice of Proposed Rule Making (NPRM) (Reference 3) for revision of the FAR Part 36 noise certification requirements. The final format and limits of a revised FAR Part 36 will probably be fairly close to the NPRM.

The airplane takeoff performance conditions of 305 m (1000 ft) elevation runway, 32.2°C (90°F) day, are not consistent with the sea level, 25°C (77°F), reference conditions of FAR Part 36, or the proposed change thereto. This will tend to make some of the results conservative. The approach noise predictions, however, are probably slightly too low because airframe noise was not included.

The aircraft designed for the short range mission are essentially equal in noise characteristics. Both are significantly quieter than the limit noise calculated by the proposed standard; viz., 8.4 and 9 EPNdB quieter in flyover, 8.2 and 8.3 EPNdB quieter in sideline, and 7.7 and 8.8 EPNdB quieter in approach respectively, for the LH_2 and Jet A aircraft.

The LH_2 airplane is slightly noisier in approach for reasons explained in Reference 1. Compared to the Jet A design, it has smaller engines, lower L/D, and in approach it has approximately equal weight. Consequently, the LH_2 aircraft is required to operate its engines at more advanced throttle setting to maintain the 3 degree glide slope. This accounts for the fact Aircraft No. 1 has a slightly larger footprint area, for both the 80 and the 90 EPNdB contours. The area of the 90 EPNdB contour for the LH_2 airplane is 2.39 km^2 (0.92 mi^2) vs 2.30 km^2 (0.89 mi^2) for the Jet A design. These areas are the total of approach plus takeoff. They are less than half the noise goal specified in the study guidelines.

5. MEDIUM RANGE AIRCRAFT

5.1 Design Requirements

The medium range aircraft are designed to meet the following requirements and constraints:

- 5560 km (3000 n.mi.) design range
- 200 passengers plus baggage and cargo for a total payload of 19,960 kg (44,000 lb)
- Maximum FAR takeoff field length of 2438 m (8000 ft)
- Minimum initial cruise altitude of 10,360 km (34,000 ft)
- Reserve fuel per ATA domestic regulations
- Maximum approach speed of 69.4 m/s (135 KEAS) for aircraft weight corresponding to end of design range.

5.2 Configuration Selection

Based on the study of alternate configurations reported in Section 4.2 on Reference 1, the medium range configurations are low-winged aircraft of conventional appearance with four wing-mounted engines. This requires a minimum 2.7 percent gradient during the critical second segment climb with an engine out. The external tank LH_2 design (Aircraft No. 5) has tanks mounted above the wing at the inboard engine position. The internal tank LH_2 aircraft (No. 4) has tanks located fore and aft of the passenger compartment.

5.3 LH_2 Internal Tank Airplane (Aircraft No. 4)

5.3.1 Aspect Ratio Selection. - The method of generation of data for the parametric aircraft evaluation, and the basis for selection of an aspect ratio of 9.5 for minimum DOC, is the same as previously described for the short range aircraft in Section 4.3.

5.3.2 Configuration Description. - A general arrangement drawing of the LH_2 internal tank, Mach 0.85, 5560 km (3000 n.mi.), 200 passenger aircraft is shown in Figure 15. Specific features of the design are as follows:

Fuselage: The passenger compartment is located in the central section of the fuselage. Liquid hydrogen fuel tanks are located fore and aft of the passenger compartment. They occupy the full available cross section of the fuselage, except for provision for protective, crushable structure around the bottom areas. No provision was made for a passageway through or around the forward tank to permit movement between flight station and passenger compartment. The flight station is provided with special lavatory and galley facilities.

Passenger accommodations are shown in Figure 16 which illustrates the 10/90 percent class mix and seat spacing of 0.965 m (38 in.) and 0.86 m (34 in.), respectively, for first class and coach. Six abreast seating is used in first class and eight in coach. Provision for doors, lavatory, and galley facilities is in accordance with the requirements of FAR 25 and current widebody standards. Separate galleys are provided for first class and coach sections.

All cargo is contained in the pressurized fuselage below the cabin floor where space is provided for nine cargo containers plus additional space for loose cargo.

Wing: The wing has an aspect ratio of 9.5, thickness ratio of 10 percent and a sweep angle of 30°. The high lift devices include 15 percent leading edge slats and 35 percent double-slotted flaps where shown. Spoilers are used in flight for direct lift control, and for landing ground run deceleration. Conventional ailerons are fitted outboard of the flaps.

Landing Gear: The main gear consists of two four-wheel bogies mounted aft of the rear spar. They retract inward into the fuselage. The space between the retracted gear contains the hydraulic service center. The forward gear is a forward retracting two-wheel strut arrangement.

Hydrogen Tank and Systems: The hydrogen tank structural concept is the integral type. All aircraft structural loads in addition to the fuel dynamic and pressure loads are taken by the tank shell. Loads are transferred from the vehicle structure to the tank at each end by low heat-leak boron-reinforced fiberglass tubes arranged in an interconnect truss structure. Six-and-one-half inches of closed-cell plastic foam insulation, e.g., Rohacell 41S, covers the tank. This is wrapped by a vapor shield (Kapton) which is to prevent cryopumping in event a crack develops in the foam insulation. A fiberglass reinforced composite layer covers the entire tank section to provide a smooth aerodynamic surface, and protection from physical damage.

CHARACTERISTICS	WING	HORIZ. TAIL	VERT. TAIL
AREA M^2 (SQ FT)	148.8 (1602.3)	19.8 (212.9)	15.6 (167.7)
ASPECT RATIO	9.5	4.5	1.6
SPAN M (FT)	37.61 (123.4)	9.43 (31.0)	4.99 (16.4)
ROOT CHORD M (IN)	6.09 (239.7)	3.22 (126.8)	4.80 (188.8)
TIP CHORD M (IN)	1.83 (71.9)	0.97 (38.0)	1.44 (56.6)
TAPER RATIO	0.3	0.3	0.3
MAC M (IN)	4.34 (170.9)	2.30 (90.4)	3.42 (134.6)
SWEEP RAD (DEG)	0.524 (30)	0.524 (30)	0.524 (30)
T/C ROOT (%)	10	9	9
T/C TIP (%)	10	9	9

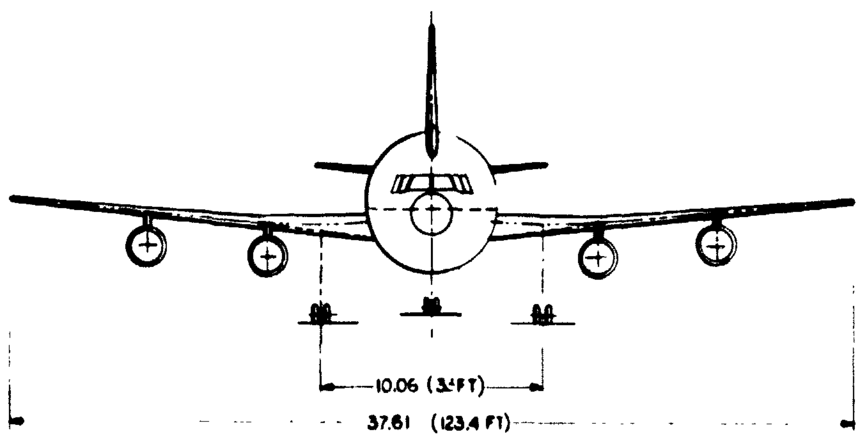
DESIGN GROSS WT. - 81,403 KG. (179,459 LB.)

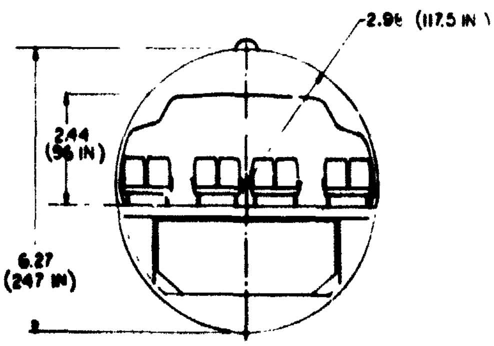
POWER PLANT - (2) TURBOFAN
INSTALLED THRUST (EA.) - 66,849 N. (15,029 LB.)

PASSENGERS - 200

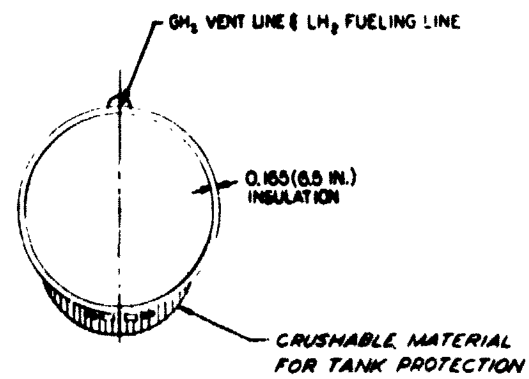
FUEL LH_2 - 9,492 KG (20,924 LB.)

RANGE - 5,559 KM. (3,000 NM.)

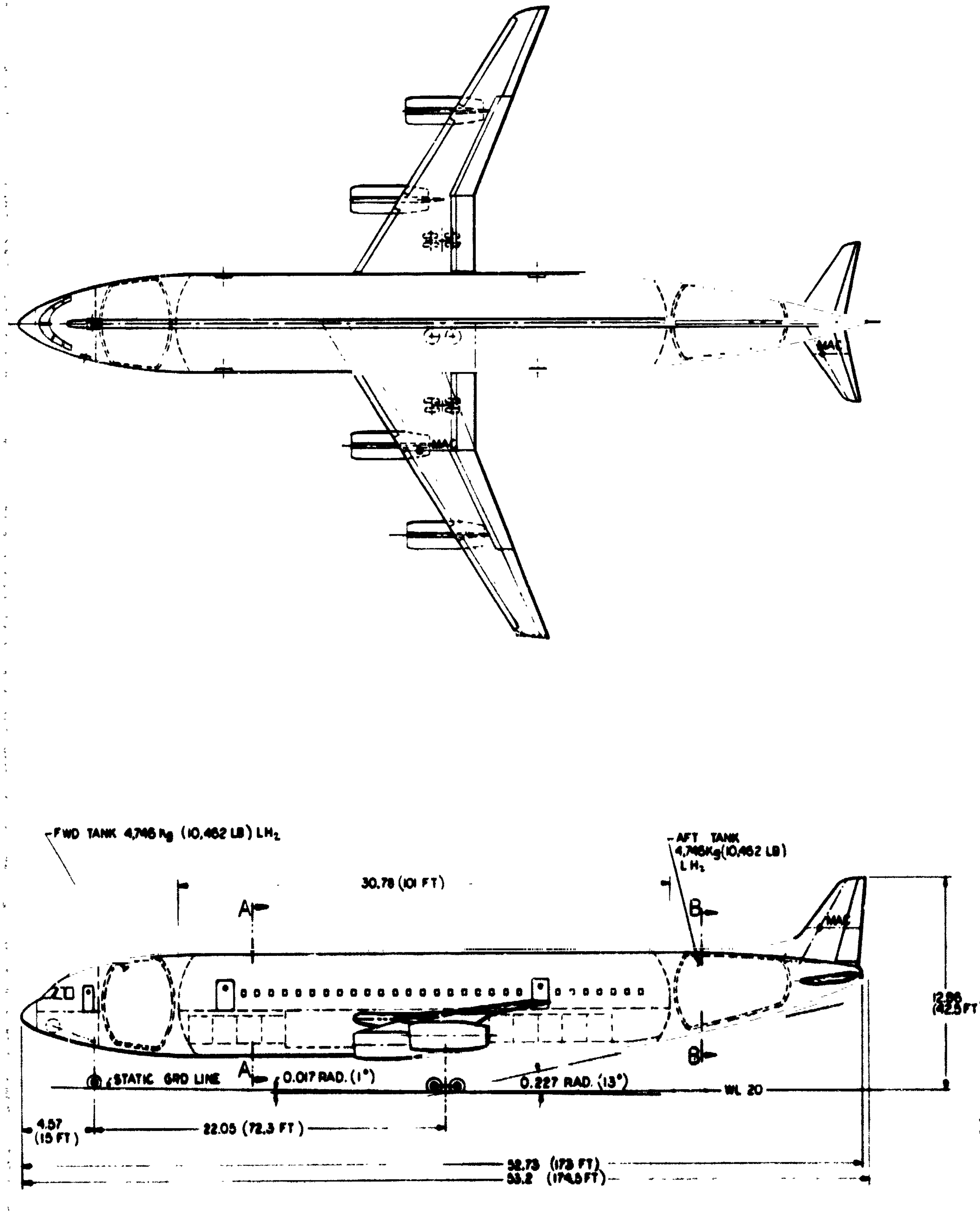




SECTION A-A
SCALE 1/90



SECTION B-B
SCALE 1/90



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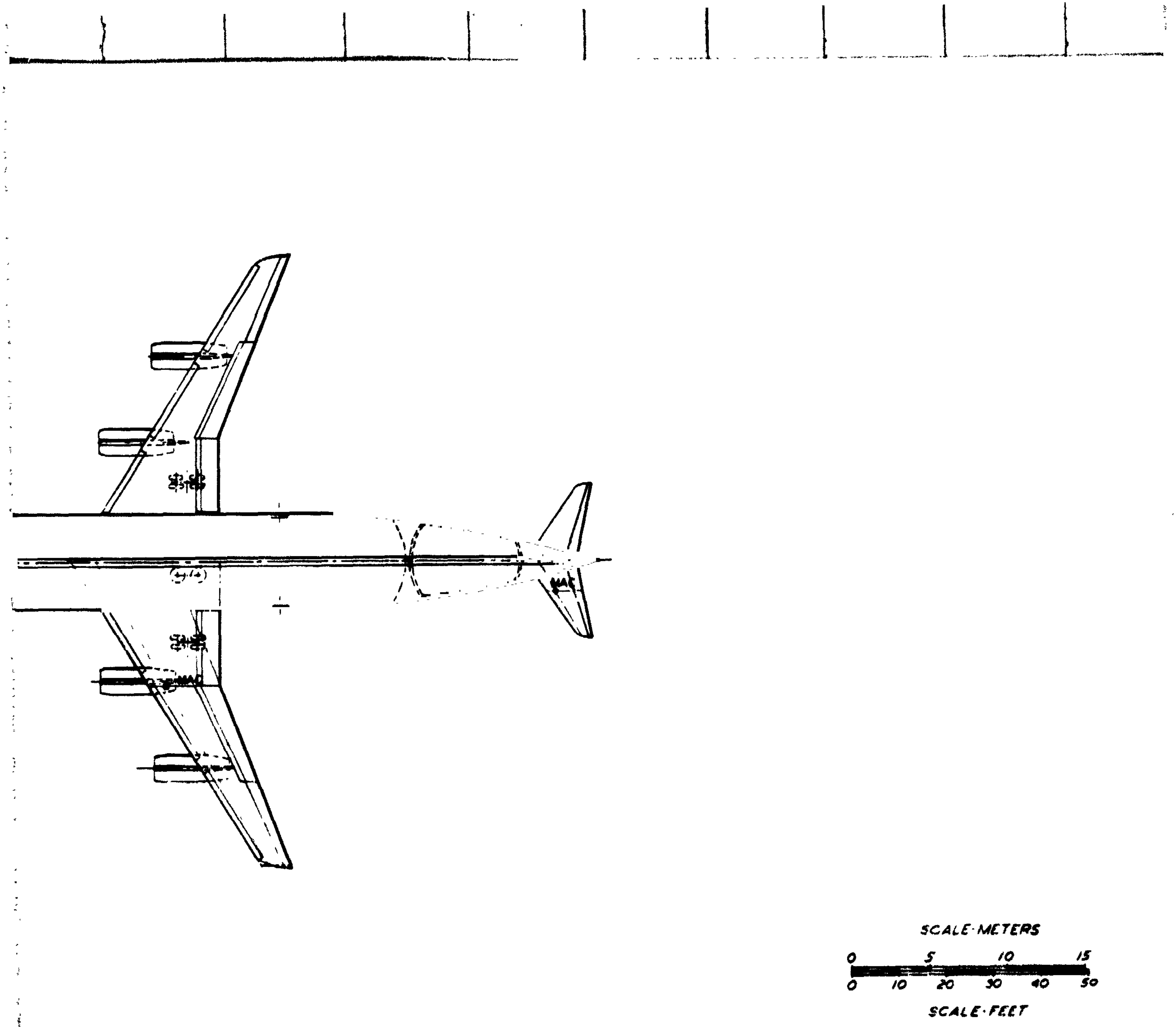
1. DIM. IN METER

Figure 15. General
Medium
Internal

FOLDOUT FRAME 2



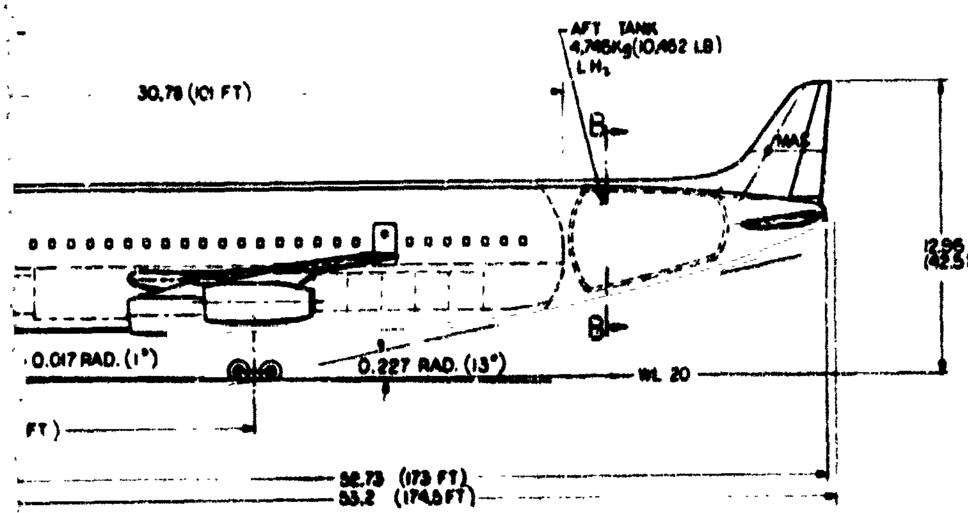
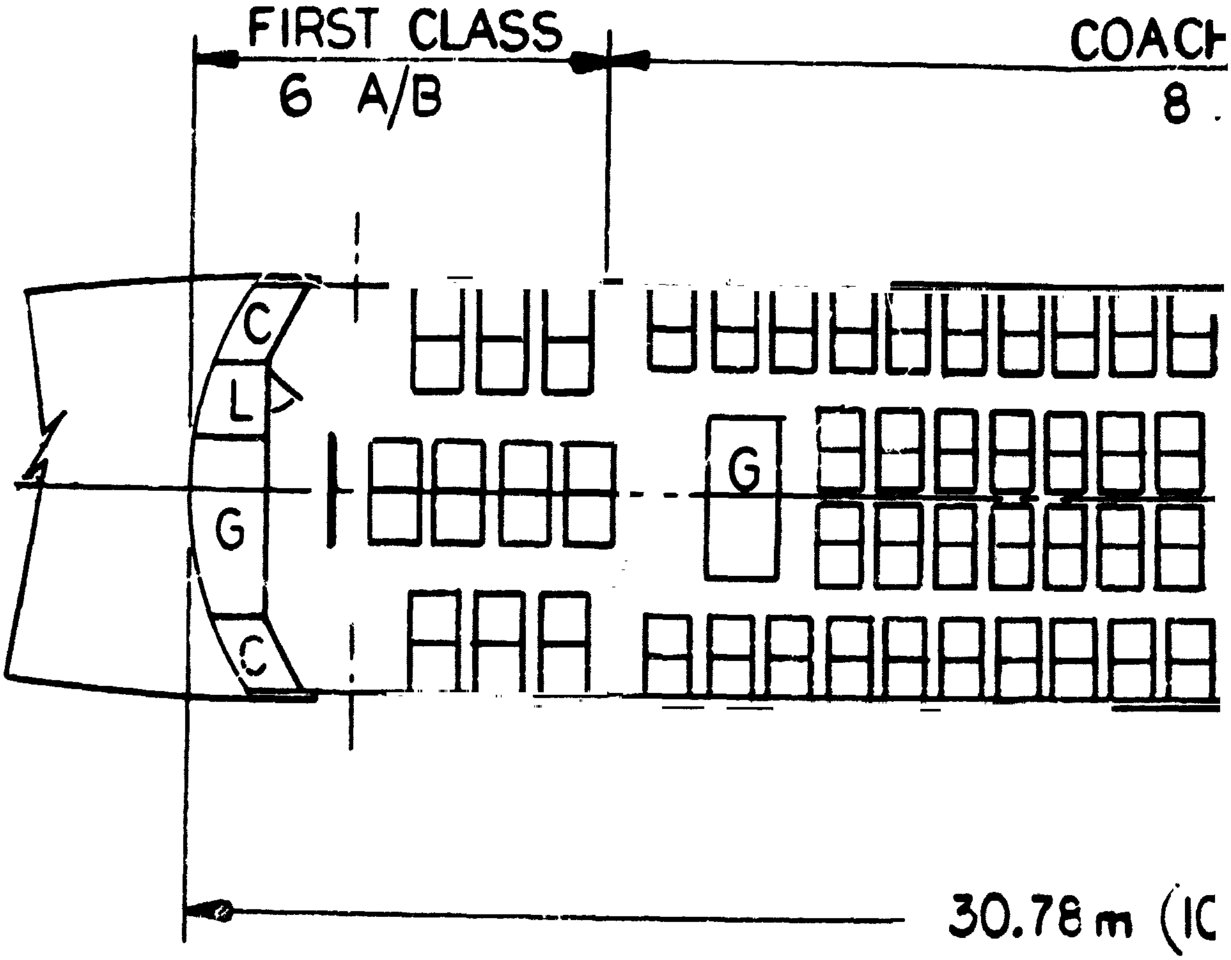


Figure 15. General Arrangement: Medium Range, LH_2 Internal Tank Transport

FOLDOUT FRAME 3



FIRST CLASS: 20 PAX, .96 m (38 IN) SPACING
COACH CLASS: 180 PAX, .86 m (34 IN) SPACING

L - LAVATORY
C - COATS
G - GALLEY

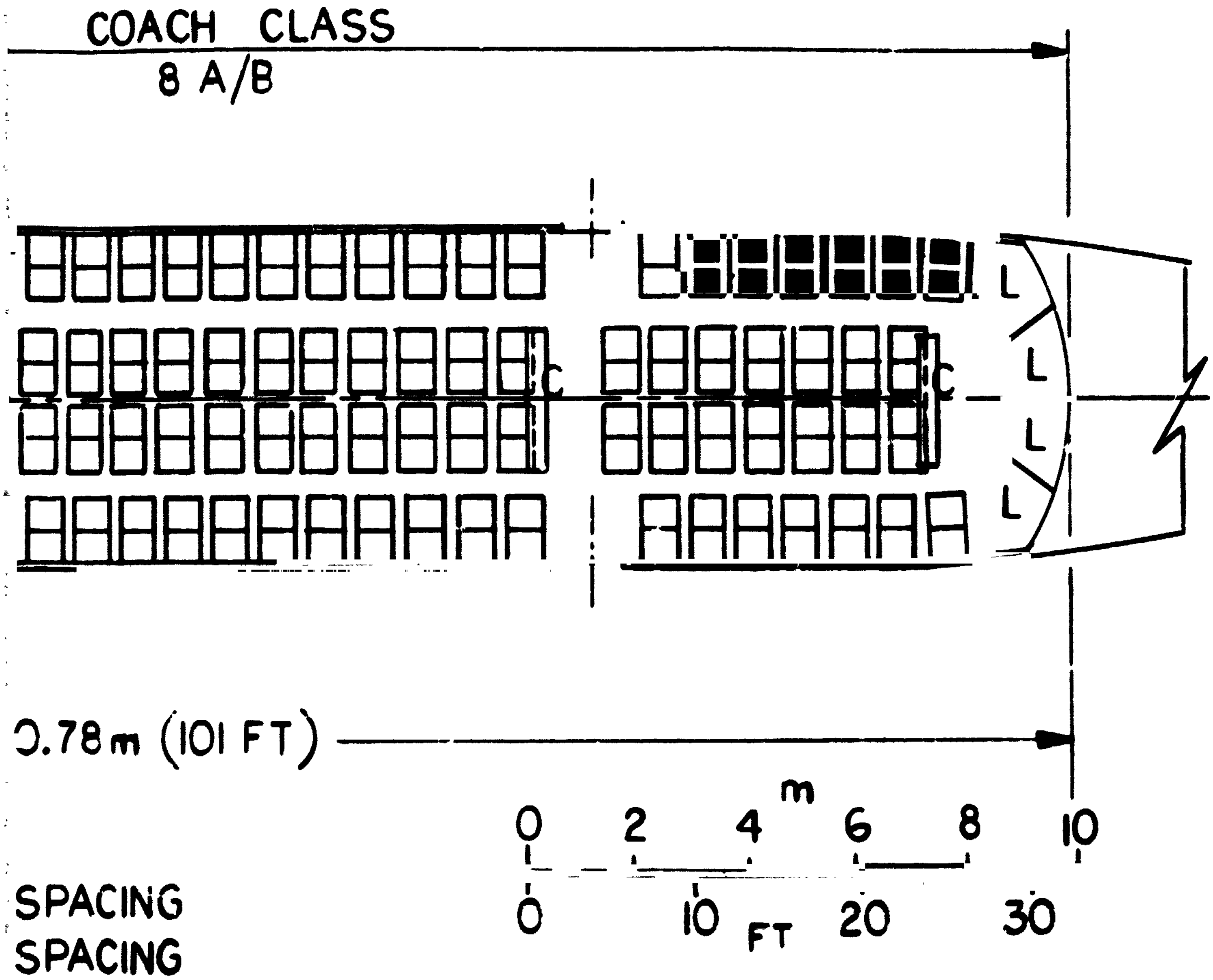


Figure 16. Interior Arrangement: 200 Pax Transport, LH_2 Internal Tank

FOLDOUT FRAME 2

5.3.3 Vehicle Data. - All weight, performance, and cost data are presented in Section 5.6.

5.4 LH_2 External Tank Airplane (Aircraft No. 5)

5.4.1 Aspect Ratio Selection. - The aspect ratio selected for this aircraft is 9.5 based on minimum DOC.

5.4.2 Configuration Description. - The general arrangement of this aircraft design is shown in Figure 17. This configuration is similar to the short range external tank LH_2 aircraft described in Section 4.4.2, with the exception that this design has four engines. Also, since the ratio of tank wetted area to volume is more favorable, only 6.5 inches of tank insulation are required to restrict boil-off to the desired fraction. The seating arrangement is shown in Figure 18. A 10/90 percent first-to-coach class mix is used with a seat spacing of 0.965 m (38 in.) in first, and 0.86 m (34 in.) in coach class. Six abreast seating is used in first class and eight in coach. An under-floor galley is used in this configuration, with elevators as shown to provide access. Five lavatories and provision for overhead coat storage is also shown.

5.4.3 Vehicle Data. - For performance, weight, and cost data see Section 5.6.

5.5 Jet A Airplane (Aircraft No. 6)

5.5.1 Aspect Ratio Selection. - The aspect ratio which provides minimum DOC for this aircraft is 9.75.

5.5.2 Configuration Description. - The general arrangement is shown in Figure 19. The aircraft design is conventional with all fuel carried in the wing box. The fuselage size and arrangment is the same as that of the external tank LH_2 aircraft described in Section 5.4.2.

5.5.3 Vehicle Data. - All weight, performance, and cost data is presented in Section 5.6.

5.6 Comparison of Medium Range Aircraft

Table X presents a summary of the characteristics of the three medium range, minimum DOC aircraft which meet the specified performance requirements.

Comparison of the external to the internal tank LH_2 aircraft shows that the internal tank version is superior in every significant respect. Aircraft No. 5 is 16 percent heavier in gross weight, 20 percent heavier in empty weight, costs 22 percent more in price and DOC, and uses 20 percent more fuel. Consequently the internal tank LH_2 design (Aircraft No. 4) was selected for comparison with the Jet A aircraft (Aircraft No. 6).

The comparison of the internal tank LH_2 aircraft and the corresponding Jet A fueled design for the medium range mission is also presented in Table X. The LH_2 fueled aircraft shows marginally superior characteristics compared to the Jet A design. It is considerably lighter in gross weight but slightly heavier in empty weight. The purchase price of the Jet A design is 4 percent less, but the LH_2 vehicle uses 5 percent less energy in performing the design missio·

Table XI shows a cost comparison breakdown for the three aircraft indicating a slightly higher price for the internal LH_2 compared to Jet A. Note that the DOC values shown in the table reflect use of arbitrarily selected values of fuel costs. Figure 20 shows the DOC versus fuel cost in \$/GJ (\$/10^6 Btu.). Equivalent cost of Jet A fuel expressed in ¢/gallon in shown at the top of the figure. The figure indicates the higher DOC of the external compared to the internal tank LH_2 aircraft and a slight advantage for the internal LH_2 compared to the Jet A design for equal fuel cost. Also shown is the average price paid by domestic truck airlines for Jet A fuel in September 1975 (28.6 ¢/gallon). At that price a differential of \$.133/GJ (\$0.14/10^6 Btu's) more could be paid for LH_2 and still maintain equal DOC's. This would increase slightly as the cost of Jet A increases.

Detailed ASSET computer printouts for aircraft No's. 4, 5, and 6 are shown in Appendix A-4, A-5 and A-6, respectively.

CHARACTERISTICS	WING	HORIZ. TAIL	VERT. TAIL
AREA M^2 (SQ FT)	174.2 (1874.7)	32.4 (349.2)	24.6 (264.6)
ASPECT RATIO	9.5	4.5	1.6
SPAN METERS (FT)	40.67 (133.4)	12.08 (39.6)	6.28 (20.6)
ROOT CHORD M (IN)	6.12 (240.8)	4.14 (162.8)	6.02 (237.1)
TIP CHORD M (IN)	2.45 96.3	1.24 48.8	1.81 71.1
TAPER RATIO	0.4	0.3	0.3
MAC METERS (IN)	4.54 (178.9)	2.95 (116.0)	4.29 (169.0)
SWEEP RAD (DEG)	0.524 (30)	0.524 (30)	0.524 (30)
T/C ROOT (%)	10	9	9
T/C TIP (%)	10	9	9

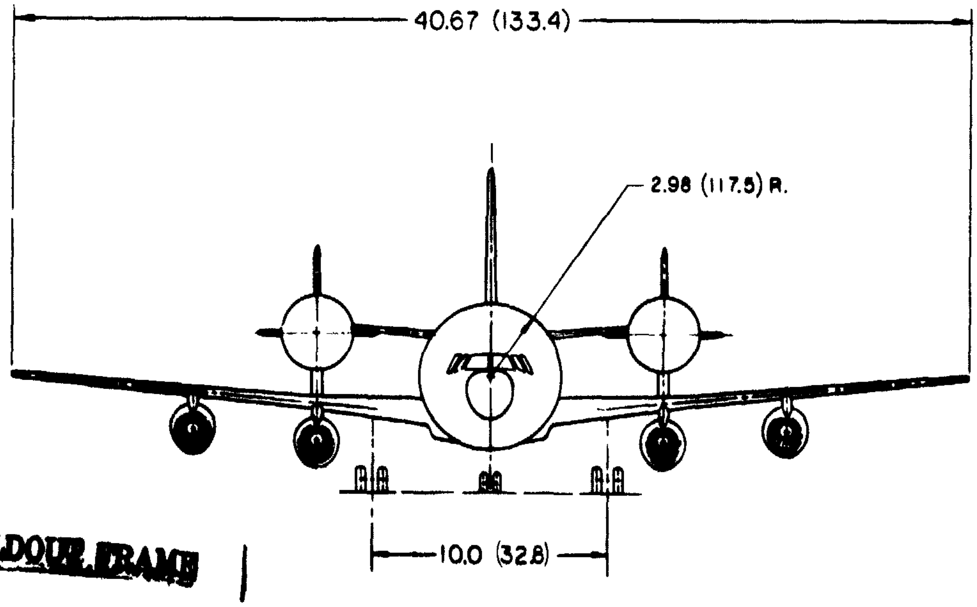
DESIGN GROSS WT. - 94,052 KG (207,346 LB.)

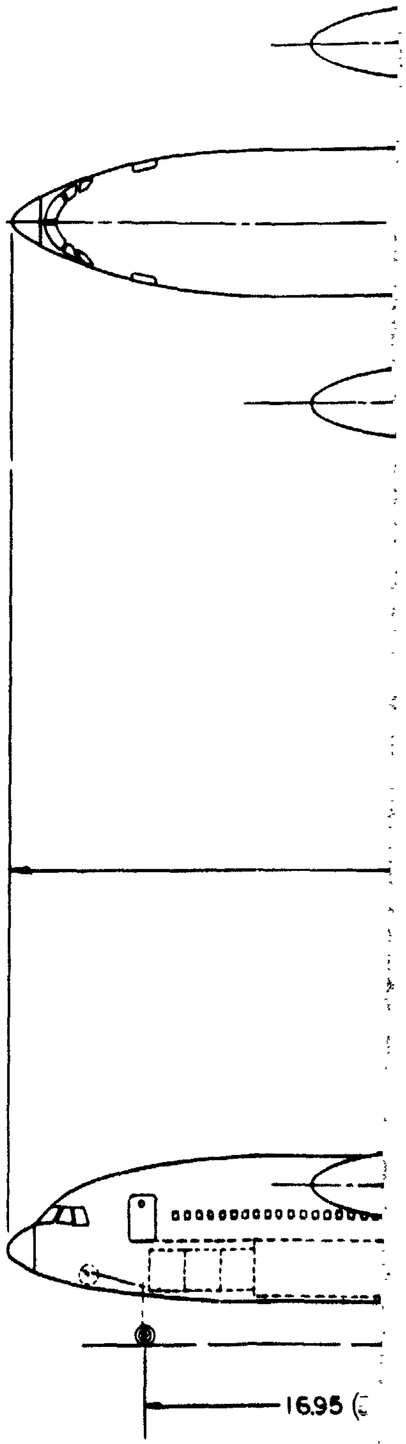
POWER PLANT - 2 TURBOFAN
INSTALLED THRUST (EA.) - 99,141 N. (22,289 LB.)

PASSENGERS - 200

FUEL LH_2 - 12,351 KG. (27,229 LB.)

RANGE - 5,559 KM. (3,000 N.M.)





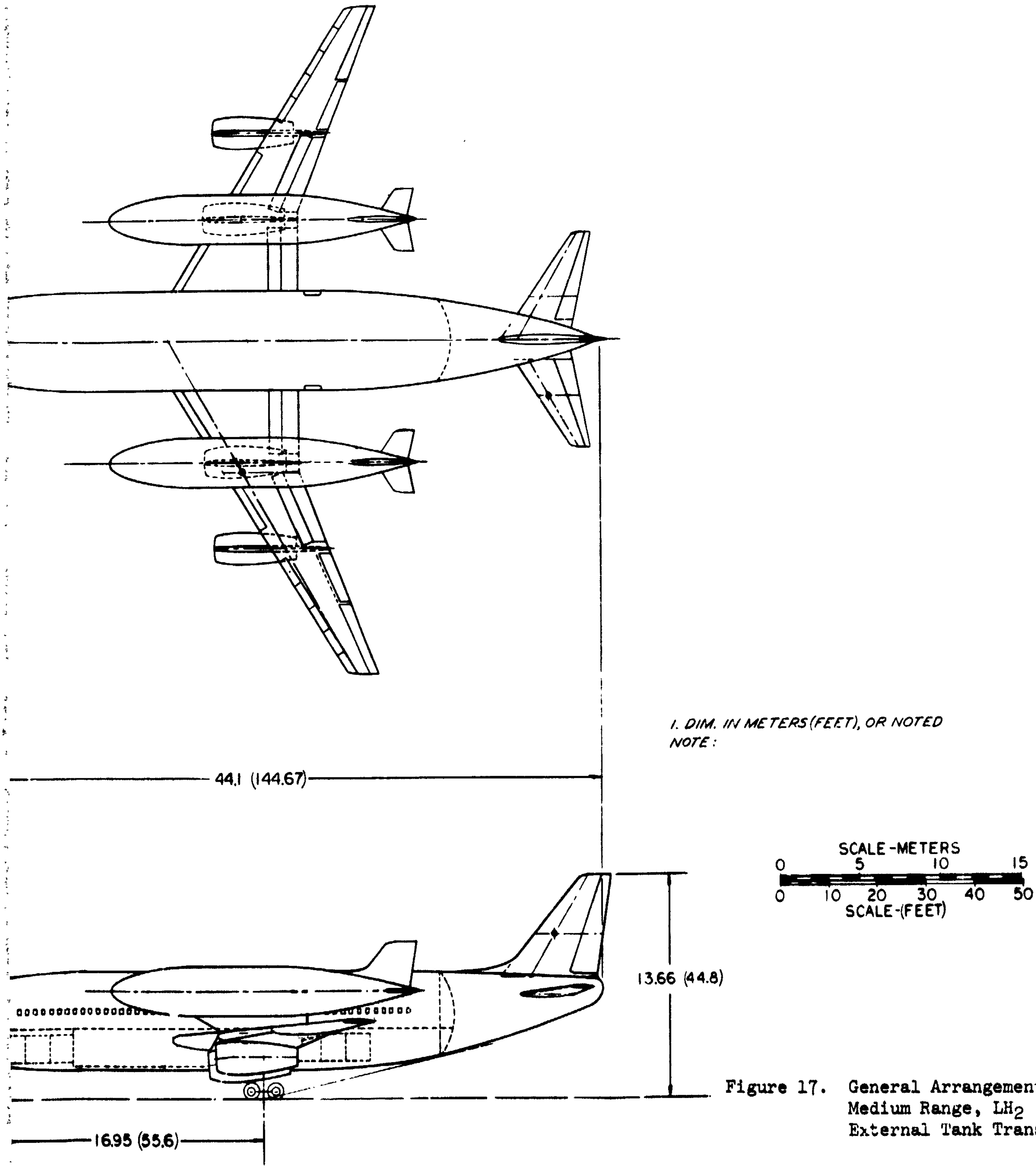
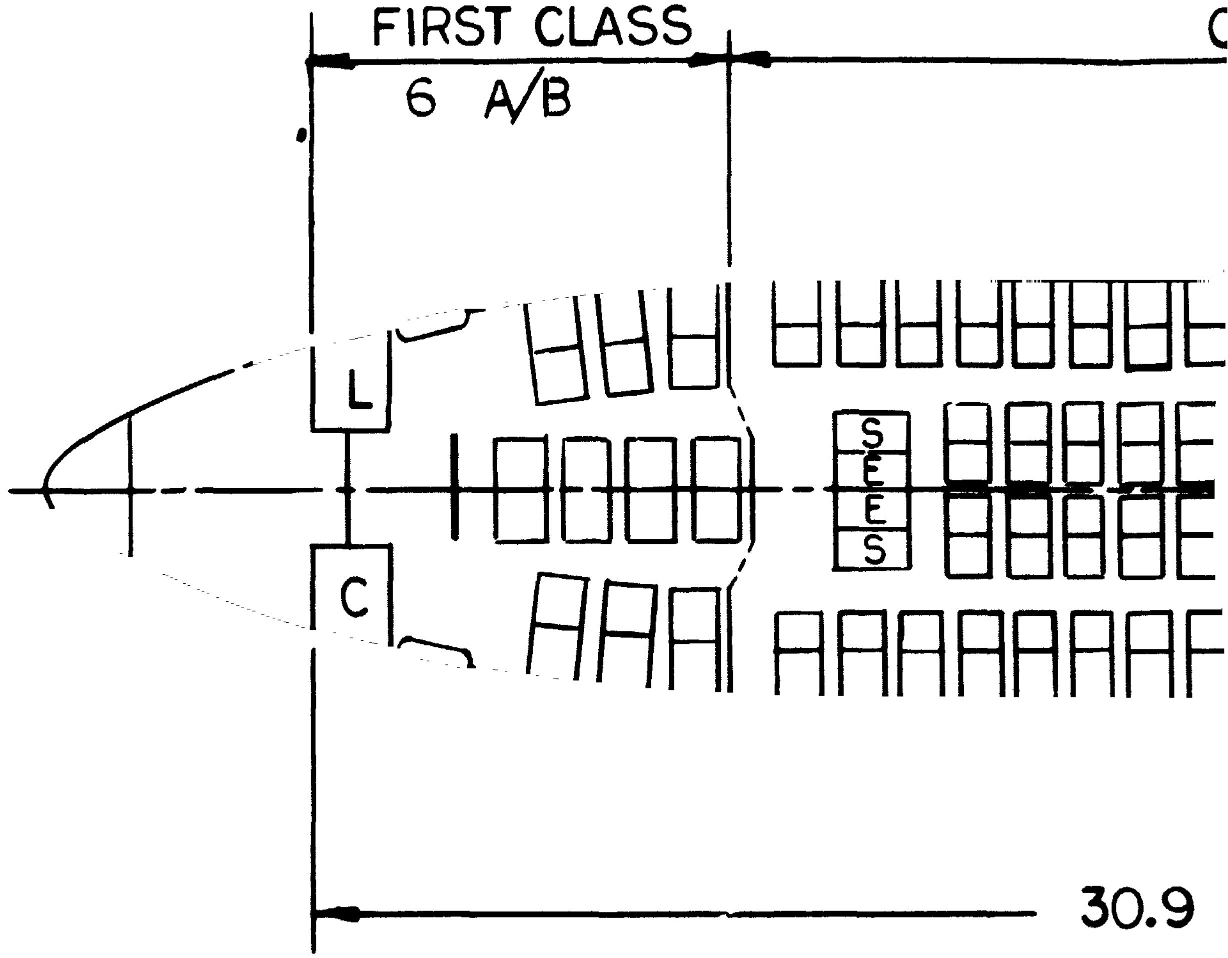
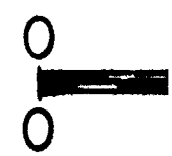


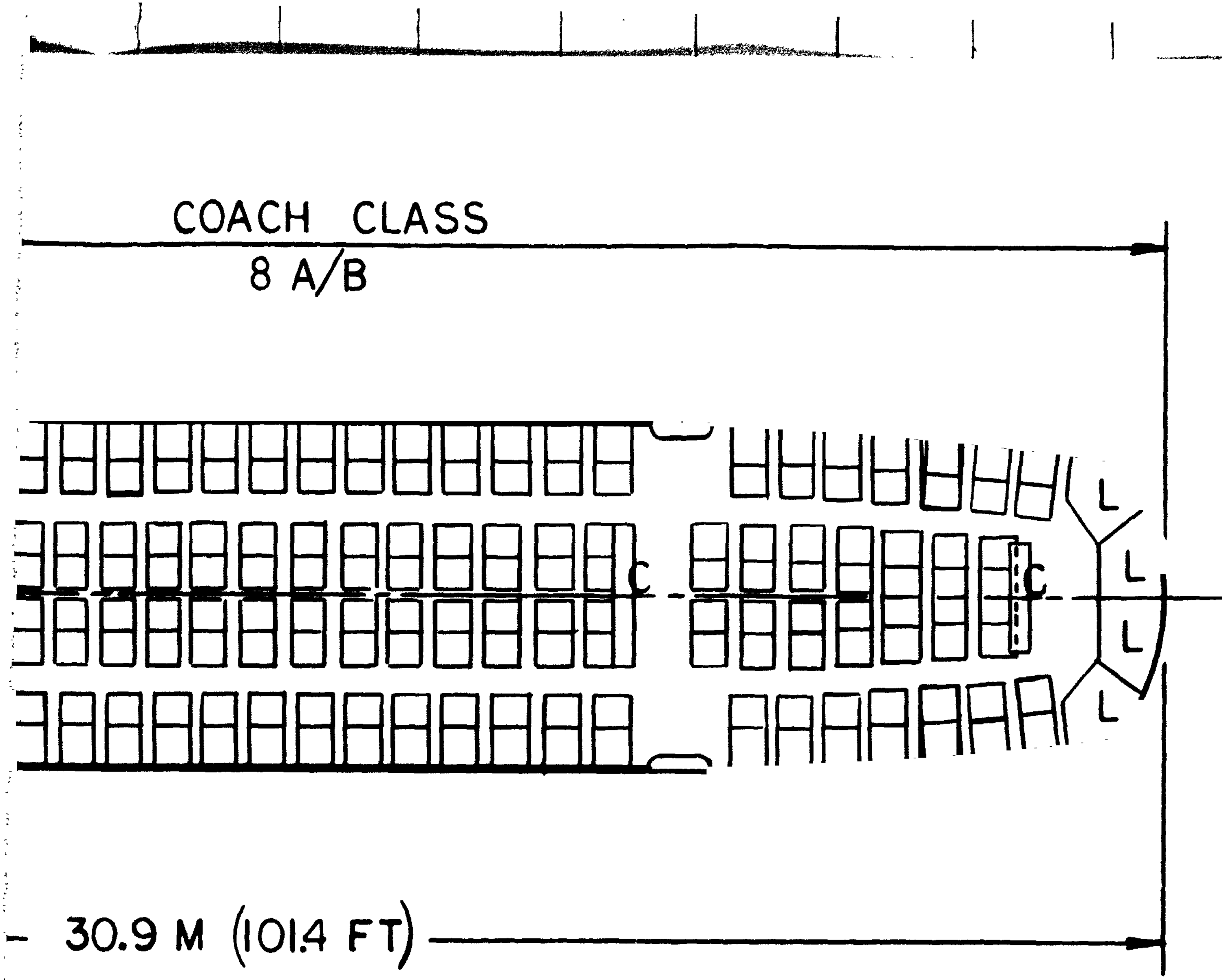
Figure 17. General Arrangement: Medium Range, LH_2 External Tank Transport



FIRST CLASS 20 PAX .96 · (38 IN) SPA
COACH CLASS 180 PAX .86 M (34 IN) SPA

L - LAVATORY
C - COATS
S - SERVICE CARTS
E - ELEVATOR TO BELOW
FLOOR KITCHEN





IN) SPACING
IN) SPACING

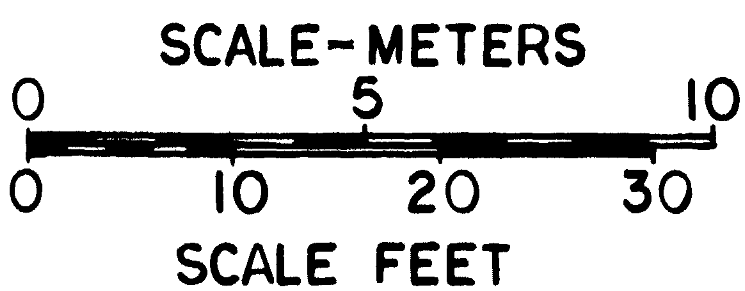


Figure 18. Internal Arrangement: 200 Pax Transport, LH_2 External Tank

CHARACTERISTICS	WING	HORIZ. TAIL	VERT. TAIL
AREA M^2 (SQ FT)	154.5 (1663.5)	27.5 (296.3)	20.6 (221.6)
ASPECT RATIO	9.75	4.5	1.6
SPAN M (FT)	38.82 (127.4)	11.13 (36.5)	5.74 (18.8)
ROOT CHORD M (IN)	6.12 (241.1)	3.81 (149.9)	5.52 (217.3)
TIP CHORD M (IN)	1.84 (72.3)	1.14 (45.0)	1.66 (65.2)
TAPER RATIO	0.3	0.3	0.3
MAC M (IN)	4.73 (171.9)	2.71 (106.8)	3.93 (154.9)
SWEEP RAD. (DEG)	0.524 (30)	0.524 (30)	0.524 (30)
T/C ROOT (%)	10	9	9
T/C TIP (%)	10	9	9

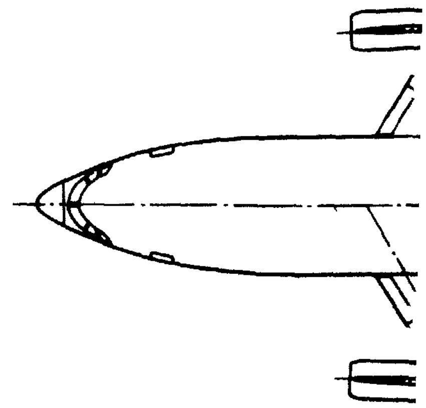
DESIGN GROSS WT. - 98,396 KG. (216,923 LB.)

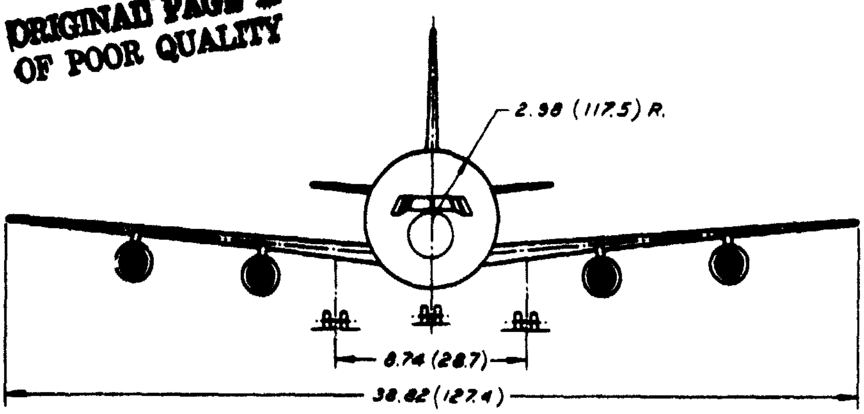
POWER PLANT - (2) TURBOFANS
INSTALLED THRUST (EA.) - 68,023 N. (15,293 LB.)

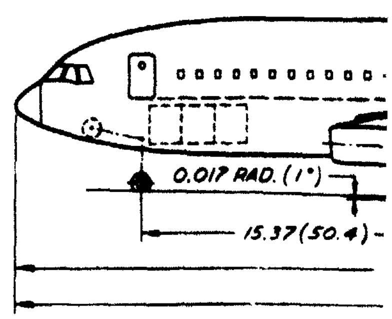
PASSENGERS - 200

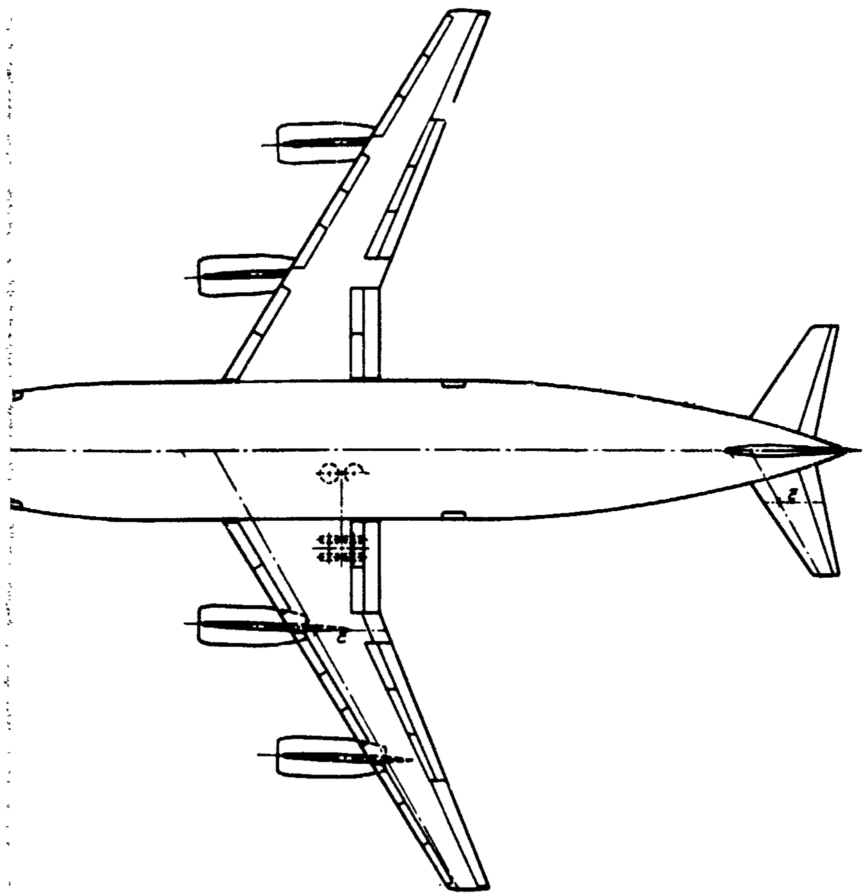
FUEL (JET A) - 27,731 KG. (61,136 LB.)

RANGE - 5,559 KM. (3,000 N.M.)









SCALE-METERS
0 5 10 15
0 10 20 30 40 50
SCALE-FEET

1. DIM. IN METERS (FEET), OR NOTED
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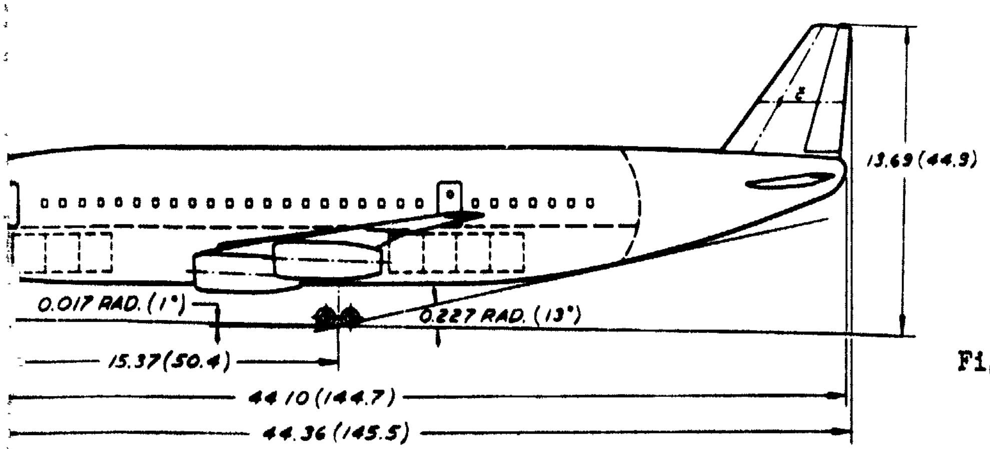


Figure 19. General Arrangement: Medium Range, Jet Fuel

FOLDOUT FRAME 2

TABLE X. COMPARISON OF FINAL DESIGN MEDIUM RANGE AIRCRAFT
(S.I. UNITS)
(5560 km RANGE – 200 PAX – Mach 0.85)

W_{pay} = 19,960 kg

		Aircraft No. 4 (Int. LH_2)	Aircraft No. 5 (Ext. LH_2)	Ratio: (Ext.)/(Int.)	Aircraft No. 6 (Jet A)	Ratio: (Jet A)/(Int. LH_2)
Gross Wt	kg	81,400	94,050	1.16	98,400	1.21
Total Fuel	kg	9,490	12,350	1.30	27,730	2.92
Block Fuel	kg	7,724	10,000	1.29	22,710	2.94
Operating Empty Wt	kg	51,950	61,740	1.19	50,710	0.98
Empty Wt	kg	47,420	57,050	1.20	46,270	0.98
Aspect Ratio		9.50	9.50		9.75	
Wing Area	m^2	149	174	1.17	155	1.04
Sweep	deg	30	30		30	
Span	m	38	41	1.08	39	1.03
Fus Length	m	53	44	0.83	44	0.83
L/D – Cruise		13.8	12.3	0.89	15.3	1.11
SFC – Cruise	$\frac{kg}{hr}$/daN	.215	.215		.627	2.92
Initial Cruise Altitude	m	10,670	11,580		10,360	
Wing Loading	kg/m^2	547	540		637	
Thrust/Weight	N/kg	3.28	4.21	1.28	2.76	0.84
No. Engines		4	4		4	
Thrust Per Engine	N	66,850	99,140	1.48	68,020	1.02
FAR T.O. Distance	m	1,640	1,290	0.79	2,430	1.48
FAR Ldg. Distance	m	1,760	1,755		1,757	
2nd Seg. Climb Grad. (Eng out)		0.094	0.146	1.55	0.066	0.70
Approach Speed	m/s	69	69		69	
Weight Fractions – Percent						
Fuel		11.7	13.1		28.2	
Payload		24.5	21.2		20.3	
Structure		31.0	30.7		27.5	
Propulsion (Includes Fuel System)		12.5	17.2		7.1	
Equipment and Operating Items		20.3	17.8		16.9	
Price	$\$10^6$	13.95	17.07	1.22	13.33	0.96
DOC	$\frac{¢}{seat\ km}$	0.723[1]	0.878[1]	0.122	0.650[2]	0.90
Energy Utilization	$\frac{kJ}{seat\ km}$	833	1,078	1.29	875	1.05

[1]DOC based of LH_2 cost = \$2.85/GJ

[2]DOC based on Jet A cost = \$1.90/GJ

TABLE X. COMPARISON OF FINAL DESIGN MEDIUM RANGE AIRCRAFT

(U.S. CUSTOMARY UNITS)

(3000 n. mi. RANGE – 200 PAX – Mach 0.85)

W_{pay} = 44,000 lbs

		Aircraft No. 4 (Int. LH_2)	Aircraft No. 5 (Ext. LH_2)	Ratio (Ext.)/(Int.)	Aircraft No. 6 (Jet A)	Ratio (Jet A)/(Int. LH_2)
Gross Wt.	lb	179,460	207,350	1.16	216,920	1.21
Total Fuel	lb	20,920	27,230	1.30	61,140	2.92
Block Fuel	lb	17,030	22,040	1.29	50,080	2.94
Operating Empty Wt	lb	114,540	136,120	1.19	111,790	0.98
Empty Wt	lb	104,530	125,770	1.20	102,000	0.98
Aspect Ratio		9.50	9.50		9.75	
Wing Area	ft^2	1,602	1,875	1.17	1,664	1.04
Sweep	deg	30	30		30	
Span	ft	123.4	133.5	1.08	127.4	1.03
Fus Length	ft	173.4	144.7	0.83	144.7	0.83
L/D - Cruise		13.8	12.3	0.89	15.3	1.11
SFC - Cruise	$\frac{lb}{hr}$ /lb	0.211	0.211		0.616	2.92
Initial Cruise Altitude	ft	35,000	38,000		34,000	
Wing Loading	lb/ft^2	112.0	110.6		130.4	
Thrust/Weight		0.335	0.430	1.28	0.282	0.84
No. Engines		4	4		4	
Thrust per Engine	lb	15,030	22,290	1.48	15,290	1.02
FAR T.O. Distance	ft	5,382	4,236	0.79	7,975	1.48
FAR Ldg. Distance	ft	5,779	5,757		5,763	
2nd Seg. Climb Grad. (Eng out)		0.094	0.146	1.55	0.066	0.70
Approach Speed	KEAS	135	135		135	
Weight Fractions – Percent						
Fuel		11.7	13.1		28.2	
Payload		24.5	21.2		20.3	
Structure		31.0	30.7		27.4	
Propulsion (Includes Fuel System)		12.5	17.2		7.2	
Equipment and Operating Items		20.3	17.8		16.9	
Price	$\$10^6$	13.95	17.07	1.22	13.33	0.96
DOC	¢/seat n.mi	1.338[1]	1.626[1]	1.22	1.203[2]	0.90
Energy Utilization	Btu/seat n.mi.	1,464	1,895	1.29	1,537	1.05

[1] DOC based on LH_2 cost = $\$3/10^6$ BTU = 15.48 ¢/lb

[2] DOC based on Jet A cost = $\$2/10^6$ Btu = 24.8¢/gal

TABLE XI. COST COMPARISON OF FINAL DESIGN MEDIUM RANGE AIRCRAFT

5560 km (3000 n.mi.) - 200 Pax - Mach 0.85

	Aircraft No. 4 (Int. LH_2)	Aircraft No. 5 (Ext. LH_2)	Aircraft No. 6 (Jet A)
Development $\$10^6$			
Airframe	362.24	469.40	390.66
Engine (Amortized in prod. cost)	0	0	0
TOTAL	362.24	469.40	390.66
Production $\$10^6$			
Airframe Cost	9.880	11.674	9.561
Engine (Including R&D)	2.540	3.559	2.148
Avionics	0.500	0.500	0.500
R&D Amortization (Airframe)	1.035	1.341	1.116
TOTAL Aircraft Price	13.955	17.074	13.325
Direct Operating Cost $\frac{\$}{km}$ $\left(\frac{\$}{n.mi.}\right)$			
Crew	0.213 (0.395)	0.213 (0.395)	0.214 (0.396)
Maintenance			
Airframe Labor (Including Burden)	0.092 (0.170)	0.103 (0.191)	0.090 (0.167)
Engine Labor (Including Burden)	0.048 (0.089)	0.058 (0.107)	0.072 (0.134)
Airframe Material	0.053 (0.098)	0.063 (0.116)	0.052 (0.096)
Engine Material	0.054 (0.100)	0.076 (0.141)	0.069 (0.128)
Fuel* and Oil	0.499 (0.924)	0.645 (1.195)	0.339 (0.628)
Insurance	0.10 (0.185)	0.123 (0.227)	0.096 (0.177)
Depreciation	0.386 (0.714)	0.475 (0.879)	0.367 (0.679)
TOTAL DOC	1.445 (2.675)	1.756 (3.251)	1.299 (2.405)
TOTAL Unit DOC $\frac{¢}{seat\ km}$ $\left(\frac{¢}{seat\ n.mi.}\right)$	0.723 (1.338)	0.878 (1.626)	0.650 (1.203)

*Fuel Cost:

Jet A = \$1.90/GJ (\$2/10^6 Btu = 24.8¢/gal = 3.68¢/lb)

LH_2 = \$2.85/GJ (\$3/10^6 Btu = 15.48¢/lb)

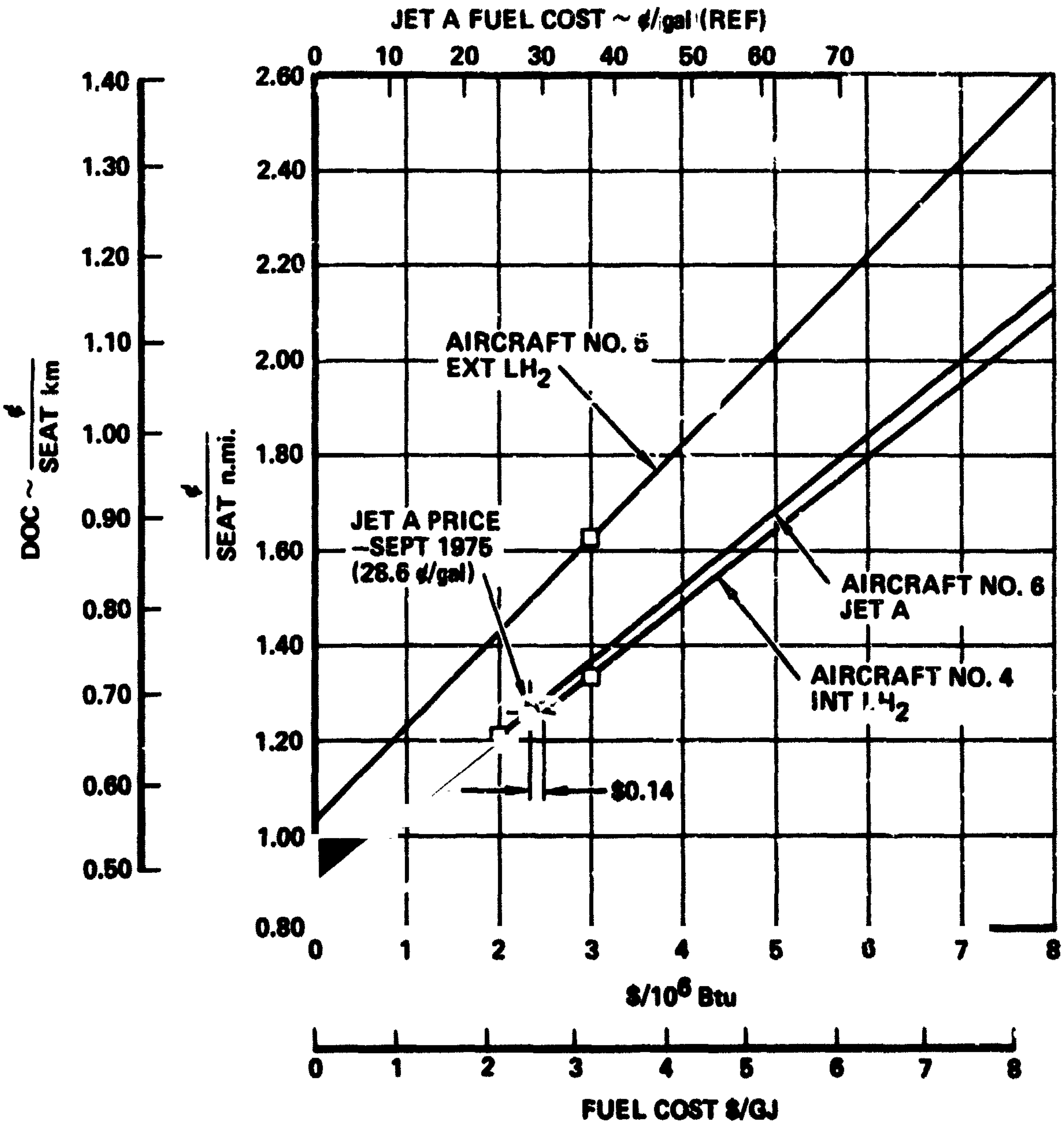


Figure 20. DOC Versus Fuel Cost - 3000 n.mi., 200 Pax Aircraft

5.6.1 Noise. - A comparison of noise generated by the two aircraft is presented numerically in Table XII and graphically in Figure 21. The analysis was made using the takeoff and approach paths generated for the respective aircraft in the ASSET program, and using engine parameters and procedures described in section 4.8.2 of the final report of the previous study (Reference 1).

As noted in section 4.6.1, noise limits which are listed in the table for comparison with the values calculated for the subject aircraft are those according to the recently published Notice of Proposed Rule Making (Reference 3) for revision of the FAR Part 36 noise certification requirements.

The LH_2 aircraft designed for the medium range mission is appreciably quieter in flyover, but slightly noisier in sideline and during approach than its Jet A fueled counterpart. Both are significantly quieter than the limit noise calculated by the proposed standard. The differences are 15.2 and 12.2 EPNdB quieter in flyover, 12.2 and 13.1 EPNdB quieter in sideline, and 7.4 and 8.3 EPNdB quieter in approach, respectively, for the LH_2 and Jet A aircraft.

The LH_2 airplane is slightly noisier in approach for reasons explained in Reference 1 and reviewed in section 4.6.1. As shown in Table XII, the area of the 90 EPNdB contour for the LH_2 airplane is 3.21 km^2 (1.24 mi^2) vs 3.75 km^2 (1.45 mi^2) for the Jet A design. These areas are the total of approach plus takeoff. They are both less than the noise goal listed in the study guidelines, Table II.

TABLE XII. NOISE EVALUATION - MEDIUM RANGE AIRCRAFT

Airplane No.	4		6	
Number of Engines	4		6	
Fuel	LH_2		Jet A	
Gross Weight - kg (lb)	81,403 (179,460)		98,395 (216,920)	
FAR 36 Flyover Level (EPNdB)	81.8		85.9	
Limit per NPRM 75-37	97.0		98.1	
FAR 36 Sideline Level	86.4		86.0	
Limit Per NPRM 75-37	98.6		99.1	
FAR 36 Approach Level (EPNdB)	93.1		92.8	
Limit Per NPRM 75-37	100.5		101.1	
Enclosed "Footprint" Contour Area				
	km^2	$st.mi.^2$	km^2	$st.mi.^2$
80 EPNdB - Takeoff	10.33	3.99	12.48	4.82
- Approach	8.08	3.12	7.85	3.03
- Total	18.41	7.11	20.33	7.85
90 EPNdB - Takeoff	2.41	0.93	3.00	1.16
- Approach	.80	0.31	.75	0.29
- Total	3.21	1.24	3.75	1.45

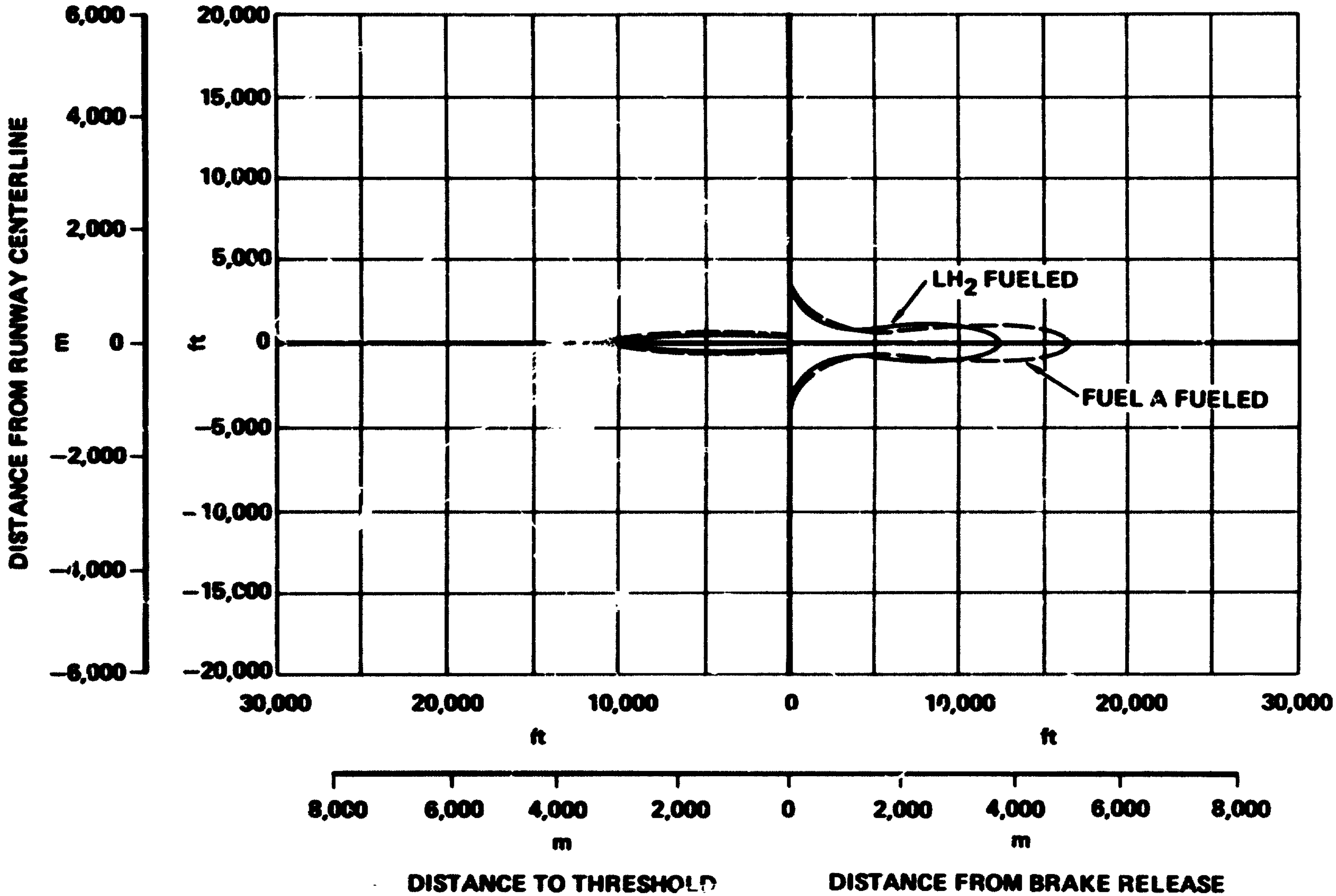


Figure 21. 90 EPNdB Contour Comparison - Medium Range Aircraft

6. LONG RANGE AIRCRAFT

6.1 Design Requirements

The long range aircraft are designed to provide the following performance and meet the specified constraints:

- 9265 km (5000 n.mi.) radius. With full payload and ATA international reserves for each segment, fly 9265 km, land, takeoff unrefueled, and fly another 9265 km segment.
- 400 passengers plus baggage and cargo for a total payload of 39,920 kg (88,000 lb)
- Maximum FAR takeoff field length of 3658 m (12,000 ft)
- Minimum initial cruise altitude of 10,360 m (34,000 ft)
- Maximum approach speed of 69.4 m/s (135 KEAS) at a landing weight equivalent to that at the end of the first 9265 km (5000 n.mi.) segment.

6.2 Configuration Selection

An external tank LH_2 configuration was not evaluated for this long range mission because the work done in Reference 1 had confirmed that the high drag and weight penalties associated with this design concept would be noncompetitive.

Designs of the internal tank LH_2 and the Jet A aircraft are similar to the medium range aircraft described in Section 5.0 with the exception that the passenger cabin of the internal LH_2 aircraft is a two deck arrangement. It is described in a following section.

Both the long range LH_2 and Jet A aircraft have relatively high growth factors because of the high fuel fraction required for the very long, unrefueled flight. During the initial parametric investigation of these aircraft, the constraints imposed on each aircraft were examined to determine which were critical in sizing the aircraft. The results indicated that initial cruise altitude was the principal design constraint for the LH_2

design, and that takeoff field length was most significant for the Jet A aircraft. Consequently, an investigation of the sensitivity of each aircraft to these parameters was made. Results are described below for the LH_2 aircraft and in Section 6.4.1 for the Jet A.

6.3 LH_2 Internal Tank Airplane (Aircraft No. 7)

6.3.1 Parametric Investigation. - Results of the study to determine the effect of initial cruise altitude on characteristics of aircraft No. 7 are shown in Table XIII. The data are plotted in Figures 22 and 23. Note that each airplane design listed in Table XIII represents the combination of wing loading (W/S) and thrust-to-weight ratio (T/W) which meets all design constraints, i.e., approach speed, 2nd segment climb gradient, and FAR takeoff field length, and achieves the specified initial cruise altitude. In Figure 22 these results are plotted to determine the minimum direct operating cost (DOC) for each aspect ratio. The locus of minima is indicated by the broken line. It shows that changing the initial cruise altitude of the long range hydrogen-fueled airplane from 10,360 m (34,000 ft) would not result in a significant decrease in DOC. Accordingly, this altitude was retained as a design constraint for the long range aircraft in this study. Also, as shown in Figure 22 the aspect ratio selected for this aircraft on the basis of minimum DOC is 10.

Following this initial investigation, corrections to the ASSET input were made as required due to the reduction of the actual gross weight over the preliminary estimates, and the final aircraft data was generated.

6.3.2 Configuration Description. - A general arrangement drawing of the LH_2 internal tank, Mach 0.85, 9265 km (5000 n.mi.) radius 400 passenger aircraft is shown in Figure 24.

Fuselage: As in the previous LH_2 fueled aircraft the passenger compartment is located in the central section of the fuselage in a double deck arrangement. Liquid hydrogen fuel tanks are located fore and aft of the passenger compartment. They occupy the full available cross section of the fuselage, except for provision for protective, crushable structure around the bottom areas.

TABLE XIII. EFFECT OF INITIAL CRUISE ALTITUDE ON LH_2 AIRCRAFT

(S.I. UNITS)

(Aircraft No. 7)

Initial Cruise Alt.-10^3m		Aspect Ratio			
		8	9	10	12
	W/S – kg/m^2	575	571	569	565
	T/W – N/kg	0.33	0.32	0.31	0.29
	DOC – ¢/seat km	.803	.784	.776	.788
	W_G – kg	282,050	278,740	278,420	284,320
	Cost – $$10^6$	41.63	41.56	41.8	43.3
	FAR T.O. – m	1,646	1,670	1,707	1,798
11.58	2nd Seg. Grad.	0.079	0.0823	0.085	0.085
	V(Appr.) – m/s	69	69	69	69
	W/S – kg/m^2	575	573	570	566
	T/W – N/kg	0.31	0.30	0.29	0.27
	DOC – ¢/seat km	.786	.772	.767	.777
	W_G – kg	277,510	275,290	275,930	283,860
	Cost – 10^6	40.53	40.54	40.96	42.7
10.97	FAR T.O. – m	1,774	1,804	1,847	1,963
	2nd Seg. Grad.	0.067	0.0716	0.073	0.073
	V(Appr.) – m/s	69	69	69	69
	W/S – kg/m^2	576	574	571	568
	T/W – N/kg	0.29	0.28	0.27	0.25
	DOC – ¢/seat km	.776	.766	.761	.781
	W_G – kg	274,880	273,970	274,750	285,630
	Cost – $$10^6$	39.7	39.86	40.28	42.42
10.36	FAR T.O. – m	1,914	1,959	2,012	2,149
	2nd Seg. Grad.	0.056	0.0605	0.062	0.062
	V(Appr.) m/s	69	69	69	69
	W/S – kg/m^2	578	575	574	570
	T/W – N/kg	0.27	0.26	0.25	0.24
	DOC – ¢/seat km	.769	.764	.767	.789
	W_G – kg	273,430	274,340	277,470	288,800
	Cost – $$10^6$	38.98	39.37	40.1	42.56
9.75	FAR T.O. – m	2,088	2,143	2,210	2,262
	2nd Seg. Grad.	0.045	0.048	0.05	0.0565
	V(Appr.) – m/s	69	69	69	69
	W/S – kg/m^2	579	577	575	571
	T/W – N/kg	0.256	0.25	0.24	0.233
	DOC – ¢/seat km	.772	.766	.774	.795
	W_G – kg	275,240	275,520	280,640	291,670
	Cost – $$10^6$	38.83	39.28	40.18	42.75
	FAR T.O. – m	2,234	2,251	2,338	2,359
9.14	2nd Seg. Grad.	0.0364	0.043	0.045	0.0525
	V(Appr.) m/s	69	69	69	69
	W/S – kg/m^2	580	578	577	572
	T/W – N/kg	0.25	0.247	0.235	0.23
	DOC – ¢/seat km	.775	.768	.780	.798
	W_G – kg	276,520	276,240	282,590	292,570
8.53	Cost – $$10^6$	38.2	39.3	42.8	42.82
	FAR T.O. – m	2,304	2,292	2,377	2,393
	2nd Seg. Grad.	0.033	0.0413	0.042	0.051
	V(Appr.) – m/s	69	69	69	69

TABLE XIII. EFFECT OF INITIAL CRUISE ALTITUDE ON LH_2 AIRCRAFT

(U.S. CUSTOMARY UNITS)
(Aircraft No. 7)

Initial Cruise Alt.-10^3m		Aspect Ratio			
		8	9	10	12
38	W/S – lb/ft^2	117.7	117	116.5	115.7
	T/W	0.33	0.32	0.31	0.29
	DOC – ¢/Seat n.mi.	1.4867	1.4527	1.437	1.46
	W_G – lb	621,800	614,500	613,800	626,800
	Cost – $\$10^6$	41.63	41.56	41.8	43.3
	FAR T.O. – ft	5,400	5,480	5,600	5,900
	2nd Seg. Grad.	0.079	0.082	0.085	0.085
	V(Appr.) – KEAS	135	135	135	135
36	W/S – lb/ft^2	117.82	117.3	116.7	116
	T/W	0.31	0.30	0.29	0.27
	DOC – ¢/Seat n.mi.	1.456	1.43	1.42	1.438
	W_G – lb	611,800	606,900	608,300	625,800
	Cost – $\$10^6$	40.53	40.54	40.96	42.7
	FAR T.O. – ft	5,820	5,920	6,060	6,440
	2nd Seg. Grad.	0.067	0.072	0.073	0.073
	V(Appr.) – KEAS	135	135	135	135
34	W/S – lb/ft^2	118	117.5	117	116.4
	T/W	0.29	0.28	0.27	0.25
	DOC – ¢/Seat n.mi.	1.437	1.418	1.410	1.446
	W_G – lb	606,000	604,000	605,700	629,700
	Cost – $\$10^6$	39.7	39.86	40.28	42.42
	FAR T.O. – ft	6,280	6,426	6,600	7,050
	2nd Seg. Grad.	0.056	0.060	0.062	0.062
	V(Appr.) – KEAS	135	135	135	135
32	W/S – lb/ft^2	118.3	117.8	117.5	116.75
	T/W	0.27	0.26	0.25	0.24
	DOC – ¢/Seat n.mi.	1.4243	1.415	1.42	1.462
	W_G – lb	602,800	604,[illegible]00	611,700	636,700
	Cost – $\$10^6$	38.98	39.37	40.1	42.56
	FAR T.O. – ft	6,850	7,030	7,250	7,420
	2nd Seg. Grad.	0.045	0.048	0.05	0.056
	V(Appr.) – KEAS	135	135	135	135
30	W/S – lb/ft^2	118.5	118.1	117.8	117
	T/W	0.256	0.25	0.24	0.233
	DOC – ¢/Seat n.mi.	1.429	1.418	1.4325	1.473
	W_G – lb	606,800	607,400	618,700	643,000
	Cost – $\$10^6$	38.83	39.28	40.18	42.75
	FAR T.O. – ft	7,330	7,385	7,670	7,740
	2nd Seg. Grad.	0.036	0.043	0.045	0.052
	V(Appr.) – KEAS	135	135	135	135
28	W/S – lb/ft^2	118.8	118.3	118.2	117.1
	T/W	0.25	0.247	0.235	0.23
	DOC – ¢/Seat n.mi.	1.4345	1.422	1.445	1.478
	W_G – lb	609,600	609,000	623,000	645,000
	Cost – $\$10^6$	38.2	39.3	42.8	42.82
	FAR T.O. – ft	7,560	7,520	7,800	7,850
	2nd Seg. Grad.	0.033	0.041	0.042	0.061
	V(Appr.) – KEAS	135	135	135	135

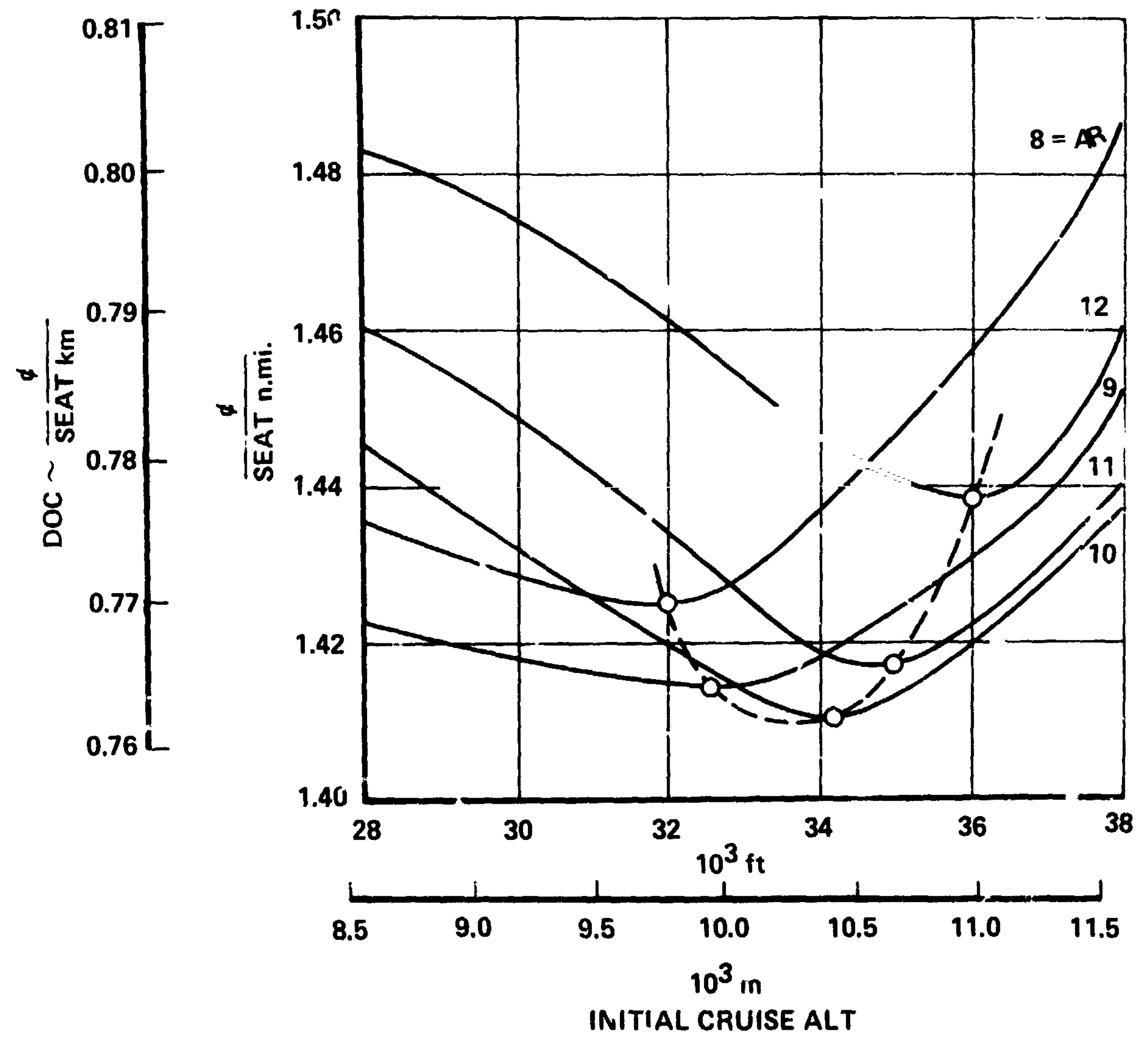


Figure 22. Effect of Aspect Ratio and Initial Cruise Altitude on Direct Operating Cost of the Long Range LH_2 Aircraft

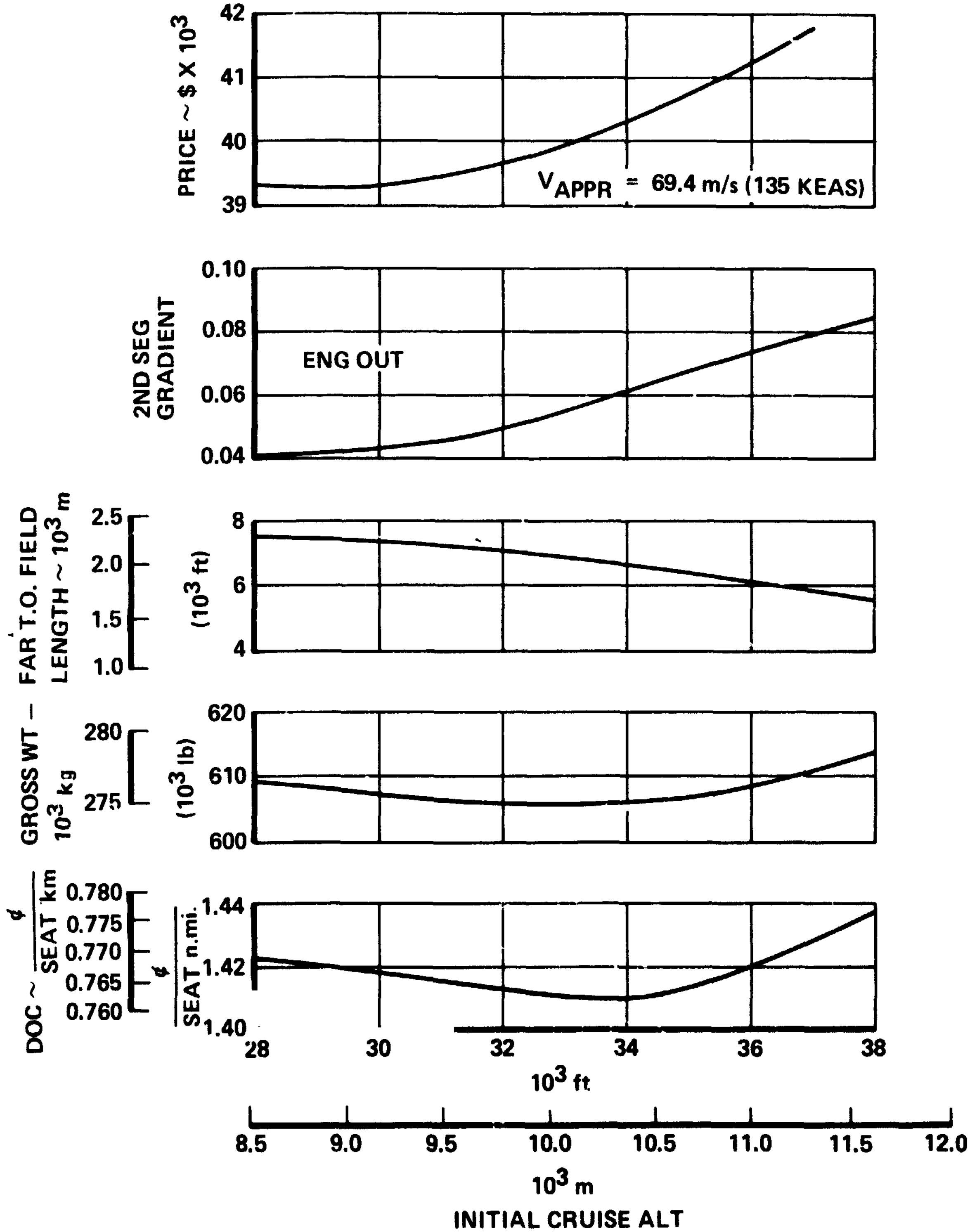


Figure 23. Effect of Initial Cruise Altitude on Performance and Cost of the Long Range LH_2 Aircraft

No provision was made for a passageway through or around the forward tank to permit movement between flight station and passengers. In the absence of such communication, the flight station is provided with special lavatory and galley facilities.

Passenger accommodations are shown in Figure 25 which shows the 10/90 percent class mix and seat spacing of 0.965 m (38 in.) and 0.86 m (34 in.) respectively, for first class and coach. Seven abreast seating is used in first class and 10 abreast in coach. The arrangement includes doors, lavatory and galley facilities in keeping with the requirements of FAR 25 and current widebody standards. Stairwells at each end of the cabin allow access to either deck in flight.

All cargo is contained in the pressurized fuselage, below the lower deck, where space is provided for cargo containers plus an additional 17 m^3 (600 ft^3) for loose cargo.

Wings: The wing has as aspect ratio of 10, and a sweep of 30°. The high lift devices include 15 percent leading edge slats and 35 percent double-slotted flaps where shown. Spoilers are used in flight for direct lift control, and for landing ground run deceleration. Conventional ailerons are fitted outboard of the flaps.

Landing Gear: The main gear consists of two six-wheel bogies mounted aft of the rear spar. They retract inward into the fuselage. The space between the retracted gear contains the hydraulic service center. The forward gear is a two-wheel strut arrangement retracting forward under the flight station.

Hydrogen Tank and Systems: The hydrogen tank structural concept selected for purposes of this study is the integral type described in Section 3.1.2. All aircraft structural loads in addition to the fuel dynamic and pressure loads are taken by the tank shell. Loads are transferred from the vehicle structure to the tank at each end by low heat-leak boron reinforced fiberglass tubes arranged in an interconnect truss structure. Seven inches of closed-cell plastic foam insulation, e.g., Rohacell 41S, covers the tank. This is then wrapped by a vapor shield (Kapton) which is to prevent cryopumping in event a crack develops in the foam insulation. A fiberglass reinforced composite layer covers the entire tank section to provide a smooth aerodynamic surface and protection from physical damage.

The tank is thus generally protected from mechanical damage by the foam insulation and its fiberglass cover. Further special protection from both foreign object damage and damage from maneuvers such as over-rotation or tail scrape is provided on the bottom of the tank. An energy absorbing, aluminum honeycomb structure is supported from

CHARACTERISTIC	WING	HORIZ. TAIL	VERT. TAIL
AREA M² (SQ FT)	466.4 (5020.2)	65.0 (699.6)	68.6 (738.0)
ASPECT RATIO	10	4.5	1.6
SPAN M (FT)	68.29 (224.1)	17.10 (56.1)	10.47 (34.4)
ROOT CHORD M (IN)	10.51 (413.6)	5.85 (230.2)	10.06 (396.1)
TIP CHORD M (IN)	3.15 (124.1)	1.75 (69.1)	3.02 (118.8)
TAPER RATIO	0.3	0.3	0.3
MAC M (IN)	7.49 (294.8)	4.17 (164.1)	7.17 (282.3)
SWEEP RAD. (DEG)	0.524 (30)	0.524 (30)	0.524 (30)
T/C ROOT (%)	10	9	9
T/C TIP (%)	10	9	9

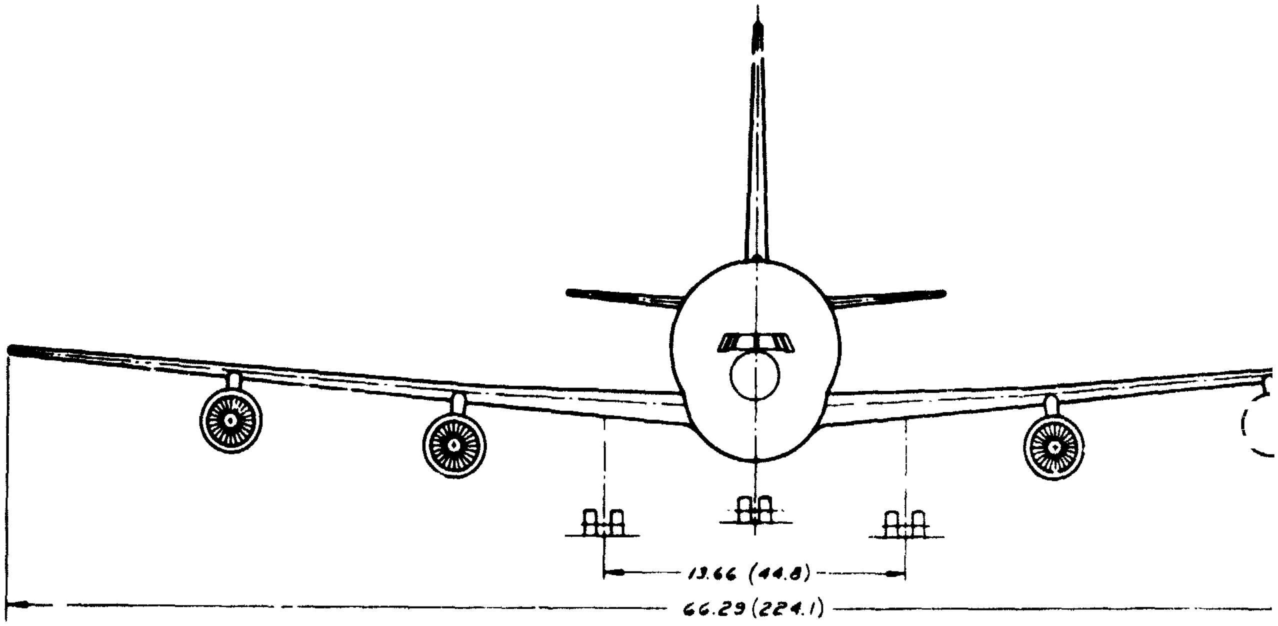
DESIGN GROSS WT - 266.429 KG (587,365 LB.)

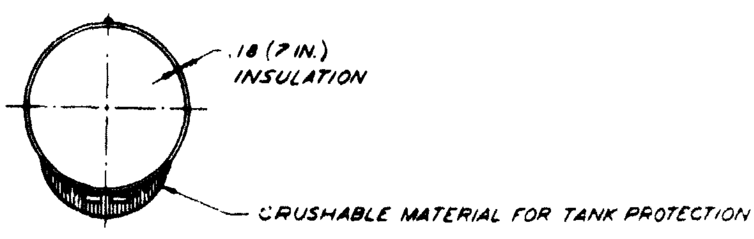
POWER PLANT - (2) TURBOFANS
INSTALLED THRUST (EA.) - 175,[illegible] N (39,353 LB.)

PASSENGERS - 400

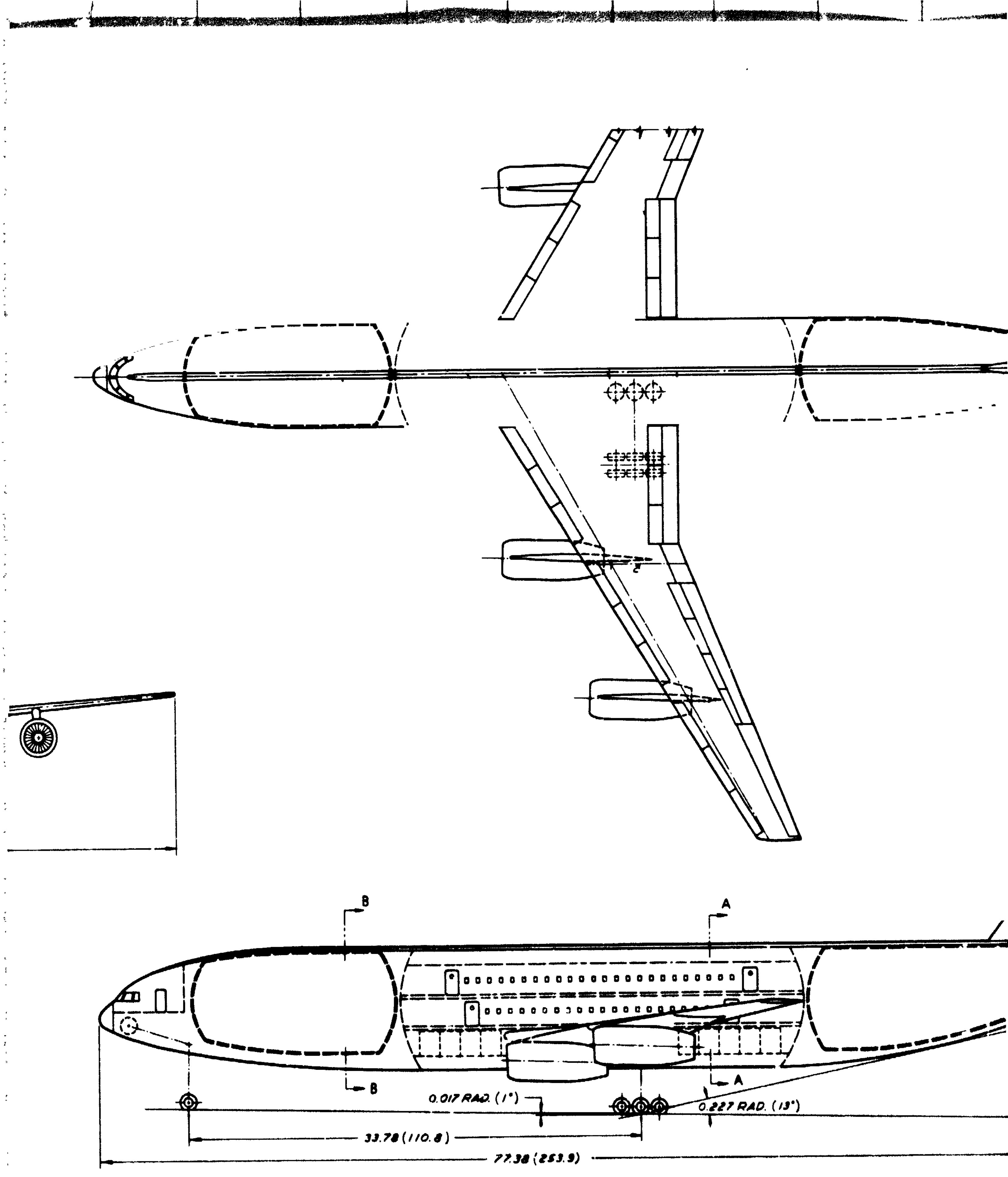
FUEL (LH_2) - 68,424 KG. (150,847 LB)

RANGE - 9,265 KM RADIUS (5,000 N.M. RADIUS)





SECTION B-B



FOLDOUT FRAME 2

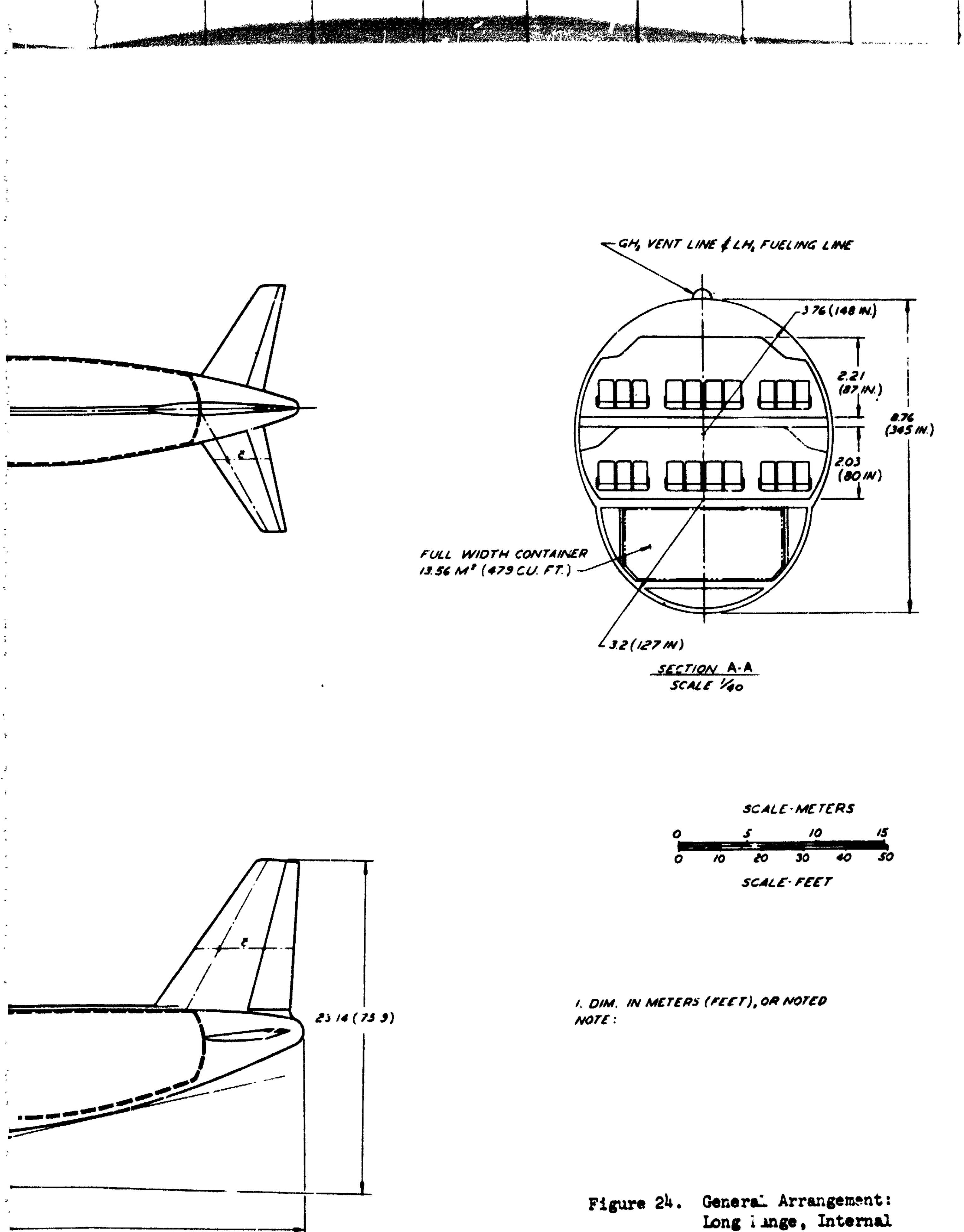
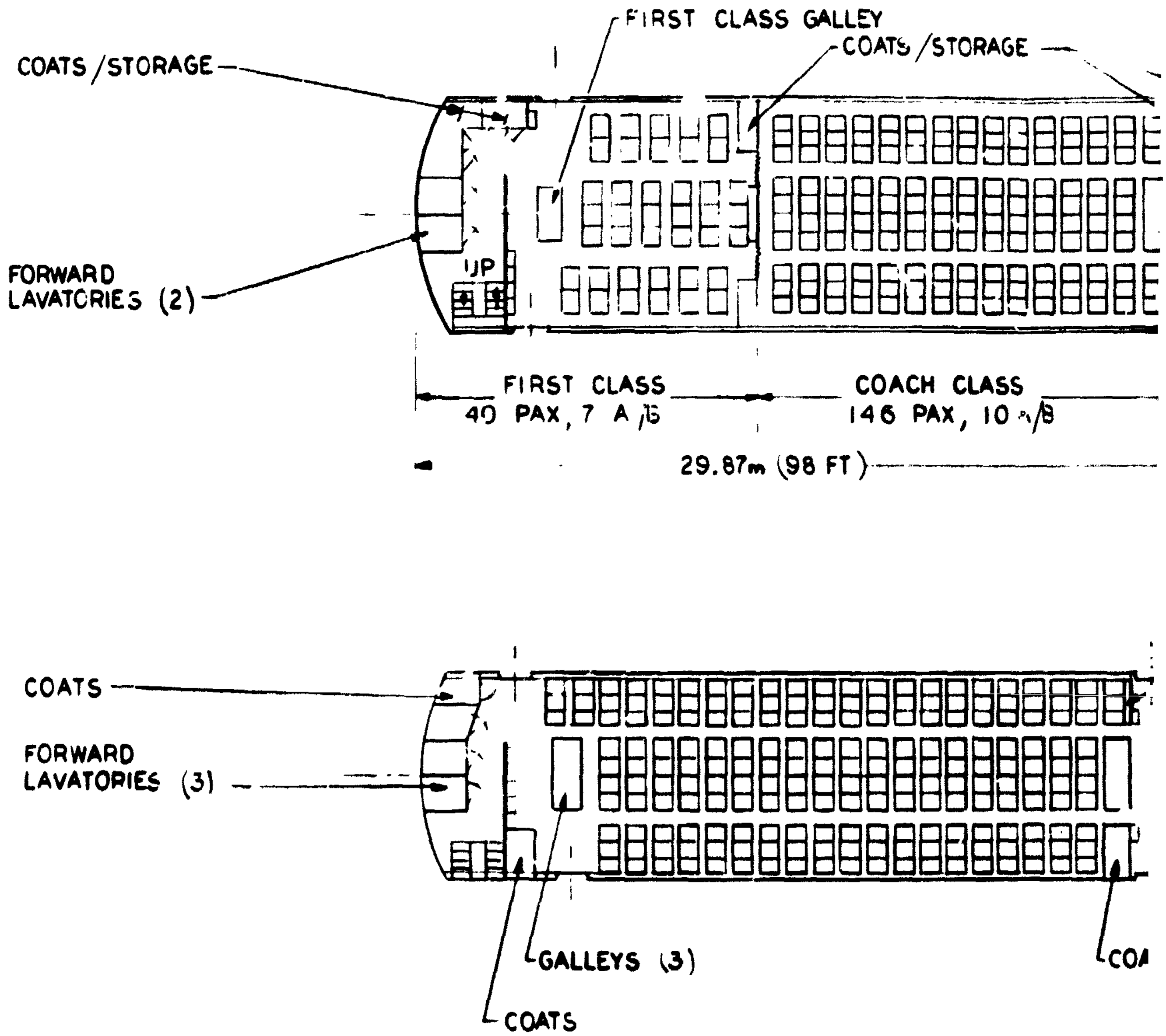
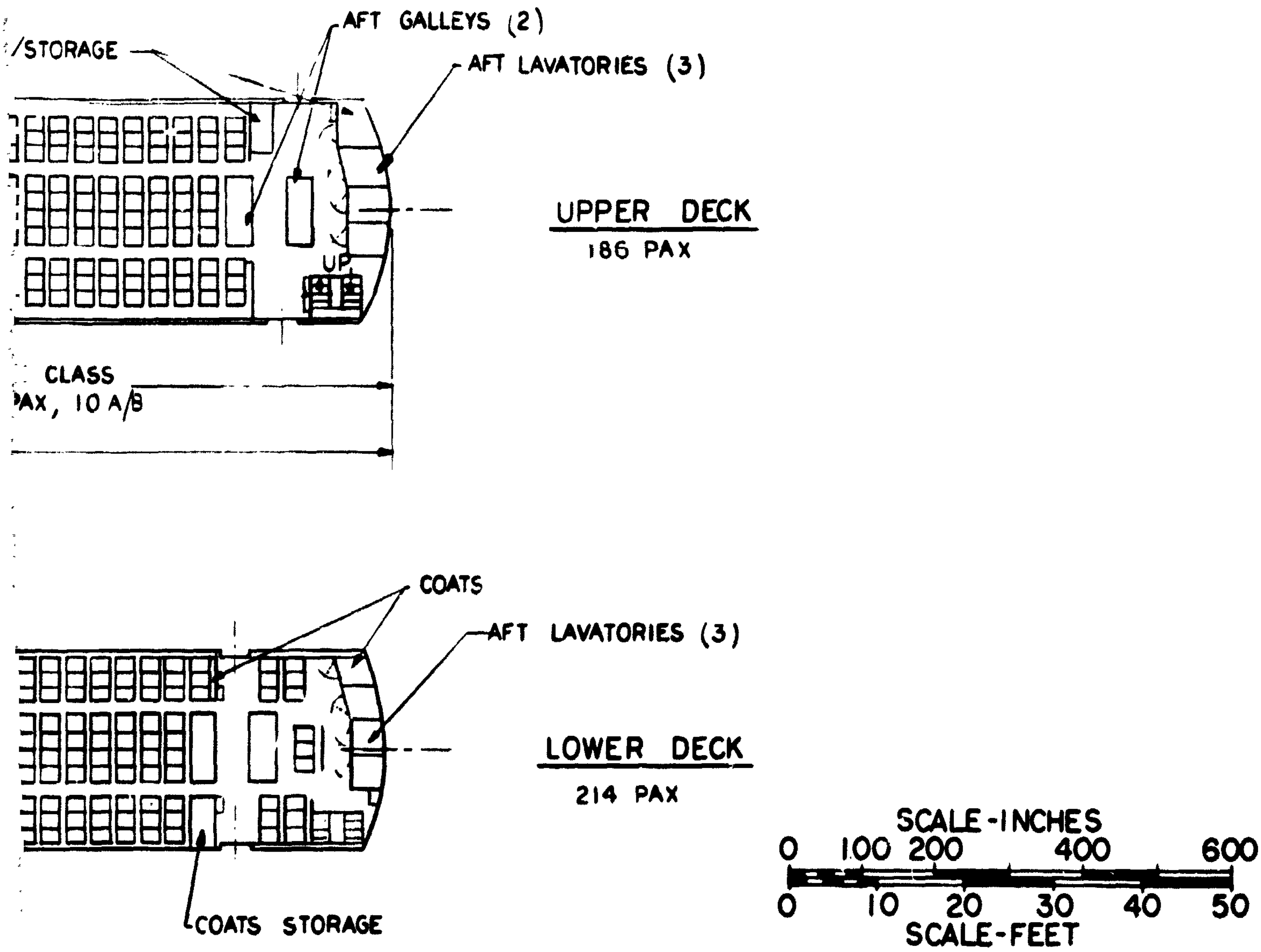


Figure 24. General Arrangement: Long Range, Internal Tank LH_2 Transport



SEATING ARRANGEMENT

TOTAL PASSENGERS = 400
FIRST CLASS = 40/.96m (38 IN) S
COACH CLASS = 360/.86m (34 IN) S



RANGEMENT

S = 400
/.96 m (38 IN) SPACING
D/.86 m (34 IN) SPACING

Figure 25. Interior Arrangement: 400 Pax Transport, LH_2 Fuel

the tank bottom. In this manner protection is also provided for plumbing, electrical wiring, and control systems routed adjacent to the tank.

The tank and mounting is designed for both inflight structural and fatigue loads (fail safe considerations) and to withstand the emergency crash load requirements of FAR 25 with a full fuel load.

6.3.3 Vehicle Data. - All weight, performance, and cost data are presented in Section 6.5.

6.4 Jet A Airplane (Aircraft No. 8)

6.4.1 Parametric Investigation. - The results of the preliminary parametric investigation are shown in Figure 26. The data show that the takeoff field length is critical since it exceeds the original constraint of 3048 m (10 000 ft). It also indicates that minimum DOC is achieved with an aspect ratio of 11. This aspect ratio was then used for the following tradeoff study. It should be noted that because the original preliminary assessment of the design characteristics of aircraft No. 7 indicated it might have a gross weight well in excess of 453,600 kg (1 million lb), it was planned that the airplane would have six engines. Subsequently, the final design was changed to four engines when it became apparent the thrust requirement could be met without resorting to excessively large engines.

At the conclusion of the initial parametric investigation, the question of the validity of the original takeoff field length specification of 3048 m (10,000 ft) was raised by the NASA technical monitor as perhaps being unduly restrictive. For an aircraft of this size and purpose, it is logical to assume it would characteristically operate from the major airports of the world where long, modern runways would be available. Accordingly, a special study was made to determine the effect various field lengths ranging from 2740 m (9000 ft) to almost 4880 m (16,000 ft) would have on the long range Jet A aircraft design and performance. Figure 27 presents the results of this investigation. A series of aircraft designs was generated, each of which meets the guideline constraints, except for the specified field length. For each, the DOC, gross weight, initial cruise altitude, second

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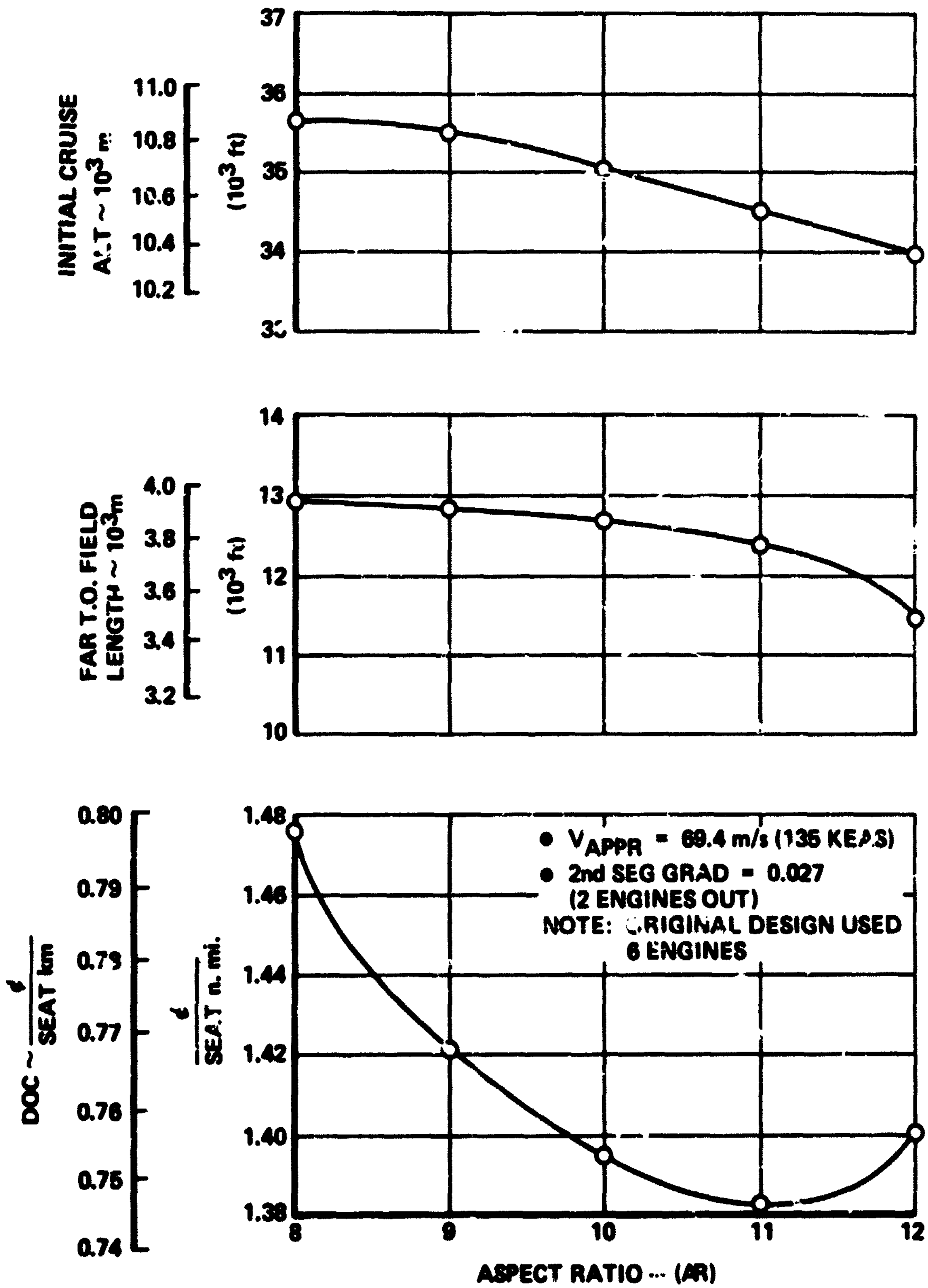


Figure 26. Aspect Ratio Selection for Long Range Jet A Aircraft

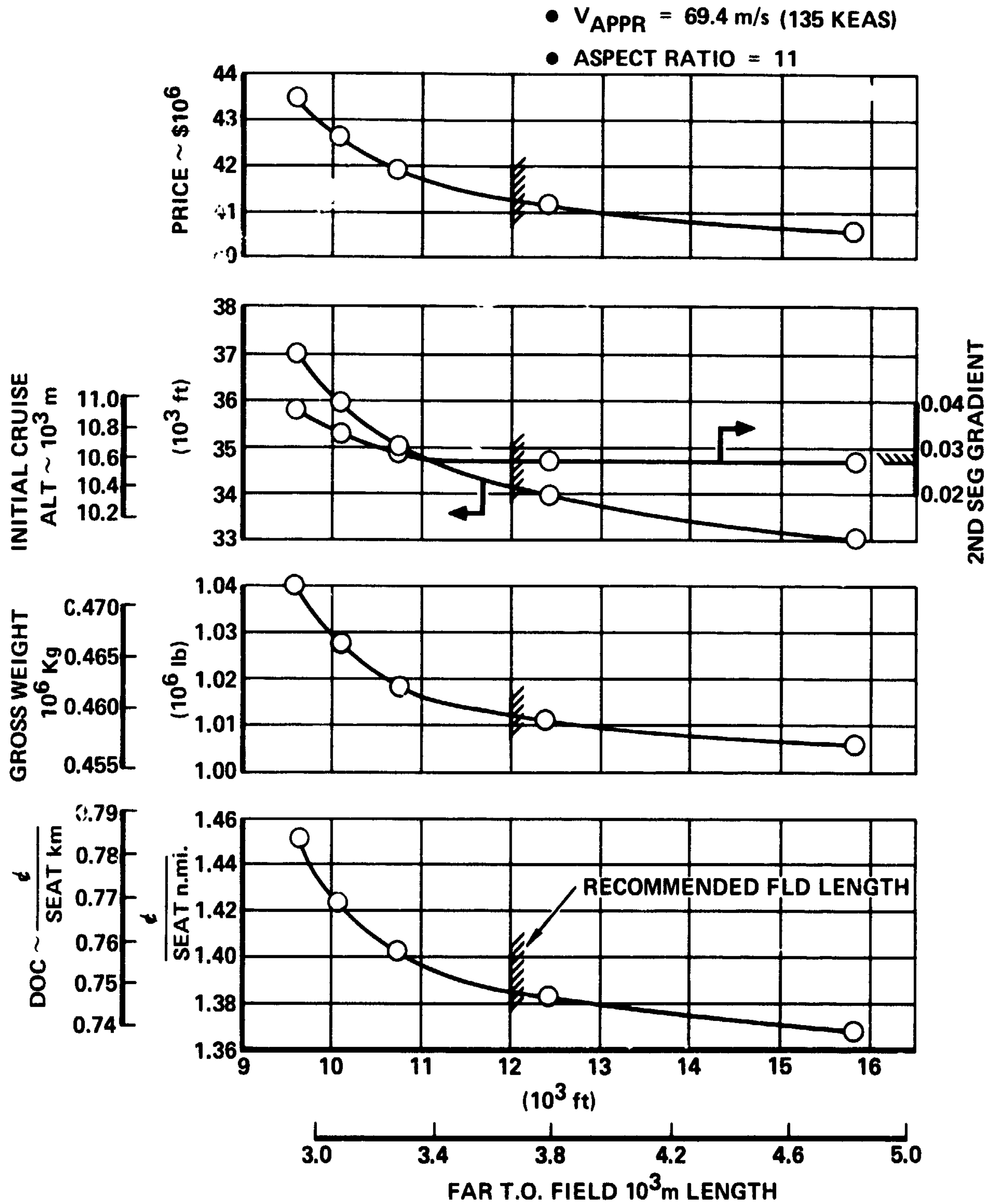


Figure 27. Recommended Field Length for the Long Range, Jet A Aircraft

C·2

segment climb gradients, and aircraft production price are all plotted to show the effect of FAR takeoff field length.

In addition, data on existing runway lengths and reference conditions of some of the major airports in the world which have high traffic densities was compiled and tabulated. These results are shown in Table XIV. Evaluation of these data showed that all the airports marked with an asterisk could be used if the subject airplane was capable of taking off from Miami which has a runway length of 3048 m (10,000 ft), elevation of 3 m (10 ft), and a reference temperature of 28.9°C. If these runway conditions are translated to the conditions of this study, i.e., 304.8 m (1000 ft) elevation and 32.2°C (90°F), the equivalent maximum allowable takeoff distance becomes approximately 3658 m (12,000 ft). This recommended field length is indicated on Figure 27.

Examination of the figure shows that considerable improvement in all of the vehicle parameters can result from increasing takeoff field length to 3658 m (12,000 ft), from the 3048 m (10,000 ft) originally proposed, and that not a great deal of further improvement would be realized if the field length requirement increased still further at the cost of eliminating the capability of operating from many of the world's major airports. Accordingly, a change to the design constraint of 3658 m (12,000 ft) FAR takeoff distance was adapted for the Jet A long range aircraft of this study.

The characteristics of the final vehicle design were generated using this constraint after modifying the ASSET inputs as required by the reduction in the vehicle size from the original estimate. For example, four engines were specified instead of the original six.

6.4.2 Configuration Description. - The general arrangement of this aircraft is shown in Figure 28. The arrangement is conventional with the exception of the main gear which consists of four six-wheel bogies mounted aft of the rear spar. The outboard bogies retract inward into the fuselage, while the inboard bogies retract aft into the fuselage. The nose gear consists of dual wheels which retract forward. All fuel is carried in the wing box and wing center section.

TABLE XIV. MAJOR AIRPORT RUNWAY LENGTHS AND REFERENCE CONDITIONS

	Runway Length m	(ft)	Elevation m	(ft)	Ref. Temp.‡ °C	(°F)
ATLANTA	3,048.	(10,000)	313.	(1,026)	30.0	(86.0)
* CHICAGO	3,556.	(11,667)	203.	(666)	23.7	(74.7)
* DALLAS - FT. WORTH	3,477.	(11,408)	183.	(600)	30.8	(87.4)
* HONOLULU	3,771.	(12,373)	4.	(13)	26.5	(79.7)
* LOS ANGELES	3,685.	(12.090)	38.	(126)	23.7	(74.7)
* MIAMI	3,200.	(10,500)	3.	(10)	28.9	(84.0)
MINNEAPOLIS	3,048.	(10,000)	256.	(840)	29.0	(84.2)
NEW ORLEANS	2,812.	(9,226)	.9	(3)	29.6	(85.3)
* NEW YORK (JFK)	4,441.	(14,571)	4.	(13)	24.8	(76.6)
* SAN FRANCISCO	3,225.	(10,581)	3.	(10)	17.8	(64.0)
* WASHINGTON (DULLES)	3,505.	(11,500)	95.	(3[illegible])	26.9	(80.4)
* AMSTERDAM	3,452.	(11,326)	4.	(13)	17.8	(64.0)
* BRUSSELS	3,638.	(11,936)	55.	(180)	19.1	(66.4)
* COPENHAGEN	3,599.	(11,808)	5.	(16)		
* FRANKFURT	3,899.	(12,792)	112.	(367)	20.9	(69.6)
* GENEVA	3,898.	(12,790)	430.	(1,411)	21.5	(70.7)
* LONDON	3,657.	(12,000)	24.	(79)	19.0	(66.2)
* MOSCOW	3,499.	(11,480)	204.	(670)	21.0	(69.8)
* MUNICH	3,998.	(13,12[illegible])	530.	(1,740)	19.2	(66.6)
* PARIS (ORLY)	3,649.	(11,972)	89.	(292)	21.0	(69.8)
* ROME	3,899.	(12,792)	2.	(7)	25.4	(77.7)

‡REF. TEMP. = Mean 24-hour temperature for hottest month of year plus one-third of difference between maximum daily mean and 24-hour mean temperature.

*Airports from which subject aircraft could operate if designed to 3658 m (12,000 ft) FAR runway length, specified conditions.

The interior arrangement is shown in Figure 29 with a 10/90 percent first-to-coach class mix with 6 abreast, 0.96 m (38 in.) seat spacing in first class and 8 abreast, 0.86 m (34 in.) spacing in coach. A below-deck galley is used. Doors and lavatories are provided in accordance with requirements of FAR 25 and current industry standards. Storage for carry-on luggage and passenger belongings suitable for a 400 passenger aircraft is also provided.

6.4.3 Vehicle Data. - All performance, weight, and cost data is shown in Section 6.5.

6.5 Comparison of Long Range Aircraft

Table XV presents a summary of significant design and performance data for the LH_2 and Jet A long range aircraft. The table also shows a ratio which compares the value of each significant parameter listed for the Jet A design with that of the LH_2 fueled airplane. Copies of pertinent sheets of the ASSET computer printouts for each of these final design aircraft are presented in Appendix A-7 and A-8 for more detailed information.

Generally, comparing the values listed in the columns of Table XV, it is seen that the LH_2 aircraft offers significant advantage in almost every category of comparison for this long range mission. The LH_2 aircraft is lighter, requires a smaller wing but a larger fuselage, uses smaller engines, can takeoff in shorter distances, and uses 25 percent less energy per seat mile in performing its mission.

The penalties occasioned by the density and cryogenic nature of liquid hydrogen, reflected in the values shown for Lift/Drag are more than overcome by the advantage of the heating value of the fuel, indicated by the values shown for specific fuel consumption (SFC).

The heating values of the fuels used in this study are 42,760 kJ/kg (18,400 Btu/lb) for Jet A, and 119,900 kJ/kg (51,590 Btu/lb) for hydrogen. This is a ratio of 2.8 in favor of hydrogen which accounts for the principle portion of the difference in specific fuel consumptions (SFC) listed in the

CHARACTERISTICS	WING	HORIZ TAIL	VERT. TAIL
AREA M^2 (SQ FT)	661 91 (7125)	70.32 (757)	70.84 (726 6)
ASPECT RATIO	11	4.5	1 6
SPAN M (FT)	85 34 (280.0)	17 60 (58 4)	10 64 (34 9)
ROOT CHORD M (IN)	11 93 (469 8)	6.08 (239 4)	10.24 (403 1)
TIP CHORD M (IN)	3 58 (141.0)	1.82 (71 8)	3.07 (120 9)
TAPER RATIO	0 3	0.3	0.3
MAC M (IN)	8 51 (334 9)	4 34 (170 7)	7 34 (287 3)
SWEEP RAD. (DEG)	0.524 (30)	0 524 (30)	0.524 (30)
T/C ROOT (%)	10	9	9
T/C TIP (%)	10	9	9

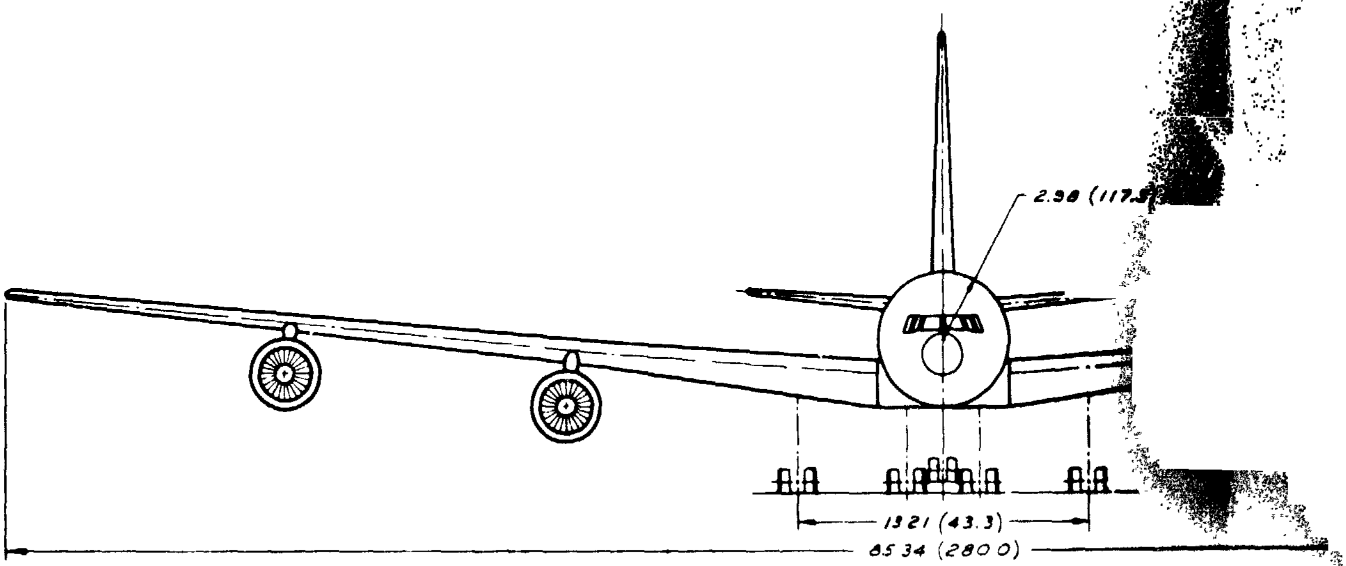
DESIGN GROSS WT - 450,206 KG (9[illegible],517 LB)

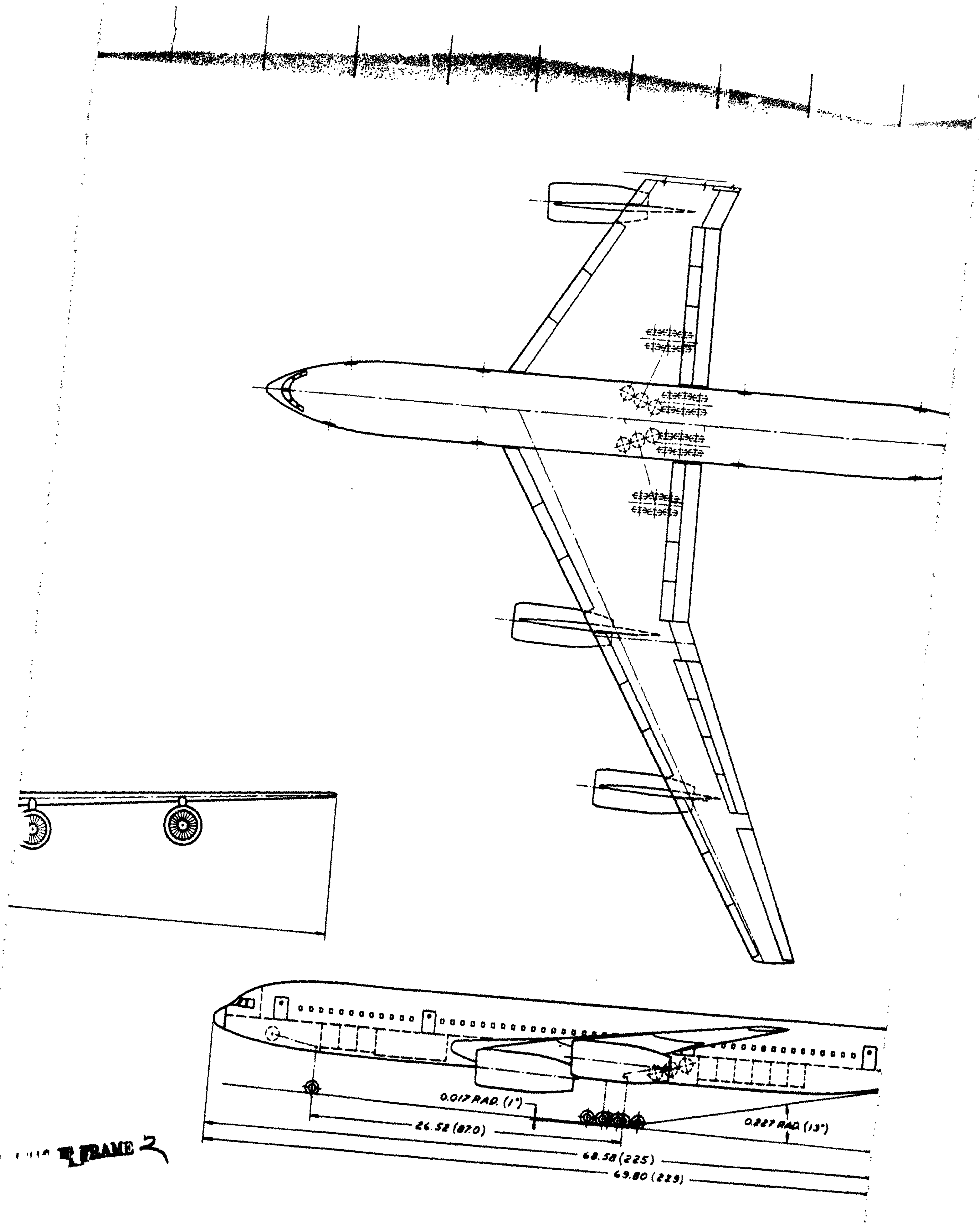
POWER PLANT - (4) TUROFANS
INSTALLED THRUST (EA) - 220,723 N (49,625 LB.)

PASSENGERS - 400

FUEL (JET A) - 237,685 KG (523,996 LB)

RANGE - 9,265 KM RADIUS (5,000 N.M. RADIUS)




0.017 RAD. (1°)
26.52 (87.0)
0.227 RAD. (13°)
68.58 (225)
69.80 (229)

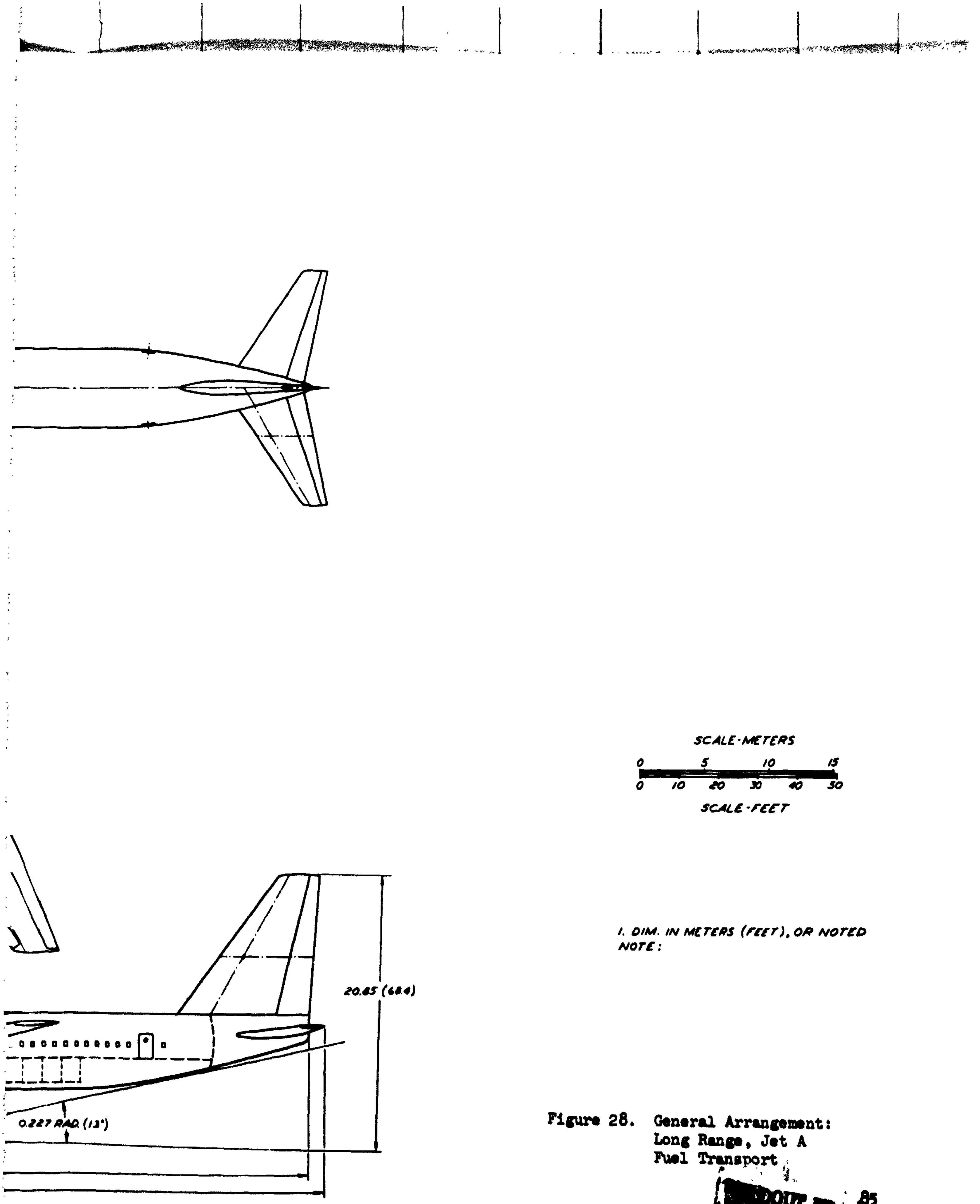
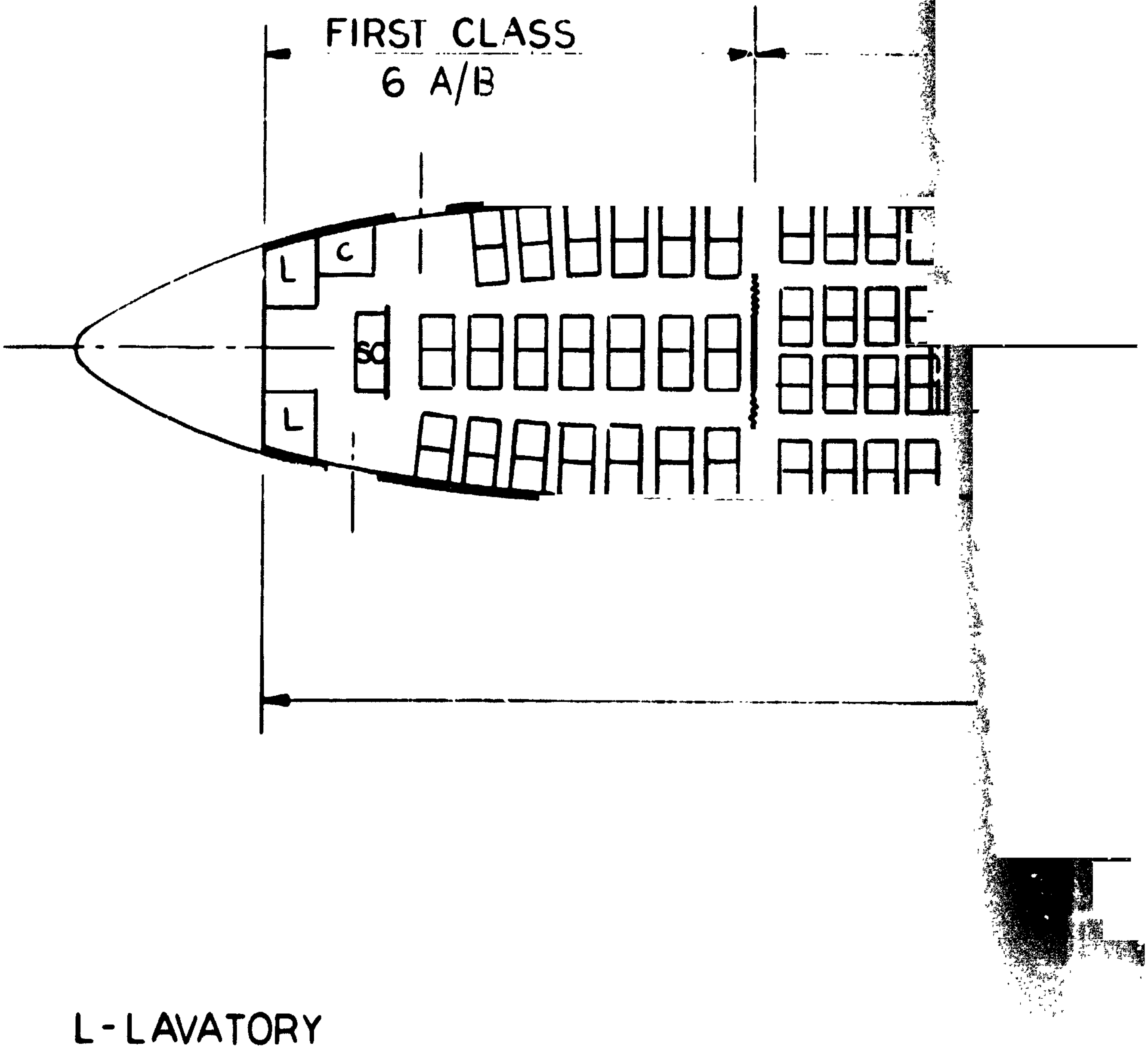
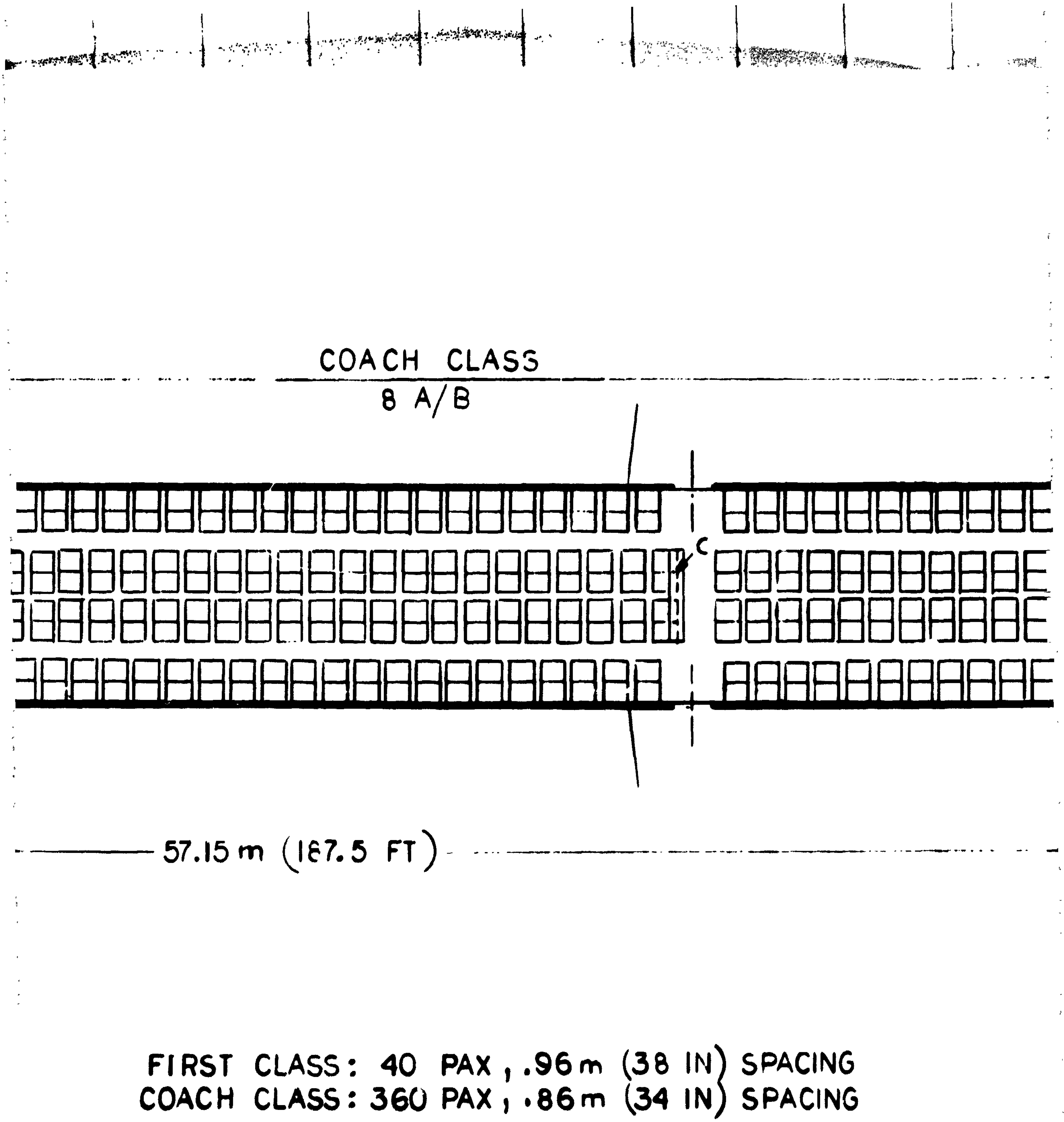


Figure 28. General Arrangement:
Long Range, Jet A
Fuel Transport



L - LAVATORY
C - COATS
E - ELEVATOR TO BELOW FLOOR KITCHEN
S - SERVICE CART
SC - SERVICE CENTER



COACH CLASS
8 A/B
C
57.15 m (187.5 FT)
FIRST CLASS: 40 PAX, .96 m (38 IN) SPACING
COACH CLASS: 360 PAX, .86 m (34 IN) SPACING

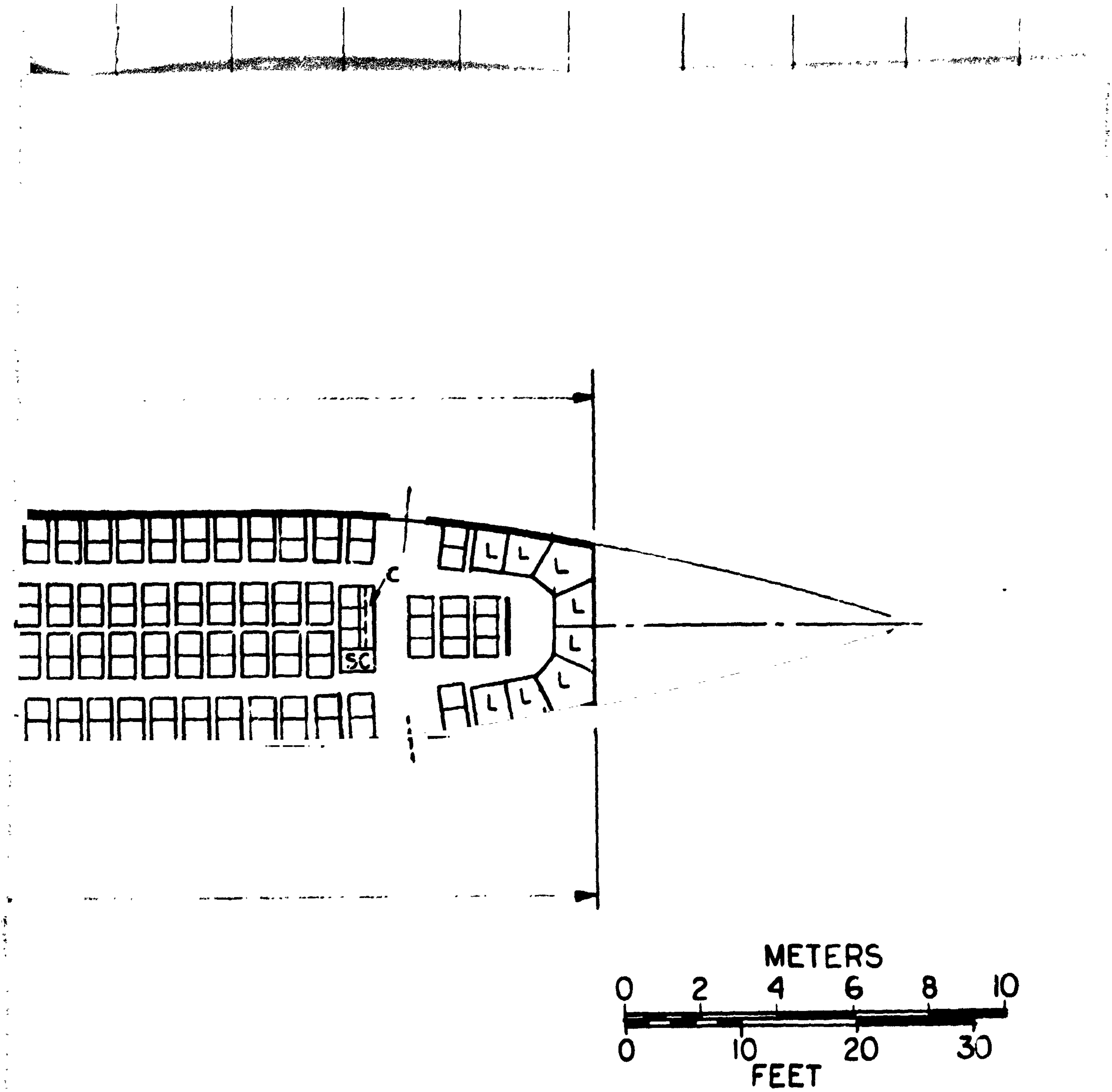


Figure 29. Interior Arrangement:
400 Pax Transport,
Jet A Fuel

TABLE XV. COMPARISON OF FINAL DESIGN LONG RANGE AIRCRAFT
(S.I. UNITS)

(9265 km radius - 400 PAX. - Mach 0.85)
(Payload - 39,920 kg)

		Aircraft No. 7 (Int. LH_2)	Aircraft No. 8 (Jet A)	Ratio (Jet A)/(Int. LH_2)
Gross Wt	kg	266,430	450,200	1.69
Total Fuel Wt	kg	68,430	237,690	3.47
Block Fuel Wt	kg	59,610	208,720	3.50
Operating Empty Wt	kg	158,090	172,600	1.09
Empty Wt	kg	147,700	159,280	1.08
Aspect Ratio		10	11	
Wing Area	m^2	466	662	1.42
Sweep	deg	30	30	
Span	m	68	85	1.25
Fuselage Length	m	77	69	0.89
L/D - Cruise		16.8	20.3	1.21
SFC - Cruise	$\frac{kg}{hr}$/daN	0.203	0.593	2.93
Initial Cruise Altitude	m	10,360	10,060	
Wing Loading	kg/m^2	571	680	
Thrust/Weight	N/kg	2.63	1.96	0.75
No. Engines		4	4	
Thrust Per Engine	N	175,000	220,700	1.26
FAR T.O. Distance	m	2,107	3,649	1.73
FAR Ldg. Distance	m	1,795	1,788	
2nd Seg Climb Grad. (Eng Out)		0.066	0.034	0.52
Approach Speed	m/s	69	69	
Weight Fractions	percent			
Fuel		25.7	52.8	
Payload		15.0	8.9	
Structure		32.6	24.6	
Propulsion (Includes Fuel System)		14.3	5.3	
Equipment and Operating Items		12.4	8.4	
Price	$\$10^6$	38.89	39.99	1.03
DOC	$\frac{¢}{seat\ km}$	0.738[1]	0.723[2]	0.98
Energy Utilization	$\frac{kJ}{seat\ km}$	964	1207	1.25
Max. Nonstop Range[3]	km	19,590	19,980	1.02

[1]DOC based on LH_2 cost = $2.85/GJ

[2]DOC based on Jet A cost = $1.90/GJ

[3]Including reserve fuel requirement.

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TABLE XV. COMPARISON OF FINAL DESIGN LONG RANGE AIRCRAFT
(U.S. CUSTOMARY UNITS)

(5000 n.mi. radius - 400 PAX. - Mach 0.85)
(Payload = 88,000 lb)

		Aircraft No. 7 (Int. LH_2)	Aircraft No. 8 (Jet A)	Ratio (Jet A)/(Int LH_2)
Gross Wt	lb	587,370	992,520	1.69
Total Fuel Wt	lb	150,850	524,000	3.47
Block Fuel Wt	lb	131,420	460,150	3.50
Operating Empty Wt	lb	348,520	380,520	1.09
Empty Wt	lb	325,630	351,150	1.08
Aspect Ratio		10	11	
Wing Area	ft^2	5020	7125	1.42
Sweep	deg	30	30	
Span	ft	224.1	279.9	1.25
Fuselage Length	ft	253.9	225.0	.89
L/D - Cruise		16.8	20.3	1.21
SFC - Cruise	(lb/hr)/lb	0.199	0.583	2.93
Initial Cruise Altitude	ft	34,000	33,000	
Wing Loading	lb/ft^2	117.0	139.3	
Thrust/Weight		0.268	0.200	0.75
No. Engines		4	4	
Thrust Per Engine	lb	39,350	49,630	1.26
FAR T.O Distance	ft	6914	11,970	1.73
FAR Ldg. Distance	ft	5890	5867	
2nd Seg Climb Grad. (Eng Out)		0.066	0.034	0.52
Approach Speed	KEAS	135	135	
Weight Fractions	percent			
Fuel		25.7	52.8	
Payload		15.9	8.9	
Structure		32.6	24.6	
Propulsion (Includes Fuel System)		14.3	5.3	
Equipment and Operating Items		12.4	8.4	
Price	$\$10^6$	38.89	39.99	1.03
DOC	¢/seat n.mi.	1.366[1]	1.339[2]	0.98
ENERGY UTILIZATION	Btu/seat n.mi.	1695	2122	1.25
Max Nonstop Range[3]	n.mi.	10,571	10,780	1.02

[1]DOC based on LH_2 cost = $\$3/10^6$ Btu = 15.48¢/lb

[2]DOC based on Jet A cost = $\$2/10^6$ Btu = 24.8¢/gal

[3]Including reserve fuel requirement

tables. The ratio of cruise SFC's, Jet A-to-LH_2, listed in Table XV is 2.93. The extra advantage given the hydrogen system over the factor of 2.8 expected from comparison of the heating values, is mostly due to the requirement to cool the high pressure turbine stages of the Jet A engine with air bled from its compressor---air on which energy has been expended and which is not available for performing useful work.

The ratio of block fuel consumed by aircraft using each type of fuel is in the ratio of 3.50. It might normally be expected that the fuel used to perform a mission would be in approximately the same ratio as the SFC's realized in cruise. Actually, there is a leverage factor which works to the advantage of the LH_2 aircraft. Because that aircraft uses less fuel, it has a lower gross weight to accelerate and to lift to cruise conditions. This advantage, reduced somewhat by the lower L/D of the hydrogen fueled aircraft, produces an iterative fuel saving which compounds to produce the final block fuel weight relationship listed. The lower gross weight also permits a reduction in structure and propulsion weight in spite of the hydrogen tankage and insulation weight penalties.

For purposes of providing data for plotting in a later section (Section 8), the conventional, non-stop range capability of both the long range aircraft was calculated and the results are shown as the bottom entry of Table X'.

Table XVI is a summary of costs calculated for the subject aircraft. The basis for these cost estimates was presented in Sections 4.4 and 4.7 of Reference I. In the comparison shown the LH_2 aircraft are seen to cost less, both to develop and to produce, than the Jet A. The price of the Jet A aircraft is 3 percent greater than the LH_2 airplane.

In considering the development costs, it should be noted that the cost of basic hydrogen technology development was assumed to be funded separate and apart from the traditional aircraft development costs represented in the table. As discussed in the Reference 1 report, Section 6.0, a six year program is suggested during which such technology development

TABLE XVI. COST COMPARISON OF FINAL DESIGN
LONG RANGE AIRCRAFT

9265 km (5000 n.mi. radius - 200 Pax. - Mach 0.85)

	Aircraft No. 7 ($Int\ LH_2$)		Aircraft No. 8 (Jet A)	
Development - $\$10^6$				
Airframe	919.64		1221.79	
Engine (Amortized in prod. cost)	0		0	
TOTAL	919.64		1221.79	
Production - $\$10^6$				
Airframe Cost	29.975		30.111	
Engine (Including R&D)	5.789		5.884	
Avionics	0.500		0.500	
R&D Amortization (Airframe)	2.628		3.491	
TOTAL AIRCRAFT PRICE	38.892		39.986	
Direct Operating Cost - $\frac{\$}{km}$ $\left(\frac{\$}{n.mi.}\right)$				
Crew	0.208	(0.385)	0.208	(0.386)
Maintenance				
Airframe Labor (Including Burden)	0.194	(0.359)	0.204	(0.377)
Engine Labor (Including Burden)	0.073	(0.135)	0.129	(0.238)
Airframe Material	0.126	(0.234)	0.131	(0.242)
Engine Material	0.113	(0.209)	0.173	(0.320)
Fuel* and Oil	1.154	(2.137)	0.933	(1.728)
Insurance	0.225	(0.416)	0.232	(0.429)
Depreciation	0.858	(1.589)	0.883	(1.635)
TOTAL DOC -	2.951	(5.465)	2.892	(5.355)
TOTAL UNIT DOC - $\frac{¢}{seat\ km}$ $\left(\frac{¢}{seat\ n.mi.}\right)$	0.738	(1.366)	0.723	(1.339)

*Fuel Cost:

Jet A = \$1.90/GJ (\$2/10^6 Btu = 24.8¢/gal = 3.68¢/lb)

LH_2 = \$2.85/GJ (\$3/10^6 Btu = 15.48¢/lb) would occur before a decision need be made to proceed with development of a commercial transport airplane. The cost of this basic technology development is not included in the costs shown in Table XV.

Direct operating cost (DOC) is very sensitive to fuel cost. As noted in Table XVI, the fuel prices which were specified for use in this study to establish baseline DOC's were $1.90 per GJ for Jet A (equivalent to $\$2/10^6$ Btu=24.8¢/gal or 3.68¢/lb), and $2.85 per GJ for LH_2 (equivalent to $\$3/10^6$ Btu's or 15.48¢/lb). The sensitivity of DOC to fuel cost is shown in Figure 30 for the long range vehicles. The price of Jet A fuel expressed in cents per gallon is shown for reference across the top of the grid.

To provide perspective for these comparisons, in September, 1975, U.S. international air carriers paid an average of 36.6¢/gal for Jet A fuel. The horizontal dotted line in Figure 30, shows that from the Jet A price of 36.6¢/gal, airlines could afford to pay $1.00 more per GJ ($\$1.05/10^6$ Btu) for LH_2 and still operate at equal DOC. This price differential increases with fuel costs as shown by the divergence of the fuel cost lines.

6.5.1 Noise. - A comparison of noise generated by the two aircraft is presented numerically in Table XVII and graphically in Figure 31. The analysis was made using the takeoff and approach paths generated for the respective aircraft in the ASSET program, and using engine parameters and procedures described in section 4.8.2 of the final report of the previous study (Reference 1).

The LH_2 aircraft designed for the long range mission is appreciably quieter in flyover, but slightly noisier in sideline and approach, compared with its Jet A fueled counterpart. The LH_2 airplane is slightly noisier in approach for reasons previously explained. Both are significantly quieter than the limit noise calculated by the proposed standard, NPRM 75-37. The differences are 10.1 and 6.5 EPNdb quieter in flyover, 8.1 and 10.2 EPNdb quieter in sideline, and 6.0 and 9.5 EPNdb quieter in approach respectively, for the LH_2 and Jet A aircraft.

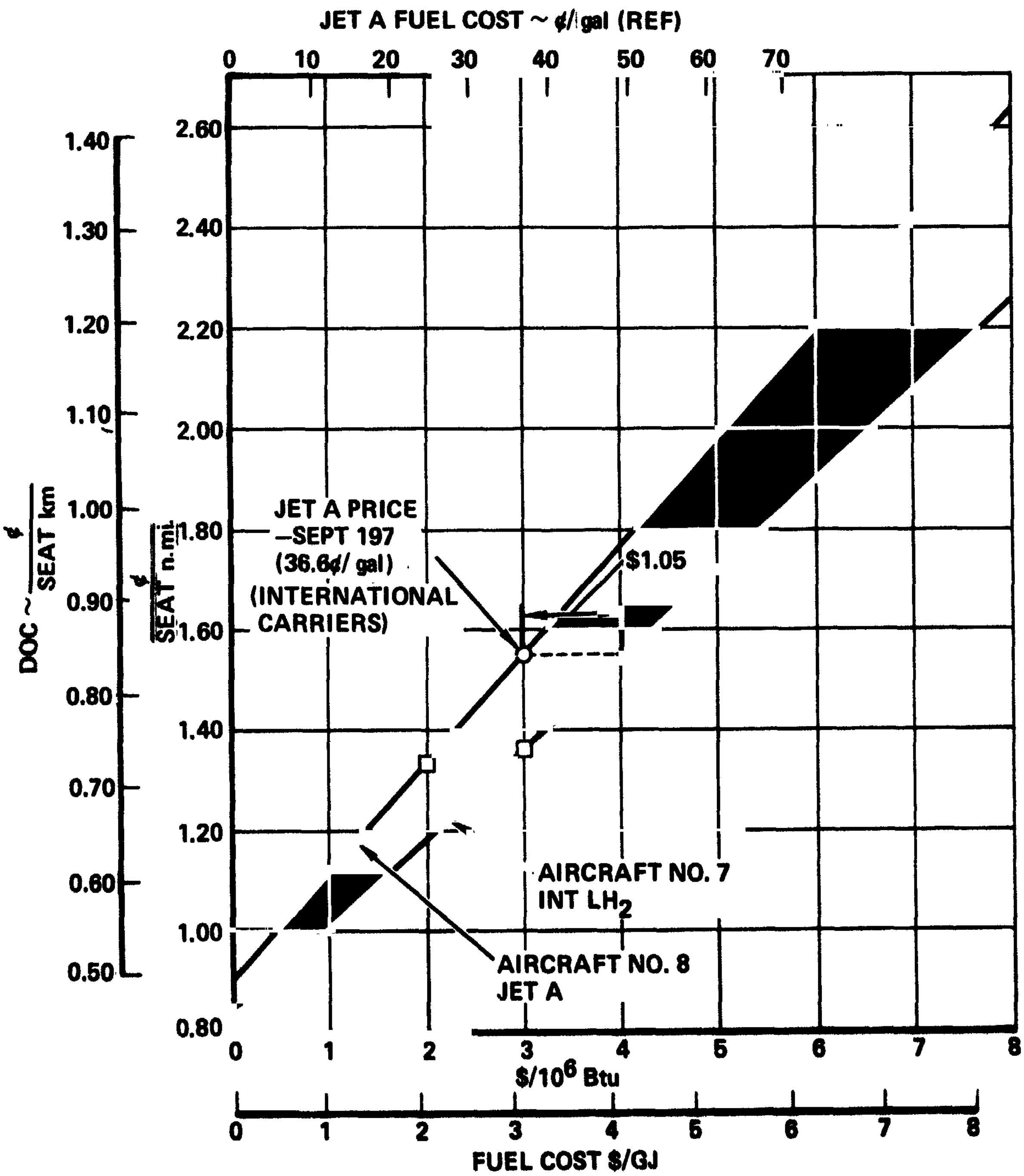

Figure 30. DOC vs Fuel Cost - 5000 n.mi. radius, 400 Pax Aircraft

TABLE XVII. NOISE EVALUATION - LONG RANGE AIRCRAFT

Airplane No.	7		8	
Number of Engines	4		4	
Fuel	LH_2		Jet A	
Gross Weight kg (lb)	266,430 (587,370)		450,210 (992,520)	
Far 36 Flyover Level (EPNdB)	93.3		99.5	
Limit Per NPRM 75-37	103.4		106.0	
FAR 36 Sideline Level (EPNdB)	93.9		92.8	
Limit Per NPRM 75-37	102.0		103.0	
FAR 36 Approach Level (EPNdB)	97.9		95.5	
Limit Per NPRM 75-37	103.9		105.0	
Enclosed "Footprint" Contour Area				
	km^2	$st.mi.^2$	km^2	$st.mi.^2$
80 EPNdB - Takeoff	35.74	13.80	50.36	19.45
- Approach	25.66	9.91	18.31	7.07
- Total	61.40	23.71	68.69	26.52
90 EPNdB - Takeoff	8.52	3.29	11.16	4.31
- Approach	3.13	1.21	1.84	0.71
- Total	11.65	4.50	13.00	5.02

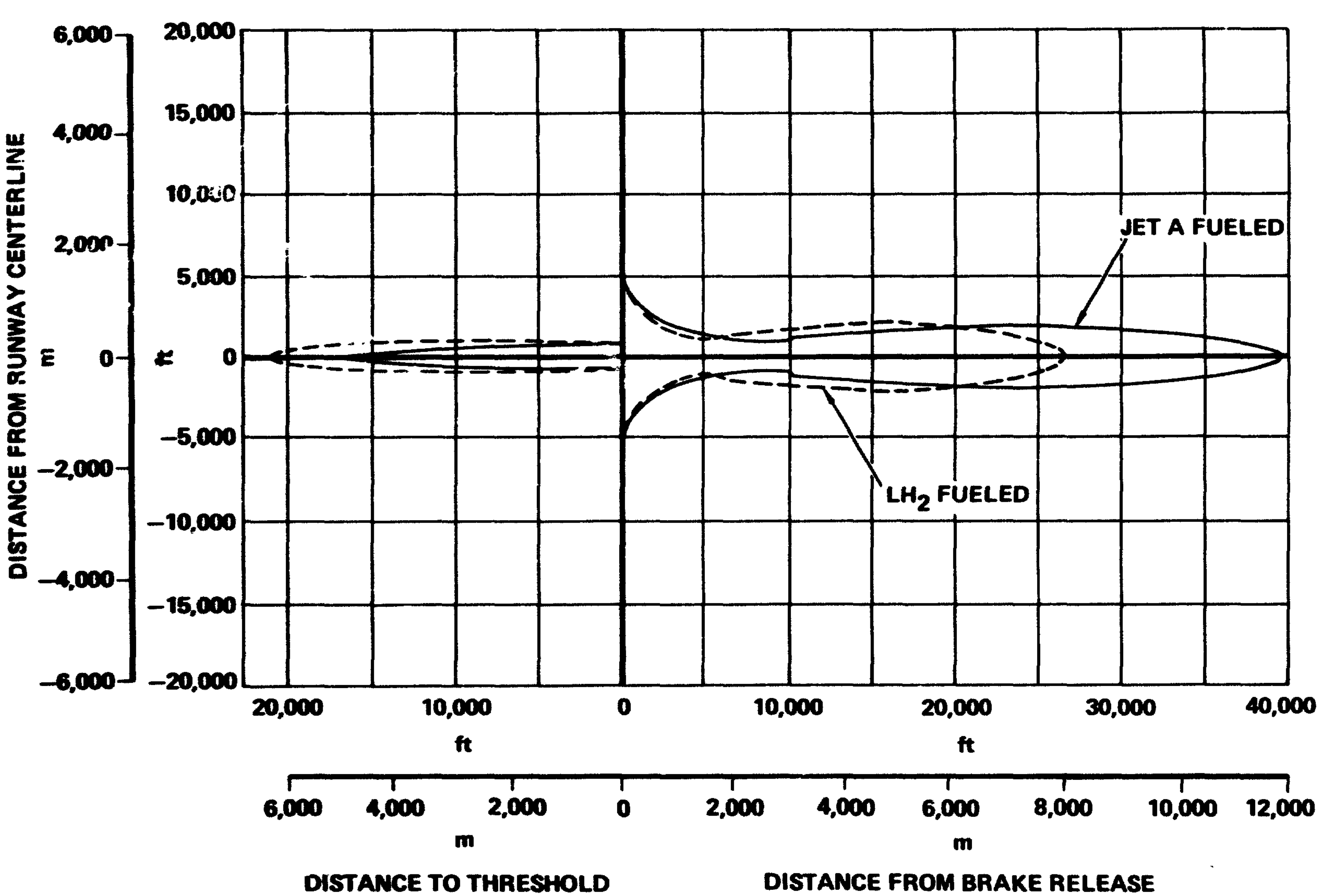

Figure 31. 9 EPNdB Contour Comparison - Long Range Aircraft

Aircraft No. 7 has a smaller total footprint area, for both the 80 and 90 EPNdb contours. As shown in Table XVII, the area of the 90 EPNdb contour for the LH_2 airplane is 11.65 km^2 (4.5 mi^2) vs 13.0 km^2 (5.02 mi^2) for the Jet A design. These areas are the total of approach plus takeoff.

6.6 Sensitivity Factors

The sensitivity of the large aircraft to increases in inert weight was briefly explored. Tables XVIII and XIX present the data which were generated for Aircraft Nos. 7 and 8, respectively. In each case, data for the baseline aircraft are presented, followed by columns representing changes in the parameters which would result from modifications in the design of the aircraft assuming 4536 kg (10,000 lb), was added to the inert weight before design freeze. For example, if detail design of the aircraft indicated that the structure was going to be 4536 kg (10,000 lb) heavier than the original allocation, in order to perform the design mission the aircraft would have to grow. The results are shown in the tables for selected parameters for both the LH_2 and the Jet A fueled aircraft.

The effect of this type of change is indicated in terms of growth factors in the tables. Gross weight and block fuel weight changes are expressed per unit of inert weight increase which caused the change. The change in airplane purchase price is also evaluated per unit of original inert weight increase. Changes in direct operating cost and energy utilization are both expressed in terms of the <u>total</u> inert weight change which perturbed the original design. Each of these growth factors is an expression of the rate of change of the given parameter as a function of a specified unit change in the variable.

The significant conclusion from this exercise follows from comparing growth factors for the LH_2 airplane from Table XVIII with corresponding factors for the Jet A design from Table XIX. The Jet A airplane is significantly more sensitive to changes in each of the parameters than is the LH_2 design. For instance, the gross weight of the Jet A airplane must increase 2.48 kg (5.49 lb) for every kilogram (pound) increase in inert weight, whereas the LH_2 design only requires 1.27 kg (2.8 lb) increase in gross weight to

TABLE XVIII. SENSITIVITY TO INERT WEIGHT INCREASE - BEFORE DESIGN FREEZE - AIRCRAFT NO. 7

		BASELINE		EFFECT OF 4536 kg (10,000 lb) Increase in Inert Weight	
Basic Data					
Gross Weight	kg (lb)	266,430	(587,370)	279,170	(615,460)
Total Fuel Weight	kg (lb)	68,430	(150,850)	70,960	(156,470)
Block Fuel Weight	kg (lb)	59,610	(131,420)	61,770	(136,180)
Empty Weight	kg (lb)	147,700	(325,630)	153,290	(337,940)
Price	$$10^6$	38.89		40.27	
DOC	$\frac{¢}{\text{seat km}}\left(\frac{¢}{\text{seat n.mi.}}\right)$	0.738	(1.366)	0.762	(1.412)
Energy Utilization	$\frac{kJ}{\text{seat km}}\left(\frac{Btu}{\text{seat n.mi.}}\right)$	964	(1695)	999	(1756)
Growth Factors					
Gross Weight	$\left(\frac{kg}{kg}\ \frac{lb}{lb}\right)$			1.27	(2.8)
Block Fuel Weight	$\left(\frac{kg}{kg}\ \frac{lb}{lb}\right)$			0.22	(0.48)
Price	$/kg $/lb			304.	(138)
DOC	$\frac{¢}{\text{seat km}/4536\ kg}\left(\frac{¢}{\text{seat n.mi.}/10{,}000\ lb}\right)$			.025	(0.046)
Energy Utilization	$\frac{kJ}{\text{seat km}/4536\ kg}\left(\frac{Btu}{\text{seat n.mi.}/10{,}000\ lb}\right)$			35.0	(61)

compensate for an unexpected 0.454 kg (1 lb) increase in inert weight. The increase in block fuel required by the Jet A vehicle is 1.01 kg (2.23 lb) per pound of inert weight increase; the value for the LH_2 airplane is only 0.22 kg (0.48 lb). For every 0.454 kg (pound) increase in inert weight the purchase price of the Jet A airplane goes up $197; the LH_2 design, $138. The growth factors for DOC and energy utilization are expressed in terms of 4536 kg (10,000 lb) increase of inert weight because these parameters are relatively insensitive.

TABLE XIX. SENSITIVITY TO INERT WEIGHT INCREASE - BEFORE DESIGN FREEZE - AIRCRAFT NO. 8

		BASELINE		EFFECT OF 4536 kg (10,000 lb) Increase in Inert Weight	
Basic Data					
Gross Weight	kg (lb)	450,200	(992,520)	475,300	(1,047,800)
Total Fuel Weight	kg (lb)	237,690	(524,000)	249,520	(550,100)
Block Fuel Weight	kg (lb)	208,720	(460,150)	218,820	(482,400)
Empty Weight	kg (lb)	159,280	(351,150)	167,570	(369,400)
Price	$$10^6$	39.99		41.96	
DOC	$\frac{¢}{\text{seat km}}\left(\frac{¢}{\text{seat n.mi.}}\right)$	0.723	(1.339)	0.755	(1.398)
Energy Utilization	$\frac{\text{kJ}}{\text{seat km}}\left(\frac{\text{Btu}}{\text{seat n.mi.}}\right)$	1,205.	(2117)	1,263.	(2219)
Growth Factors					
Gross Weight	$\frac{\text{kg}}{\text{kg}}\left(\frac{\text{lb}}{\text{lb}}\right)$		(0)	2.49	(5.49)
Block Fuel Weight	$\frac{\text{kg}}{\text{kg}}\left(\frac{\text{lb}}{\text{lb}}\right)$		(0)	1.01	(2.23)
Price	$/kg ($/lb)		(0)	434	(197)
DOC	$\frac{¢}{\text{seat km}}$/4536 kg $\left(\frac{¢}{\text{seat n.mi.}}/10,000 \text{ lb}\right)$		(0)	0.032	(0.059)
Energy Utilization	$\frac{\text{kJ}}{\text{seat km}}$/4536 kg $\left(\frac{\text{Btu}}{\text{seat n.mi.}}/10,000 \text{ lb}\right)$		(0)	58.	(102)

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7. RESEARCH AND DEVELOPMENT RECOMMENDATIONS

Technology development required for LH_2 fueled transport aircraft is essentially as described in the final report of the previous study (Reference 1). For convenience, the recommended development program schedule from that report (Figure 99, p 302 from Reference 1) has been updated and is presented as Figure 32. Of the items recommended, a preliminary assessment of task 4, "Airport Fuel Supply System Analysis" has been funded and the work is in progress.

In addition to the technology development listed in Figure 32, a very significant event for which there is an immediate need is an assessment of the impact the initiation of use of hydrogen as fuel for commercial transport aviation would have on society in general.* In a sense this effort would be a preliminary study of task 9, Figure 32, since one output would be a hypothetical but realistic scenario depicting the transition to hydrogen. In addition, the economic ramifications, the institutional barriers and incentives, and the social dislocations and opportunities of all major stakeholder classes in society would be disclosed. Stakeholder classes whose participation in the evolutionary scenario would be described include the following:

- airlines
- aircraft manufacturers
- fuel suppliers
- airport operators
- consumers
- government regulators
- work forces
- general public

*This study suggested by Stanford Research Institute, September 26, 1975.

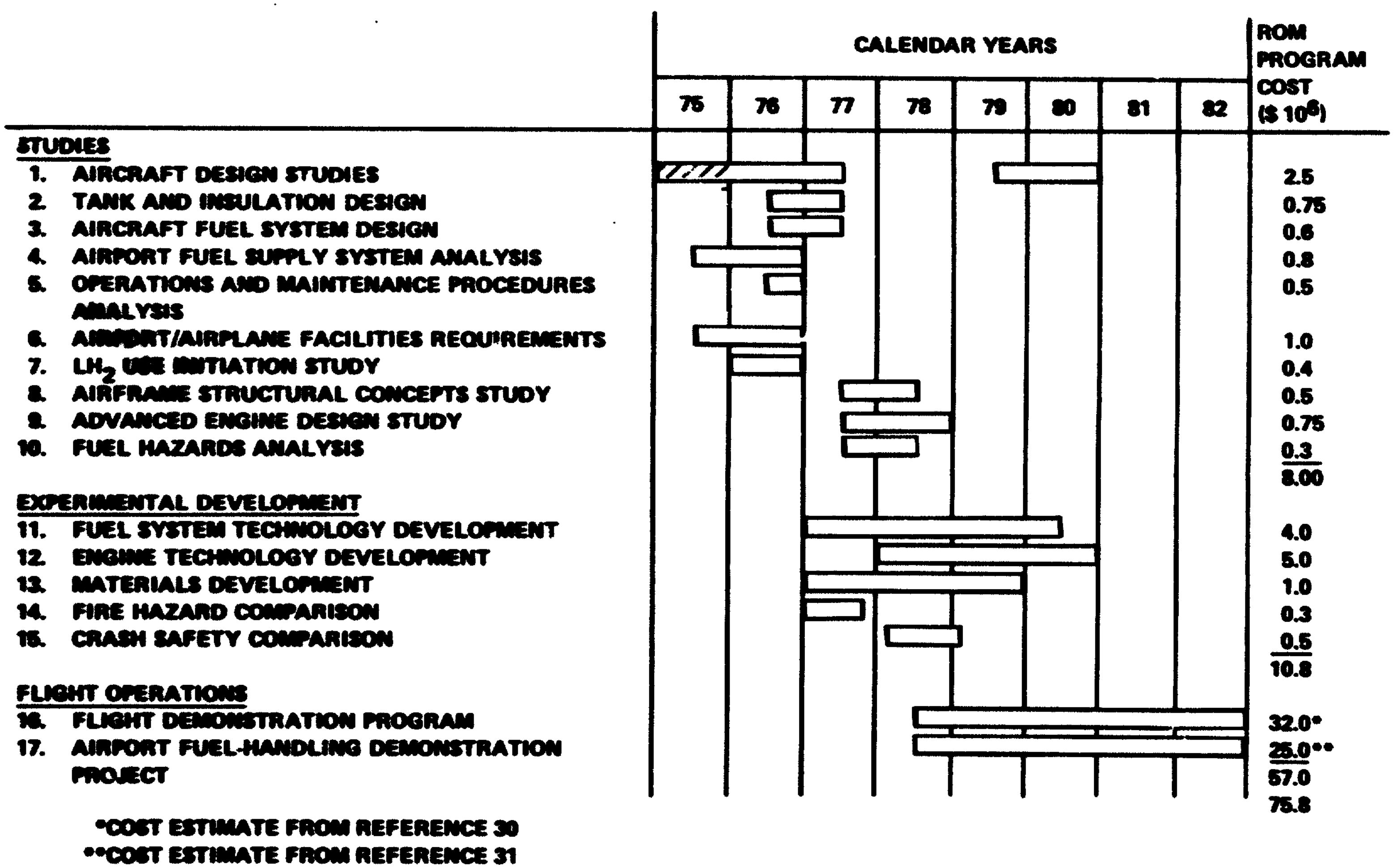

Figure 32. Technology Development Program

While not classified as a "technology development," this study would provide important input and an order of priorities for the technical work. In addition it would acquaint, and hopefully convince, many stakeholders of the need for early conversion of commercial aviation to hydrogen fuel.

8. CONCLUSIONS AND RECOMMENDATIONS

This study explored an enlarged matrix of passenger/range mission requirements to determine the comparative desirability of LH_2 vs Jet A fuel, relative to the missions studied in the original program (Reference 1).

The analysis showed that even for short range missions the internal tank arrangement for LH_2 fueled aircraft is clearly preferred from a performance and cost point of view over the design concept which uses external tanks. In order to provide a fineness ratio for the externally mounted tanks which is aerodynamically acceptable, the surface-to-volume ratio of the tanks is increased to the point that insulation must be both thick and therefore heavy to achieve acceptable boiloff percentages.

The results of the study of small payload - short range aircraft, designed to carry 130 passengers 2780 km (1500 n.mi.), showed that use of LH_2 offers no performance advantage compared to a Jet A fueled design. This mission appears to represent an approximate crossover point. Payload/range requirements which involve use of larger Jet A fuel loads show increasing advantage for using LH_2 fuel. It is probable that aircraft designed for even shorter ranges and smaller payloads would begin to show net disadvantages for LH_2 fueled aircraft. The advantages of using the higher energy fuel are mitigated by the penalties involved: weight of tanks, insulation, and fuel system, plus the increased drag due to the larger volume required for the LH_2 fuel and the insulation surrounding the tanks. The aircraft are essentially equal insofar as noise is concerned. They are both significantly quieter than limits calculated according to the newly proposed change to the noise standard (Reference 3).

Analysis of aircraft designs for the medium range mission, which involves carrying 200 passengers 5560 km (3000 n.mi.), showed the internal tank LH_2 aircraft to have marginally superior characteristics, compared with the Jet A design. It is considerably lighter in gross weight but slightly heavier in empty weight. The Jet A aircraft requires 9 percent more energy to perform the design mission. The LH_2 design is 4 EPNdB quieter in flyover but slightly noisier in sideline and approach than its Jet A counterpart. Its 90 EPNdB contour is slightly smaller.

The long range mission involved a requirement for carrying 400 passengers 9265 km (5000 n.mi.), landing, then taking off without refueling and flying another 9265 km segment with full payload. Full reserve fuel calculated by ATA international definition was provided for each segment. The LH_2 fueled aircraft showed important advantages over the Jet A design for this mission. It is lighter, requires a smaller wing but a larger fuselage, uses smaller engines, can operate from shorter runways, and uses 25 percent less energy per seat mile in performance of the design mission. The LH_2 airplane would cost less both to develop and to produce. A differential of \$1.00 more per GJ (\$1.05/10^6 Btu) can be paid for LH_2, relative to a current price for Jet A, and still provide equal DOC. The LH_2 airplane is nearly 6 EPNdB quieter in flyover, but slightly noiser in sideline and approach compared to the Jet A design. Both aircraft are significantly quieter than the noise limit calculated according to the pending revision to FAR 36. The LH_2 airplane has a slightly smaller 90 EPNdB contour.

A study of sensitivities of the long range aircraft to increases in inert weight before design freeze showed the LH_2 design to be considerably less sensitive.

Results of analyses from the previous study of subsonic passenger transport aircraft (Reference 1) are combined with those from the present work and are plotted in Figures 33 and 34. The total energy (represented by the energy content of the block fuel) required to perform various payload-range missions is displayed as a function of the mission requirements (expressed in available seats times design range in Figure 33. Two characteristics are plotted, the trend of energy requirement for aircraft of a given passenger capacity - with range as the variable, and the energy requirement of aircraft designed for a given range - with passenger capacity as the variable.

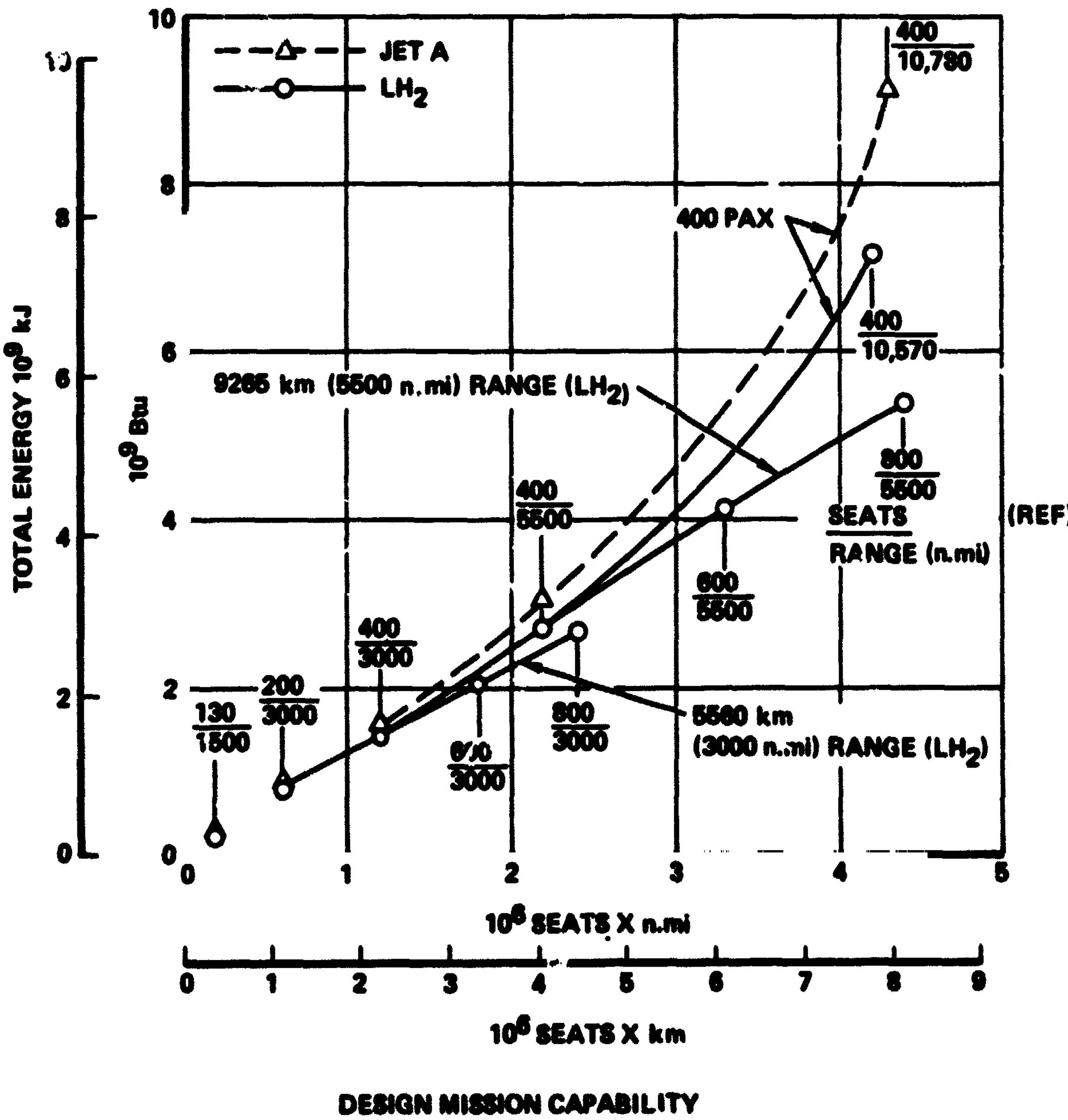

Figure 33. Total Energy vs Design Mission Capability

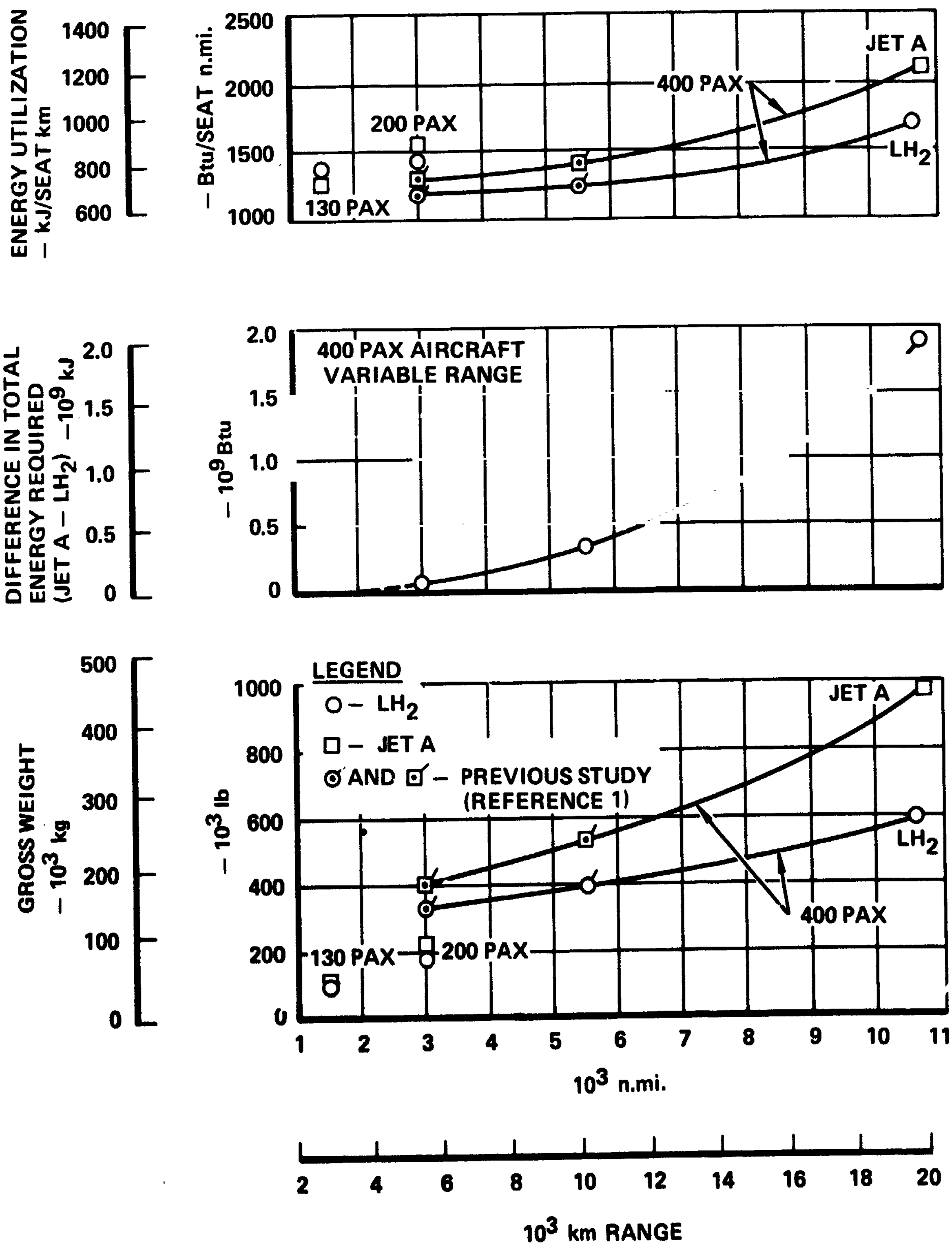

Figure 34. Growth Characteristics

The figure shows that the energy requirement varies almost linearly as passenger capacity increases from 400 to 800 seats in aircraft designed for a given range. On the other hand, as the range requirement changes in aircraft designed for a constant number of passengers, the energy requirement varies exponentially. In other words, more energy is required to increase the mission capability (seats x distance) of a given aircraft configuration by increasing its range than by adding to its passenger seating capacity. It is also apparent that the energy requirement for Jet A fueled aircraft increases substantially faster than for aircraft fueled with LH_2.

Three additional relationships for the 400 passenger aircraft are plotted in Figure 34. Gross weight, energy utilization, and the difference in energy required by the Jet A fueled aircraft - relative to the LH_2 - to perform the various design missions, are all plotted vs range. For reference, points representing the 130 passenger and 200 passenger aircraft design are also shown.

The advantage of using LH_2 as fuel in transport aircraft increases with the amount of energy required to perform the mission. The crossover point, above which LH_2 can be used to advantage, and below which Jet A is more energy efficient, seems to vary somewhat with the passenger load. For the 130 passenger Mach 0.85 aircraft shown in the lower left corner of Figure 33 the crossover point is approximately the 2780 km (1500 n.mi.) design range, which requires about 0.264 kJ (0.25 x 10^9 Btu). For a 400 passenger Mach 0.85 aircraft the crossover appears to be just under 3700 km (2000 n.mi.) design range, a mission which needs approximately 1.054 kJ (10^9 Btu).

In view of the obvious advantages of LH_2 fuel in long range aircraft an aggressive program of technology investigation and development is recommended. In particular, a societal impact study is recommended for immediate undertaking.

APPENDIX A

SELECTED PAGES OF ASSET COMPUTER PRINTOUT FOR EIGHT AIRCRAFT

A-1	Internal Tank LH_2	Short Range Aircraft
A-2	External Tank LH_2	Short Range Aircraft
A-3	Jet A	Short Range Aircraft
A-4	Internal Tank LH_2	Medium Range Aircraft
A-5	External Tank LH_2	Medium Range Aircraft
A-6	Jet A	Medium Range Aircraft
A-7	Internal Tank LH_2	Long Range Aircraft
A-8	Jet A	Long Range Aircraft

LIQUID HYDROGEN---BASIC DESIGN MISSION/130 PASS/ 1500 N MI   MISS   INT. LH_2

T/C	T/R	AR	LAM	W/S	T/W
10.00	0.30	10.00	30.00	107.8	0.345

CONFIGURATION GEOMETRY

WING--	AREA(SQ.FT)	SPAN(FT)	TAPER RATIO	C/4 SWEEP (DEG)	L.E. SWEEP (DEG)	L.F.P/CHORD	
	911.5	95.47	0.300	30.000	32.260	0.0	
	CR(FT)	CT(FT)	MAC(FT)	CRE(FT)	S WET(SQ.FT)	REF L(FT)	
	14.69	4.41	10.47	13.29	1568.6	10.47	
WING TANK--	CBAR1(FT)	CBAR2(FT)	FTL(FT)	FVWING(CU FT)	FVBOX(CU FT)		
	13.29	5.15	37.77	0.00	0.00		
FUSELAGE--	LENGTH(FT)	S WET(SQ FT)	BWH(FT)	EQUIV D(FT)	SPI(SQ FT)		
	139.47	5100.5	13.00	13.32	139.30		
	BW(FT)	BH(FT)	SBW(SQ FT)	FVB(CU FT)			
	13.00	13.66	5100.49	1807.29			
TAIL--	SHT(SQ.FT)	SHTX(SQ.FT)	HT REF L(FT)	SVT(SQ.FT)	SVTX(SQ.FT)	VT REF L(FT)	
	94.04	77.55	4.68	89.96	89.96	8.25	
PROPULSION--	ENG L(FT)	ENG D(FT)	POD L(FT)	POD D(FT)	POD S WET (SQ. FT)	NO. PODS	INLET L(FT)
	7.22	4.91	16.16	5.37	545.09	2.	0.0

A-1
Aircraft No. 1
LH_2 Internal Tank
130 PAX, 1500 n mi range
Mach 0.85

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LIQUID HYDROGEN---BASIC DESIGN MISSION/130 PASS/ 1500 N MI MISS

T/C	T/R	AR	LAM	W/S	T/W
10.00	0.30	10.00	30.00	107.8	0.345

		POUNDS	0/0	POUNDS	0/0
DESIGN GROSS WEIGHT		98257.	100.00		
FUEL		7364.	7.49		
ZERO FUEL WEIGHT				90893.	
PAYLOAD		28600.	29.11		
OPERATING WEIGHT EMPTY				62293.	63.40
OPERATIONAL ITEMS		2871.	2.92		
STANDARD ITEMS		1457.	1.48		
EMPTY WEIGHT-MFG.				57965.	
WING		7923.	8.06		
TAIL		904.	0.92		
BODY		11665.	11.87		
LANDING GEAR		3762.	3.83		
FLIGHT CONTROLS		1530.	1.56		
NACELLES		2031.	2.07		
PROPULSION SYSTEM		12538.	12.76		
ENGINE	6815.				
AIR INTAKE	787.				
EXHAUST	617.				
COOLING	0.				
OIL SYSTEM (LESS OIL)	11.				
ENGINE CONTROLS	38.				
ENGINE STARTING	118.				
TANKS	1588.				
INSULATION	1603.				
FUEL-PLUMBING	960.				
INSTRUMENTS		831.	0.85		
HYDRAULICS		948.	0.96		
ELECTRICAL		2586.	2.63		
ELECTRONICS		968.	0.99		
FURNISHINGS AND EQUIP.		9440.	9.61		
AIR CONDITIONING		1873.	1.91		
ANTI-ICING		137.	0.14		
AUXILIARY POWER UNIT		830.	0.84		
MISCELLANEOUS		0.	0.0		
DESIGN RESERVE		0.	0.0		

NO. OF PASSENGERS	130.
NO. OF CREW	7.
STRUCTURAL T/C	12.50
FUEL VOLUME REQD	1761.0
WING FUEL VOLUME AVAILABLE	0.0

MISSION SUMMARY

LIQUID HYDROGEN---BASIC DESIGN MISSION/130 PASS/ 1500 N MI MISS

SEGMENT	INIT ALTITUDE (FT)	INIT MACH NO	INIT WEIGHT (LB)	SEGMT FUEL (LB)	TOTAL FUEL (LB)	SEGMT DIST (N MI)	TOTAL DIST (N MI)	SEGMT TIME (MIN)	TOTAL TIME (MIN)	EXTERN STORE TAB ID	ENGINE THRUST TAB ID	EXTERN F TANK TAB ID	AVG L/D RATIO	AVG SFC (FF/T)
TAKEOFF POWER 1	0.	0.0	98257.	49.	49.	0.	0.	14.0	14.0	0.	-83101.	0.	0.0	0.124
POWER 2	0.	0.0	98208.	56.	105.	0.	0.	1.0	15.0	0.	83401.	0.	0.0	0.100
CLIMB	0.	0.378	98152.	154.	260.	13.	13.	2.9	17.9	0.	83101.	0.	15.75	0.161
ACCEL	10000.	0.456	97998.	58.	318.	7.	20.	1.2	19.1	0.	83101.	0.	13.06	0.184
CLIMB	10000.	0.638	97939.	1386.	1703.	332.	352.	40.7	59.8	0.	83101.	0.	11.93	0.212
CRUISE	36000.	0.850	96554.	2668.	4372.	898.	1250.	110.4	170.2	0.	-83101.	0.	13.87	0.211
DESCENT	36000.	0.850	93886.	43.	4415.	51.	1301.	6.5	176.7	0.	83301.	0.	11.01	-1.716
DECEL	10000.	0.638	93842.	13.	4428.	8.	1309.	1.4	178.0	0.	83301.	0.	13.13	47.336
DESCENT	10000.	0.456	93829.	79.	4506.	32.	1341.	7.2	185.2	0.	83301.	0.	15.50	0.847
CRUISE	36000.	0.850	93751.	469.	4975.	159.	1500.	19.6	204.8	0.	-83101.	0.	13.75	0.211
LOITER	1500.	0.248	93282.	86.	5061.	0.	1500.	6.0	210.8	0.	-83101.	0.	16.07	0.148
RESET	0.	0.0	93196.	0.	5061.	0.	1500.	0.0	210.8	0.	0.	0.	0.0	0.0
RESET	0.	0.0	93196.	0.	5061.	-1500.	0.	-210.8	0.0	0.	0.	0.	0.0	0.0
CRUISE	36000.	0.850	93196.	1429.	6490.	0.	0.	60.0	60.0	0.	-83101.	0.	13.67	0.211
RESET	0.	0.0	91767.	0.	6490.	0.	0.	0.0	60.0	0.	0.	0.	0.0	0.0
CLIMB	0.	0.378	91767.	142.	6632.	12.	12.	2.7	62.7	0.	83101.	0.	15.27	0.161
ACCEL	10000.	0.456	91625.	23.	6654.	3.	15.	0.5	63.2	0.	83101.	0.	13.95	0.175
CLIMB	10000.	0.547	91603.	393.	7048.	70.	84.	10.4	73.6	0.	83101.	0.	13.15	0.193
CRUISE	30000.	0.650	91209.	44.	7091.	15.	100.	2.4	76.0	0.	-83101.	0.	15.67	0.169
DESCENT	30000.	0.700	91166.	50.	7141.	47.	147.	7.1	83.1	0.	83301.	0.	12.97	-5.275
DECEL	10000.	0.547	91116.	7.	7148.	4.	151.	0.8	83.8	0.	83301.	0.	14.01	1.705
DESCENT	10000.	0.456	91109.	57.	7205.	25.	175.	5.4	89.2	0.	83301.	0.	15.25	0.889
CRUISE	30000.	0.650	91052.	70.	7274.	25.	200.	3.8	93.0	0.	-83101.	0.	15.66	0.169
LOITER	1500.	0.245	90983.	84.	7358.	0.	200.	6.0	99.0	0.	-83101.	0.	16.04	0.148

TOGWT= 98257.3 FUEL A= 7364.4 FUEL R= 7358.2

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COST SUMMARY

WING		534489.81		
TAIL		73178.00		
BODY		1034711.88		
LANDING GEAR		91055.06		
FLIGHT CONTROLS		105000.81		
NACELLES		230582.38		
PROPULSION				
ENGINE	9462.58			
AIR INDUCTION	67597.69			
FUEL SYSTEM	375387.75			
START SYSTEM	1855.53			
ENGINE CONTROLS	737.11			
EXH/THRUST REV.	843.25			
LUBE SYSTEM	2186.88			
TOTAL PROPULSION		458070.69		
INSTRUMENTS		127731.75		
HYDRAULICS		66037.75		
ELECTRICAL		223768.69		
ELECTRONIC RACKS		61507.32		
FURNISHING		212208.00		
AIR CONDITIONING		154680.63		
ANTI ICING		11275.36		
APU		90520.56		
SYS. INTEGRATION		81474.25		
TOTAL EMPTY MFG. COST			3556301.00	
SUSTAINING ENGINEERI	242578.25			
TECHNICAL DATA	0.0			
PROD. TOOLING MAINT.	319432.44			
MISC.	88743.44			
ENG. CHANGE ORDER	0.0			
QUALITY ASSURANCE	333295.19			
AIRFRAME WARRANTY		227017.38		
AIRFRAME FEE		715104.75		
AIRFRAME COST			5482470.00	
ENGINE WARRANTY		65034.79		
ENGINE FEE		163887.50		
ENGINE COST			1529618.00	
AVIONICS COST			220000.00	
RESEARCH AND DEVELOPMENT			617740.38	
TOTAL FLY AWAY COST				7849828.00

R AND D	
DEVELOPMENT TECHNICAL DATA	4956555.
DESIGN ENGINEERING	110145660.
DEVELOPMENT TOOLING	53545904.
DEVELOPMENT TEST ARTICLE	17999564.
FLIGHT TEST	12482084.
SPECIAL SUPPORT EQUIPMENT	1321747.
DEVELOPMENT SPARES	15257614.
ENGINE DEVLEOPMENT	0.
AVIONICS DEVLEOPMENT	0.
TOTAL R AND D	216209120.

DIRECT OPERATING COST-DOLLARS/N. MILE		O/O
CREW	0.4216	22.95
AIRFRAME LABOR AND BURDEN MAINT.	0.1336	7.27
ENGINE LABOR AND BURDEN MAINT.	0.0531	2.89
AIRFRAME MATERIAL MAINT.	0.0689	3.75
ENGINE MATERIAL MAINT.	0.0692	3.77
FUEL AND OIL	0.5450	29.89
INSURANCE	0.1114	6.07
DEPRECIATION (INCLUDING SPARES)	0.4303	23.42
TOTAL DOC $/N. MILE	1.8371	100.00

RANGE N. MI	730.	859.	987.	1115.	1243.	1372.	1500.
DOC C/ASM	1.6527	1.5830	1.5314	1.4916	1.4601	1.4344	1.4132
TR-HR	1.9360	2.1969	2.4618	2.7247	2.9876	3.2505	3.5134
$/TRP	1569.	1767.	1965.	2163.	2360.	2558.	2756.

A S S E T   P A R A M E T R I C   A N A L Y S I S

SUMMARY ID NO. 101
NOVEMBER 12 1975

AIRCRAFT MODEL —CL1317-10
I.O.C. DATE —1996
DESIGN SPEED —SUBSONIC

ENGINE I.D. -- 83000
SLS SCALE 1.0 = 35000
NUMBER OF ENGINES = 2.

WING QUARTER CHORD SWEEP = 30.00 DEG
WING TAPER RATIO = 0.300

1 W/S	108.2	108.2	108.2	108.2	108.0	108.0	108.0	108.0	107.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2 T/W	0.345	0.342	0.340	0.34	0.345	0.342	0.340	0.338	0.345	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3 AR	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4 T/C	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5 RADIUS N. MI	1500	1500	1500	1500	1500	1500	1500	1500	1500	0	0	0	0	0	0	0
6 GROSS WEIGHT	98205	98166	98068	98019	98231	98193	98094	98045	98257	0	0	0	0	0	0	0
7 FUEL WEIGHT	7358	7398	7396	7414	7361	7402	7400	7417	7364	0	0	0	0	0	0	0
8 OP. WT. EMPTY	62247	62168	62071	62004	62270	62191	62094	62027	62292	0	0	0	0	0	0	0
9 ZERO FUEL WT.	90847	90768	90671	90604	90870	90791	90694	90627	90892	0	0	0	0	0	0	0
10 THRUST/ENGINE	16940	16786	16671	16565	16944	16791	16676	16569	16949	0	0	0	0	0	0	0
11 ENGINE SCALE	0.484	0.480	0.476	0.473	0.484	0.480	0.476	0.473	0.484	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12 WING AREA	908.	907.	906.	906.	910.	909.	908.	908.	911.	0.	0.	0.	0.	0.	0.	0.
13 WING SPAN	95.3	95.3	95.2	95.2	95.4	95.4	95.3	95.3	95.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14 H. TAIL AREA	93.	93.	93.	93.	94.	94.	93.	93.	94.	0.	0.	0.	0.	0.	0.	0.
15 V. TAIL AREA	89.	89.	89.	89.	90.	90.	89.	89.	90.	0.	0.	0.	0.	0.	0.	0.
16 BODY LENGTH	139.5	139.5	139.5	139.6	139.5	139.6	139.6	139.6	139.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17 WING FUEL LIMIT	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0	0.0	0.0	0.0	0.0
COST DATA—MILLION DOLLARS/AIRCRAFT																
18 FLYAWAY COST	7.844	7.828	7.811	7.798	7.847	7.831	7.814	7.801	7.850	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19 AIRFRAME COST	6.095	6.091	6.083	6.078	6.098	6.093	6.085	6.081	6.100	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20 ENGINE COST	1.529	1.517	1.508	1.500	1.529	1.517	1.508	1.500	1.530	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21 AVIONICS COST	0.220	0.220	0.220	0.220	0.220	0.220	0.220	0.220	0.220	0.0	0.0	0.0	0.0	0.0	0.0	0.0
COST DATA—DIRECT OPERATING COST																
22 $ PER MILE	1.836	1.836	1.833	1.834	1.837	1.837	1.834	1.834	1.837	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23 CENTS/A S MILE	1.412	1.412	1.410	1.411	1.413	1.413	1.410	1.411	1.413	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FLIGHT PATH MISSION CHARACTERISTICS																
24 MISSION SYM(1)	36000	35000	35000	35000	36000	35000	35000	35000	36000	0	0	0	0	0	0	0
25 MISSION SYM(2)	5056	5098	5091	5120	5058	5101	5094	5123	5061	0	0	0	0	0	0	0
CONSTRAINT OUTPUT																
26 CEILING PWR(1)	36293	36117	35918	35824	36299	36123	35924	35829	36307	0	0	0	0	0	0	0
27 TAKEOFF DST(1)	4713	4755	4785	4814	4703	4746	4775	4804	4693	0	0	0	0	0	0	0
28 CLIMB GRAD(1)	0.1779	0.1754	0.1736	0.1719	0.1780	0.1754	0.1737	0.1720	0.1781	0.0	0.0	0.0	0.0	0.0	0.0	0.0
29 TAKEOFF DST(2)	7959	8182	8347	8516	7922	8142	8305	8473	7885	0	0	0	0	0	0	0
30 CLIMB GRAD(2)	0.0275	0.0264	0.0256	0.0249	0.0275	0.0264	0.0257	0.0250	0.0276	0.0	0.0	0.0	0.0	0.0	0.0	0.0
31 AP SPEED-KT(1)	135.3	135.3	135.3	135.3	135.2	135.2	135.2	135.2	135.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
32 CTOL LNDG D(1)	5742	5739	5738	5736	5735	5732	5731	5729	5728	0	0	0	0	0	0	0
33 AP SPEED-KT(2)	149.2	149.1	149.2	149.1	149.0	149.0	149.0	149.0	148.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
34 CTOL LNDG D(2)	6576	6574	6574	6572	6568	6565	6565	6564	6559	0	0	0	0	0	0	0
35 AP SPEED-KT(3)	135.5	135.5	135.5	135.5	135.3	135.3	135.3	135.3	135.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
36 CTOL LNDG D(3)	5748	5747	5746	5745	5741	5740	5739	5738	5734	0	0	0	0	0	0	0

LIQUID HYDROGEN---BASIC DESIGN MISSION/130 PASS/ 1500 N MI MISS EXT LH_2

T/C	T/F	AR	LAM	W/S	T/W
16.00	0.40	9.50	30.00	108.0	0.450

C O N F I G U R A T I O N   G E O M E T R Y

WING--	AREA(SQ.FT)	SPAN(FT)	TAPER RATIO	C/4 SWEEP (DEG)	L.E. SWEEP (DEG)	L.E.R/CHORD	
	1017.6	98.32	0.400	30.000	31.901	0.0	
	CR(FT)	CT(FT)	MAC(FT)	CRE(FT)	S WET(SQ.FT)	REF L(FT)	
	14.79	5.91	10.98	13.61	1792.2	10.98	
WING TANK--	CHAR1(FT)	CHAR2(FT)	FTL(FT)	FVWING(CU FT)	FVEDX(CU FT)		
	13.61	6.56	39.10	0.00	0.00		
FUSELAGE--	LENGTH(FT)	S WET(SQ FT)	BW(FT)	EQUIV D(FT)	SPI(SQ FT)		
	113.00	4077.0	13.00	13.32	139.30		
	HW(FT)	BH(FT)	SBW(SQ FT)	FVB(CU FT)			
	13.66	13.66	4077.00	0.0			
TAIL--	SHT(SQ.FT)	SHTX(SQ.FT)	HT REF L(FT)	SVT(SQ.FT)	SVTX(SQ.FT)	VT REF L(FT)	
	163.16	176.66	6.12	138.78	138.78	10.20	
PROPULSION--	ENG L(FT)	ENG D(FT)	POD L(FT)	POD D(FT)	POD S WET (SQ. FT)	NO. PODS	INLET L(FT)
	9.55	5.93	14.16	6.48	280.37	2.	0.0
FUEL PODS--	VOL(CU FT)	LENGTH(FT)	SPI(SQ FT)	S WET(SQ FT)	NO PODS		
	2356.21	45.68	107.[illegible]	2290.5	2.		

A-2
Aircraft No. 2
LH_2 External Tank
130 PAX, 1500 n mi range
Mach 0.85

LIQUID HYDROGEN---BASIC DESIGN MISSION/130 PASS/ 1500 N MI   MISS

T/C	T/R	AR	LAM	W/S	T/W
10.00	0.40	9.50	30.00	108.0	0.450

		POUNDS	O/O	POUNDS	O/O
DESIGN GROSS WEIGHT		109902.	100.00		
FUEL		9616.	8.75		
ZERO FUEL WEIGHT				100286.	
PAYLOAD		28600.	26.02		
OPERATING WEIGHT EMPTY				71686.	65.23
OPERATIONAL ITEMS		2886.	2.63		
STANDARD ITEMS		1528.	1.39		
EMPTY WEIGHT-MFC.				67272.	
WING		9357.	8.51		
TAIL		1505.	1.37		
BODY		10791.	9.82		
LANDING GEAR		3937.	3.58		
FLIGHT CONTROLS		1684.	1.53		
NACELLES		3043.	2.77		
PROPULSION SYSTEM		19393.	17.64		
ENGINE	10204.				
AIR INTAKE	1179.				
EXHAUST	925.				
COOLING	0.				
OIL SYSTEM (LESS OIL)	11.				
ENGINE CONTROLS	57.				
ENGINE STARTING	176.				
TANKS	2655.				
INSULATION	3302.				
FUEL-PUMPING	789.				
INSTRUMENTS		842.	0.77		
HYDRAULICS		1027.	0.93		
ELECTRICAL		2499.	2.27		
ELECTRONICS		918.	0.84		
FURNISHINGS AND EQUIP.		9440.	8.59		
AIR CONDITIONING		1873.	1.70		
ANTI-ICING		144.	0.13		
AUXILIARY POWER UNIT		830.	0.76		
MISCELLANEOUS		0.	0.0		
DESIGN RESERVE		0.	0.0		

NO. OF PASSENGERS	130.
NO. OF CREW	7.
STRUCTURAL T/C	12.50
FUEL VOLUME REQD	2295.9
WING FUEL VOLUME AVAILABLE	0.0

MISSION SUMMARY

LIQUID HYDROGEN---BASIC DESIGN MISSION/130 PASS/ 1500 N MI MISS

SEGMENT	INIT ALTITUDE (FT)	INIT MACH NO	INIT WEIGHT (LB)	SEGMT FUEL (LB)	TOTAL FUEL (LB)	SEGMT DIST (N MI)	TOTAL DIST (N MI)	SEGMT TIME (MIN)	TOTAL TIME (MIN)	EXTERN STORE TAB ID	ENGINE THRUST TAB ID	EXTERN F TANK TAB ID	AVG L/D RATIO	AVG SFC (FF/T)
TAKEOFF POWER 1	0.	0.0	109902.	71.	71.	0.	0.	14.0	14.0	0.	-83101.	0.	0.0	0.124
POWER 2	0.	0.0	109831.	82.	153.	0.	0.	1.0	15.0	0.	83401.	0.	0.0	0.100
CLIMB	0.	0.378	109748.	168.	321.	10.	10.	2.2	17.2	0.	83101.	0.	12.77	0.161
ACCEL	10000.	0.456	109580.	63.	385.	5.	15.	0.9	18.1	0.	83101.	0.	10.35	0.184
CLIMB	10000.	0.638	109517.	1472.	1856.	251.	266.	30.9	49.0	0.	83101.	0.	9.79	0.212
CRUISE	38000.	0.850	108045.	3846.	5703.	984.	1250.	121.1	170.0	0.	-83101.	0.	11.74	0.211
DESCENT	38000.	0.850	104199.	52.	5754.	43.	1293.	5.5	175.5	0.	83301.	0.	8.83	-1.658
DECEL	10000.	0.638	104148.	15.	5769.	6.	1299.	1.1	176.6	0.	83301.	0.	10.39	46.587
DESCENT	10000.	0.456	104133.	94.	5862.	26.	1325.	5.9	182.5	0.	83301.	0.	12.52	0.847
CRUISE	38000.	0.850	104039.	675.	6537.	175.	1500.	21.5	203.9	0.	-83101.	0.	11.61	0.211
LOITER	1500.	0.243	103364.	110.	6647.	0.	1500.	6.0	209.9	0.	-83101.	0.	14.29	0.152
RESET	0.	0.0	103254.	0.	6647.	0.	1500.	0.0	209.9	0.	0.	0.	0.0	0.0
RESET	0.	0.0	103254.	0.	6647.	-1500.	0.	-209.9	0.0	0.	0.	0.	0.0	0.0
CRUISE	38000.	0.850	103254.	1834.	8482.	0.	0.	60.0	60.0	0.	-83101.	0.	11.78	0.211
RESET	0.	0.0	101420.	0.	8482.	0.	0.	0.0	60.0	0.	0.	0	0.0	0.0
CLIMB	0.	0.378	101420.	153.	8634.	0.	0.	2.0	62.0	0.	83101.	0.	12.22	0.161
ACCEL	10000.	0.456	101267.	24.	8659.	2.	11.	0.3	62.3	0.	83101.	0.	11.05	0.175
CLIMB	10000.	0.447	101243.	411.	9069.	50.	60.	7.4	69.8	0.	83101.	0.	10.38	0.192
CRUISE	30000.	0.605	100832.	150.	9220.	40.	100.	6.6	76.3	0.	-83101.	0.	13.48	0.184
DESCENT	30000.	0.700	100682.	57.	9276.	37.	137.	5.6	81.9	0.	83301.	0.	10.19	-5.262
DECEL	10000.	0.547	100625.	8.	9284.	3.	140.	0.6	82.5	0.	83301.	0.	11.10	1.701
DESCENT	10000.	0.456	100617.	67.	9351.	20.	160.	4.4	86.9	0.	83301.	0.	12.29	0.889
CRUISE	36000.	0.605	100550.	152.	9504.	40.	200.	6.7	93.5	0.	-83101.	0.	13.47	0.184
LOITER	1500.	0.240	100398.	107.	9611.	0.	200.	6.0	99.5	0.	-83101.	0.	14.28	0.153

TOGWT= 109901.9 FUEL A= 9615.8 FUEL R= 9610.9

C O S T   S U M M A R Y

WING		676719.88		
TAIL		121065.04		
BODY		950616.62		
LANDING GEAR		95033.29		
FLIGHT CONTROLS		115182.63		
NACELLES		342159.56		
PROPULSION				
ENGINE	14051.32			
AIR INDUCTION	100926.69			
FUEL SYSTEM	613026.19			
START SYSTEM	2769.39			
ENGINE CONTROLS	1109.16			
EXH/THRUST REV.	1252.19			
LUBE SYSTEM	2176.15			
TOTAL PROPULSION		734897.04		
INSTRUMENTS		128902.13		
HYDRAULICS		71105.56		
ELECTRICAL		215102.69		
ELECTRONIC RACKS		57967.46		
FURNISHING		211164.13		
AIR CONDITIONING		153862.19		
ANTI ICING		11814.62		
APU		96252.88		
SYS. INTEGRATION		93763.31		
TOTAL EMPTY MFG. COST			6620345.00	
SUSTAINING ENGINEERI	279059.00			
TECHNICAL DATA	0.0			
PROD. TOOLING MAINT.	367471.13			
MISC.	132089.31			
ENG. CHANGE ORDER	0.0			
QUALITY ASSURANCE	383418.69			
AIRFRAME WARRANTY		257619.06		
AIRFRAME FEE		811500.00		
AIRCRAFT COST			6221501.00	
ENGINE WARRANTY		40958.38		
ENGINE FEE		226442.06		
ENGINE COST			2113469.00	
AVIONICS COST			220000.00	
RESEARCH AND DEVELOPMENT			784744.56	
TOTAL FLY AWAY COST				9330714.00

R AND D

DEVELOPMENT TECHNICAL DATA	6910873.
DESIGN ENGINEERING	153573872.
DEVELOPMENT TOOLING	58828632.
DEVELOPMENT TEST ARTICLE	20597552.
FLIGHT TEST	14199978.
SPECIAL SUPPORT EQUIPMENT	1842886.
DEVELOPMENT SPARES	18708408.
ENGINE DEVLEOPMENT	0.
AVIONICS DEVLEOPMENT	0.
TOTAL R AND D	274660252.

DIRECT OPERATING COST-DOLLARS/N. MILE		O/O
CREW	0.4199	19.35
AIRFRAME LABOR AND BURDEN MAINT.	0.1446	6.67
ENGINE LABOR AND BURDEN MAINT.	0.0643	2.96
AIRFRAME MATERIAL MAINT.	0.0785	3.62
ENGINE MATERIAL MAINT.	0.0952	4.39
FUEL AND OIL	0.7209	33.23
INSURANCE	0.1320	6.09
DEPRECIATION (INCLUDING SPARES)	0.5140	23.69
TOTAL DOC $/N. MILE	2.1696	100.00

RANGE N. MI	657.	797.	938.	1079.	1219.	1359.	1500.
DOC C/ASM	2.0051	1.8997	1.8259	1.7713	1.7293	1.6960	1.6689
TP-HP	1.7696	2.0579	2.3461	2.6343	2.9226	3.2108	3.4991
1/TFP	1712.	1969.	2226.	2483.	2740.	2997.	3254.

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OF POOR QUALITY

A S S E T   P A R A M E T R I C   A N A L Y S I S

SUMMARY ID NO. 101
SEPTEMBER 30 1975

AIRCRAFT MODEL —CL1317-11
I.O.C. DATE —1990
DESIGN SPEED —SUBSONIC

ENGINE I.D. — 83000
SLS SCALE 1.0 35000
NUMBER OF ENGINES = 2.

WING QUARTER CHORD SWEEP = 30.00 DEG
WING TAPER RATIO = 0.400

1 W/S	110.0	110.0	110.0	110.0	108.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2 T/W	0.45	0.43	0.43	0.42	0.45	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3 AR	9.50	9.50	9.50	9.50	9.50	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4 T/C	10.00	10.00	10.00	10.00	10.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5 RADIUS N. MI	1500	1500	1500	1500	1500	0	0	0	0	0	0	0	0	0	0	0
6 GROSS WEIGHT	109565	109320	109255	109221	109901	0	0	0	0	0	0	0	0	0	0	0
7 FUEL WEIGHT	9579	9705	9961	10106	9615	0	0	0	0	0	0	0	0	0	0	0
8 OP. WT. EMPTY	71385	71816	70753	70512	71686	0	0	0	0	0	0	0	0	0	0	0
9 ZERO FUEL WT.	99985	99614	99352	99112	100286	0	0	0	0	0	0	0	0	0	0	0
10 THRUST/ENGINE	24652	24050	23474	22936	24727	0	0	0	0	0	0	0	0	0	0	0
11 ENGINE SCALE	0.704	0.687	0.671	0.655	0.707	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12 WING AREA	996.	986.	983.	983.	1018.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
13 WING SPAN	97.3	97.2	97.1	97.1	98.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14 H. TAIL AREA	158.	157.	157.	157.	163.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
15 V. TAIL AREA	134.	134.	133.	133.	139.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
16 BODY LENGTH	113.0	113.0	113.0	113.0	113.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17 WING FUEL LIMIT	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
COST DATA—MILLION DOLLARS/AIRCRAFT																
18 FLYAWAY COST	9.302	9.235	9.182	9.132	9.340	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19 AIRFRAME COST	6.974	6.951	6.946	6.930	7.004	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20 ENGINE COST	2.108	2.064	2.022	1.982	2.113	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21 AVIONICS COST	0.220	0.220	0.220	0.220	0.220	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
COST DATA—DIRECT OPERATING COST																
22 $ PER MILE	2.161	2.163	2.174	2.180	2.170	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23 CENTS/A S MILE	1.662	1.664	1.672	1.677	1.669	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FLIGHT PATH MISSION CHARACTERISTICS																
24 MISSION SYM(1)	38000	37000	36000	35000	38000	0	0	0	0	0	0	0	0	0	0	0
25 MISSION SYM(2)	6606	6704	6874	7030	6647	0	0	0	0	0	0	0	0	0	0	0
CONSTRAINT OUTPUT																
26 CEILING PAR(1)	38665	38352	37718	37133	38790	0	0	0	0	0	0	0	0	0	0	0
27 TAKEOFF DST(1)	3763	3860	3922	4008	3693	0	0	0	0	0	0	0	0	0	0	0
28 CLIMB GRAD(1)	0.2600	0.2512	0.2424	0.2336	0.2611	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
29 TAKEOFF DST(2)	4700	4979	5187	5416	4661	0	0	0	0	0	0	0	0	0	0	0
30 CLIMB GRAD(2)	0.0575	0.0538	0.0501	0.0464	0.0583	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
31 AP SPEED—KT(1)	136.7	136.7	136.5	136.4	135.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
32 CTOL LNDG D(1)	5822	5814	5804	5795	5752	0	0	0	0	0	0	0	0	0	0	0
33 AP SPEED—KT(2)	149.6	149.6	149.3	149.2	148.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
34 CTOL LNDG D(2)	6586	6579	6569	6560	6499	0	0	0	0	0	0	0	0	0	0	0
35 AP SPEED—KT(3)	137.6	137.5	137.5	137.5	136.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
36 CTOL LNDG D(3)	5865	5862	5856	5855	5795	0	0	0	0	0	0	0	0	0	0	0

```
JP FUEL REFERENCE BASELINE DESIGN / 130 PASS / 1500 N MI      MISS      JET A

      T/C     T/R     AR     LAM    W/S     T/W

     10.00   0.30   11.00  30.00  117.0   0.348


                 C O N F I G U R A T I O N   G E O M E T R Y

WING--          AREA(SQ.FT)   SPAN(FT)  TAPER RATIO  C/4 SWEEP  L.E. SWEEP  L.E.R/CHORD
                                                       (DEG)      (DEG)
                   928.7       101.07      0.300      30.000     32.059      0.0

                  CR(FT)       CT(FT)      MAC(FT)    CRF(FT)  S WET(SQ.FT)  REF L(FT)
                  14.14         4.24       10.08      12.86      1602.8      10.08

WING TANK--      CBAR1(FT)    CBAR2(FT)    FTL(FT)  FVWING(CU FT)  FVBOX(CU FT)
                  12.86         4.96       40.37      333.80        96.65

FUSELAGE--      LENGTH(FT)  S WET(SQ FT)   BW(FT)   EQUIV D(FT)   SP(SQ FT)
                 113.00       4077.0       13.00      13.32        139.30

                   FW(FT)       BH(FT)   SBW(SQ FT)  FV(CU FT)
                   13.00        13.66     4077.00    99999.00

TAIL--          SHT(SQ.FT)  SHTX(SQ.FT) HT REF L(FT) SVT(SQ.FT)  SVTX(SQ.FT)  VT REF L(FT)
                  132.64       44.25        5.40       125.38      125.38       9.70

PROPULSION--      ENG L(FT)    ENG D(FT)   POD L(FT)   POD D(FT)  POD S WET    NO. PODS  INLET L(FT)
                                                                  (SQ. FT)
                    7.58         5.17       17.87        5.63      632.44        2.        0.0
```

A-3
Aircraft No. 3
JET A Fueled
130 PAX., 1500 n mi range
Mach 0.85

JP FUEL REFERENCE BASELINE DESIGN / 130 PASS / 1500 N MI MISS

T/C	T/F	AR	LAM	W/S	T/W
10.00	0.30	11.00	30.00	117.0	0.348

		POUNDS	O/O	POUNDS	O/O
DESIGN GROSS WEIGHT		108659.	100.00		
FUEL		19704.	18.13		
ZERO FUEL WEIGHT				88953.	
PAYLOAD		28600.	26.32		
OPERATING WEIGHT EMPTY				60353.	55.54
OPERATIONAL ITEMS		2875.	2.65		
STANDARD ITEMS		1351.	1.24		
EMPTY WEIGHT-MFG.				56128.	
WING		8455.	7.78		
TAIL		1278.	1.18		
BODY		10769.	9.91		
LANDING GEAR		3892.	3.58		
FLIGHT CONTROLS		1668.	1.53		
NACELLES		2283.	2.10		
PROPULSION SYSTEM		10018.	9.22		
ENGINE	7660.				
AIR INTAKE	885.				
EXHAUST	694.				
COOLING	0.				
OIL SYSTEM (LESS OIL)	11.				
ENGINE CONTROLS	43.				
ENGINE STARTING	132.				
TANKS	201.				
INSULATION	0.				
FUEL-PUMPING	393.				
INSTRUMENTS		841.	0.77		
HYDRAULICS		1019.	0.94		
ELECTRICAL		2509.	2.31		
ELECTRONICS		924.	0.85		
FURNISHINGS AND EQUIP.		9440.	8.69		
AIR CONDITIONING		2058.	1.89		
ANTI-ICING		143.	0.13		
AUXILIARY POWER UNIT		830.	0.76		
MISCELLANEOUS		0.	0.0		
DESIGN RESERVE		0.	0.0		

NO. OF PASSENGERS	130.
NO. OF CREW	7.
STRUCTURAL T/C	12.50
FUEL VOLUME REQD	393.2
WING FUEL VOLUME AVAILABLE	428.4

MISSION SUMMARY

JP FUEL REFERENCE BASELINE DESIGN / 130 PASS / 1500 N MI MISS

SEGMENT	INIT ALTITUDE (FT)	INIT MACH NO	INIT WEIGHT (LB)	SEGMT FUEL (LB)	TOTAL FUEL (LB)	SEGMT DIST (N MI)	TOTAL DIST (N MI)	SEGMT TIME (MIN)	TOTAL TIME (MIN)	EXTERN STORE TAB ID	ENGINE THRUST TAB ID	EXTERN F TANK TAB ID	AVG L/D RATIO	AVG SFC (FF/T)
TAKEOFF POWER 1	0.	0.0	108658.	205.	205.	0.	0.	14.0	14.0	0.	-81101.	0.	0.0	0.465
POWER 2	0.	0.0	108453.	188.	393.	0.	0.	1.0	15.0	0.	81401.	0.	0.0	0.298
CLIMB	0.	0.378	108265.	485.	877.	12.	12.	2.8	17.8	0.	81101.	0.	17.57	0.482
ACCEL	10000.	0.456	107780.	168.	1045.	6.	18.	1.0	18.8	0.	81101.	0.	14.83	0.544
CLIMB	10000.	0.638	107613.	3167.	4212.	254.	272.	31.3	50.1	0.	81101.	0.	14.29	0.619
CRUISE	40000.	0.850	104446.	7646.	11858.	978.	1250.	120.3	170.5	0.	-81101.	0.	16.30	0.618
DESCENT	41000.	0.850	96800.	163.	12021.	67.	1317.	8.5	179.0	0.	81301.	0.	12.58	-4.507
DECEL	10000.	0.638	96637.	43.	12064.	9.	1325.	1.5	180.4	0.	81301.	0.	14.27	131.889
DESCENT	10000.	0.456	96593.	275.	12340.	36.	1361.	8.0	188.5	0.	81301.	0.	16.84	2.372
CRUISE	41000.	0.850	96318.	1045.	13384.	139.	1500.	17.1	205.5	0.	-81101.	0.	16.13	0.618
LOITER	1500.	0.247	95273.	260.	13645.	0.	1500.	6.0	211.5	0.	-81101.	0.	17.54	0.481
RESET	0.	0.0	95013.	0.	13645.	0.	1500.	0.0	211.5	0.	0.	0.	0.0	0.0
RESET	0.	0.0	95013.	0.	13645.	-1500.	0.	-211.5	0.0	0.	0.	0.	0.0	0.0
CRUISE	41000.	0.850	95013.	3560.	17204.	0.	0.	60.0	60.0	0.	-81101.	0.	16.19	0.618
RESET	0.	0.0	91453.	0.	17204.	0.	0.	0.0	60.0	0.	0.	0.	0.0	0.0
CLIMB	0.	0.378	91453.	395.	17599.	10.	10.	2.2	62.2	0.	81101.	0.	16.30	0.482
ACCEL	10000.	0.456	91058.	60.	17659.	2.	12.	0.4	62.6	0.	81101.	0.	14.84	0.516
CLIMB	10000.	0.547	90999.	916.	18575.	48.	60.	7.2	69.8	0.	81101.	0.	13.88	0.568
CRUISE	30000.	0.650	90082.	316.	18891.	40.	100.	6.1	75.9	0.	-81101.	0.	16.59	0.571
DESCENT	30000.	0.700	89766.	167.	19058.	49.	149.	7.5	83.4	0.	81301.	0.	13.66	-14.768
DECEL	10000.	0.547	89603.	23.	19078.	4.	153.	0.6	84.2	0.	81301.	0.	14.81	4.771
DESCENT	10000.	0.456	89576.	194.	19272.	27.	180.	5.9	90.1	0.	81301.	0.	16.24	2.491
CRUISE	30000.	0.645	89386.	154.	19426.	20.	200.	3.0	93.1	0.	-81101.	0.	16.64	0.569
LOITER	1500.	0.242	89232.	247.	19673.	0.	200.	6.0	99.1	0.	-81101.	0.	17.47	0.485

TOGWT= 108657.7 FUEL A= 19704.4 FUEL B= 19672.9

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COST SUMMARY

WING		618464.00		
TAIL		103659.13		
BODY		956650.39		
LANDING GEAR		94250.61		
FLIGHT CONTROLS		114513.06		
NACELLES		259598.38		
PROPULSION				
ENGINE	10656.41			
AIR INDUCTION	76101.75			
FUEL SYSTEM	109640.69			
START SYSTEM	2087.33			
ENGINE CONTROLS	829.19			
EXH/THRUST REV.	949.64			
LUBE SYSTEM	2189.64			
TOTAL PROPULSION		202454.56		
INSTRUMENTS		129454.75		
HYDRAULICS		71042.69		
ELECTRICAL		217456.56		
ELECTRONIC RACKS		58792.23		
FURNISHING		212434.94		
AIR CONDITIONING		170197.63		
ANTI ICING		11926.72		
APU		90577.38		
SYS. INTEGRATION		79039.81		
TOTAL EMPTY MFG. COST			3390401.00	
SUSTAINING ENGINEERI	227943.75			
TECHNICAL DATA	0.0			
PROD. TOOLING MAINT.	300161.44			
MISC.	82369.63			
ENG. CHANGE ORDER	0.0			
QUALITY ASSURANCE	313187.81			
AIRFRAME WARRANTY		215754.00		
AIRFRAME FEE		679625.13		
AIRFRAME COST			5210460.00	
ENGINE WARRANTY		59509.50		
ENGINE FEE		149963.75		
ENGINE COST			1399663.00	
AVIONICS COST			220000.00	
RESEARCH AND DEVELOPMENT			676571.19	
TOTAL FLY AWAY COST				7506694.00

R AND D	
DEVELOPMENT TECHNICAL DATA	5278414.
DESIGN ENGINEERING	117298096.
DEVELOPMENT TOOLING	65516176.
DEVELOPMENT TEST ARTICLE	16988560.
FLIGHT TEST	16059858.
SPECIAL SUPPORT EQUIPMENT	1407576.
DEVELOPMENT SPARES	14251270.
ENGINE DEVELOPMENT	0.
AVIONICS DEVELOPMENT	0.
TOTAL R AND D	236799904.

DIRECT OPERATING COST-DOLLARS/N. MILE		0/0								
CREW	0.4231	25.50								
AIRFRAME LABOR AND BURDEN MAINT.	0.1266	7.75								
ENGINE LABOR AND BURDEN MAINT.	0.0844	5.09	RANGE							
AIRFRAME MATERIAL MAINT.	0.0667	4.02	N. MI	662.	802.	941.	1081.	1221.	1360.	1500.
ENGINE MATERIAL MAINT.	0.0955	5.75	DOC							
FUEL AND OIL	0.3420	20.61	C/ASM	1.5586	1.4706	1.4087	1.3628	1.3274	1.2993	1.2764
INSURANCE	0.1069	6.44								
DEPRECIATION (INCLUDING SPARES)	0.4120	24.83	TB-HR	1.8067	2.0932	2.3797	2.6662	2.9527	3.2392	3.5257
			$/TRP	1341.	1532.	1724.	1915.	2106.	2296.	2489.
TOTAL DOC $/N. MILE	1.6593	100.00								

A S S E T   P A R A M E T R I C   A N A L Y S I S

SUMMARY ID NO. 103
OCTOBER 09 1975

AIRCRAFT MODEL —CL1317-12
I.O.C. DATE —1990
DESIGN SPEED —SUBSONIC

ENGINE I.D. — 81000
SLS SCALE 1.0 = 35000
NUMBER OF ENGINES = 2.

WING QUARTER CHORD SWEEP = 30.00 DEG
WING TAPER RATIO = 0.300

1 W/S	117.0	117.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2 T/W	0.350	0.390	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3 AR	11.00	11.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4 T/C	10.00	10.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5 RADIUS N. MI	1500	1500	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6 GROSS WEIGHT	108885	108657	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7 FUEL WEIGHT	19722	19704	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8 OP. WT. EMPTY	60562	60353	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9 ZERO FUEL WT.	89162	88953	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10 THRUST/ENGINE	19163	16906	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11 ENGINE SCALE	0.548	0.540	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12 WING AREA	931.	929.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
13 WING SPAN	101.2	101.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14 H. TAIL AREA	133.	132.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
15 V. TAIL AREA	126.	125.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
16 BODY LENGTH	113.0	113.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17 WING FUEL LIMIT	1.092	1.090	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
COST DATA—MILLION DOLLARS/AIRCRAFT																
18 FLYAWAY COST	7.540	7.507	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19 AIRFRAME COST	5.904	5.887	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20 ENGINE COST	1.416	1.400	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21 AVIONICS COST	0.220	0.220	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
COST DATA—DIRECT OPERATING COST																
22 $ PER MILE	1.664	1.659	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23 CENTS/A S MILE	1.280	1.276	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FLIGHT PATH MISSION CHARACTERISTICS																
24 MISSION SYM(1)	40000	40000	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25 MISSION SYM(2)	13654	13644	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CONSTRAINT OUTPUT																
26 CEILING PWR(1)	38911	38691	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27 TAKEOFF DST(1)	5086	5146	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28 CLIMB GRAD(1)	0.1911	0.1877	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
29 TAKEOFF DST(2)	7736	7967	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30 CLIMB GRAD(2)	0.0379	0.0365	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
31 AP SPEED-KT(1)	135.0	135.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
32 CTOL LNDG D(1)	5756	5754	0	0	0	0	0	0	0	0	0	0	0	0	0	0
33 AP SPEED-KT(2)	148.5	148.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
34 CTOL LNDG D(2)	6573	6572	0	0	0	0	0	0	0	0	0	0	0	0	0	0
35 AP SPEED-KT(3)	140.7	140.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
36 CTOL LNDG D(3)	6092	6090	0	0	0	0	0	0	0	0	0	0	0	0	0	0

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LIQUID HYDROGEN---BASIC DESIGN MISSION/200 PASS/ 3000 N MI   MISS   INT. LH_2

T/C	T/R	AR	LAM	W/S	T/W
10.00	0.30	9.50	30.00	112.0	0.335

C O N F I G U R A T I O N   G E O M E T R Y

WING--	AREA(SQ.FT)	SPAN(FT)	TAPER RATIO	C/4 SWEEP (DEG)	L.E. SWEEP (DEG)	L.E.R/CHORD
	1602.3	123.38	0.300	30.000	3. 776	0.0
	CR(FT)	CT(FT)	MAC(FT)	CRE(FT)	S WET(SQ.FT)	REF L(FT)
	19.98	5.99	14.24	17.76	2638.7	14.24

WING TANK--	CRAR1(FT)	CRAR2(FT)	FTL(FT)	FVWING(CU FT)	FVBOX(CU FT)
	17.76	7.01	47.43	0.01	0.00

FUSELAGE--	LENGTH(FT)	S WET(SQ FT)	BWW(FT)	EQUIV D(FT)	SPI(SQ FT)
	173.35	9306.3	19.58	20.13	318.20
	FW(FT)	BH(FT)	SPW(SQ FT)	FVB(CU FT)	
	19.58	20.58	9306.31	5131.63	

TAIL--	SHT(SQ.FT)	SHTX(SQ.FT)	HT REF L(FT)	SVT(SQ.FT)	SVTX(SQ.FT)	VT REF L(FT)
	212.93	157.56	5.68	167.71	167.71	11.21

PROPULSION--	ENG L(FT)	ENG D(FT)	POD L(FT)	POD D(FT)	POD S WET (SQ. FT)	NO. PODS	INLET L(FT)
	6.84	4.62	16.12	5.07	1027.51	4.	0.0

A-4
Aircraft No. 4
LH_2 Internal Tank
200 PAX, 3000 n mi range
Mach 0.85

LIQUID HYDROGEN---BASIC DESIGN MISSION/200 PASS/ 3000 N MI MISS

T/C	T/R	AR	LAM	W/S	T/W
10.00	0.30	9.50	30.00	112.0	0.335

		POUNDS	O/O	POUNDS	O/O
DESIGN GROSS WEIGHT		179460.	100.00		
FUEL		20924.	11.66		
ZERO FUEL WEIGHT				158536.	
PAYLOAD		44000.	24.52		
OPERATING WEIGHT EMPTY				114536.	63.82
OPERATIONAL ITEMS		7777.	4.33		
STANDARD ITEMS		2225.	1.24		
EMPTY WEIGHT-MFG.				104533.	
WING		14888.	8.30		
TAIL		2014.	1.12		
BODY		25033.	13.95		
LANDING GEAR		7676.	4.28		
FLIGHT CONTROLS		2561.	1.43		
NACELLES		3465.	1.93		
PROPULSION SYSTEM		22405.	12.48		
ENGINE	11628.				
AIR INTAKE	1343.				
EXHAUST	1053.				
COOLING	0.				
OIL SYSTEM (LESS OIL)	11.				
ENGINE CONTROLS	65.				
ENGINE STARTING	201.				
TANKS	4166.				
INSULATION	2426.				
FUEL-PLUMBING	1512.				
INSTRUMENTS		1013.	0.56		
HYDRAULICS		1500.	0.84		
ELECTRICAL		3895.	2.17		
ELECTRONICS		1588.	0.89		
FURNISHINGS AND EQUIP.		14353.	8.00		
AIR CONDITIONING		3122.	1.74		
ANTI-ICING		187.	0.10		
AUXILIARY POWER UNIT		830.	0.46		
MISCELLANEOUS		0.	0.0		
DESIGN RESERVE		0.	0.0		

NO. OF PASSENGERS	200.
NO. OF CREW	8.
STRUCTURAL T/C	12.50
FUEL VOLUME REQD	5000.3
WING FUEL VOLUME AVAILABLE	0.0

MISSION SUMMARY

LIQUID HYDROGEN---BASIC DESIGN MISSION/200 PASS/ 3000 N MI MISS

SEGMENT	INIT ALTITUDE (FT)	INIT MACH NO	INIT WEIGHT (LB)	SEGMT FUEL (LB)	TOTAL FUEL (LB)	SEGMT DIST (N MI)	TOTAL DIST (N MI)	SEGMT TIME (MIN)	TOTAL TIME (MIN)	EXTERN STORE TAB ID	ENGINE THRUST TAB ID	EXTERN F TANK TAB ID	AVG L/D RATIO	AVG SFC (FF/T)
TAKEOFF POWER 1	0.	0.0	179460.	87.	87.	0.	0.	14.0	14.0	0.	-83101.	0.	0.0	0.124
POWER 2	0.	0.0	179373.	100.	186.	0.	0.	1.0	15.0	0.	83401.	0.	0.0	0.100
CLIMB	0.	0.378	179273.	285.	472.	14.	14.	3.1	18.1	0.	83101.	0.	15.85	0.161
ACCEL	10000.	0.456	178988.	107.	579.	7.	21.	1.2	19.3	0.	83101.	0.	13.35	0.184
CLIMB	10000.	0.638	178881.	2061.	2640.	260.	281.	31.9	51.2	0.	83101.	0.	11.99	0.213
CRUISE	35000.	0.850	176820.	13170.	15810.	2469.	2750.	303.1	354.2	0.	-83101.	0.	13.79	0.211
DESCENT	36000.	0.850	163649.	76.	15886.	51.	2801.	6.4	360.6	0.	83301.	0.	10.95	-1.716
DECEL	10000.	0.638	163573.	22.	15909.	8.	2808.	1.4	362.0	0.	83301.	0.	13.03	47.438
DESCENT	10000.	0.456	163551.	138.	16047.	32.	2840.	7.1	369.1	0.	83301.	0.	15.33	0.847
CRUISE	36000.	0.850	163412.	828.	16875.	160.	3000.	19.7	388.8	0.	-83101.	0.	13.63	0.211
LOITER	1500.	0.247	162585.	154.	17028.	0.	3000.	6.0	394.8	0.	-83101.	0.	15.59	0.147
RESET	0.	0.0	162431.	0.	17028.	0.	3000.	0.0	394.8	0.	0.	0.	0.0	0.0
RESET	0.	0.0	162431.	0.	17028.	-3000.	0.	-394.8	0.0	0.	0.	0.	0.0	0.0
CRUISE	36000.	0.850	162431.	1643.	18672.	0.	0.	40.0	40.0	0.	-83101.	0.	13.84	0.211
RESET	0.	0.0	160788.	0.	18672.	0.	0.	0.0	40.0	0.	0.	0.	0.0	0.0
CLIMB	0.	0.378	160788.	248.	18920.	12.	12.	2.7	42.7	0.	83101.	0.	15.14	0.161
ACCEL	10000.	0.456	160539.	39.	18959.	2.	14.	0.5	43.1	0.	83101.	0.	13.88	0.175
CLIMB	10000.	0.547	160500.	681.	19640.	68.	82.	10.1	53.3	0.	83101.	0.	13.11	0.193
CRUISE	30000.	0.655	159819.	87.	19727.	17.	100.	2.7	55.4	0.	-83101.	0.	15.43	0.190
DESCENT	30000.	0.700	159732.	88.	19815.	47.	146.	7.1	63.0	0.	83301.	0.	12.93	-5.277
DECEL	10000.	0.547	159644.	12.	19827.	4.	150.	0.7	63.8	0.	83301.	0.	13.93	1.706
DESCENT	10000.	0.456	159632.	100.	19927.	24.	175.	5.4	69.1	0.	83301.	0.	15.16	0.889
CRUISE	30000.	0.655	159532.	125.	20052.	25.	200.	3.8	72.9	0.	-83101.	0.	15.42	0.190
LOITER	1500.	0.246	159407.	898.	20950.	0.	200.	36.0	108.9	0.	-83101.	0.	15.66	0.147

TOGRWT= 179459.6 FUEL A= 20924.1 FUEL R= 20950.3

COST SUMMARY

WING		974538.75		
TAIL		158938.44		
BODY		2160814.00		
LANDING GEAR		183904.81		
FLIGHT CONTROLS		173523.75		
NACELLES		382040.50		
PROPULSION				
ENGINE	15594.38			
AIR INDUCTION	112060.44			
FUEL SYSTEM	713234.81			
START SYSTEM	3120.31			
ENGINE CONTROLS	1239.55			
EXH/THRUST.REV.	1389.69			
LUBE SYSTEM	2137.05			
TOTAL PROPULSION		848776.06		
INSTRUMENTS		152981.56		
HYDRAULICS		102395.00		
ELECTRICAL		329801.31		
ELECTRONIC RACKS		98400.44		
FURNISHING		316431.00		
AIR CONDITIONING		252521.31		
ANTI ICING		15153.31		
APU		89491.00		
SYS. INTEGRATION		141989.81		
TOTAL EMPTY MFG. COST			6383688.00	
SUSTAINING ENGINEERI	443379.63			
TECHNICAL DATA	0.0			
PROD. TOOLING MAINT.	583852.13			
MISC.	162203.38			
ENG. CHANGE ORDER	0.0			
QUALITY ASSURANCE	609190.19			
AIRFRAME WARRANTY		409115.56		
AIRFRAME FEE		128' 713.00		
AIRFRAME COST			9880140.00	
ENGINE WARRANTY		107985.88		
ENGINE FEE		272124.19		
ENGINE COST			2530828.00	
AVIONICS COST			500000.00	
RESEARCH AND DEVELOPMENT			1034958.94	
TOTAL FLY AWAY COST -				13954926.00

R AND D	
DEVELOPMENT TECHNICAL DATA	8206321.
DESIGN ENGINEERING	182362704.
DEVELOPMENT TOOLING	88812128.
DEVELOPMENT TEST ARTICLE	32720032.
FLIGHT TEST	21019664.
SPECIAL SUPPORT EQUIPMENT	2188352.
DEVELOPMENT SPARES	26927328.
ENGINE DEVLEOPMENT	0.
AVIONICS DEVLEOPMENT	0.
TOTAL R AND D	362235392.

DIRECT OPERATING COST-DOLLARS/N. MILE		O/O
CREW	0.3948	14.76
AIRFRAME LABOR AND BURDEN MAINT.	0.1702	6.36
ENGINE LABOR AND BURDEN MAINT.	0.0886	3.31
AIRFRAME MATERIAL MAINT.	0.0981	3.67
ENGINE MATERIAL MAINT.	0.1006	3.76
FUEL AND OIL	0.9237	34.53
INSURANCE	0.1855	6.93
DEPRECIATION (INCLUDING SPARES)	0.7139	26.68
TOTAL DOC $/N. MILE	2.6753	100.00

RANGE N. MI	884.	1236.	1589.	1942.	2295.	2647.	3000.
DOC C/ASM	1.6195	1.5055	1.4421	1.4018	1.3738	1.3533	1.3376
TB-HR	2.2501	2.9716	3.6932	4.4147	5.1363	5.8578	6.5794
$/TRP	2862.	3723.	4583.	5444.	6305.	7165.	8026.

TAKEOFF PERFORMANCE

POWER	ENCOP	OVERSPD	WEIGHT	FLAP								
CLRN	CORNI	DCDSTA	CDRN	CLRT	CDRT1	DCDSTA	CDRT	DCLSPD	CLST	CLST1	DCDSPD	CDST
CLTO	TWTO	LDTO	CLCLMB	TWCLMB	LDCLMB	CL2	TW2	LD2				
VSTALL	V1	VROT	VTO	V2	XG	XG1	XRDT	XOB	XTO	FIELDL	GRAD	
83401.	4.00	1.0C	179460.	18.00								
0.28184	0.11295	0.01063	0.12357	1.96987	0.16235	0.01063	0.17298	-0.57424	-0.29240	0.12411	0.07308	0.19719
2.06046	0.25809	12.12550	1.88959	0.25489	12.08684	1.55444	0.25489	11.12763				
112.06	130.21	130.21	140.07	146.88	3158.51	0.0	684.27	796.01	4638.78	5334.59	0.1672	
83401.	3.00	1.00	179460.	18.00								
0.28184	0.11295	C.01063	0.12357	1.91480	0.15815	0.01063	0.16878	-0.57424	-0.29240	0.12411	0.07308	0.19719
1.92117	0.19357	12.11145	1.78633	0.19157	11.94464	1.61663	0.19157	10.88595				
112.06	129.86	134.27	140.07	145.67	3137.52	429.14	694.56	1121.53	5382.75	5382.75	0.0937	

BRAKING RUN COEFFIENTS---LANDING

CLRN	DCLSPD	CLGRD	CDGRD1	DCDSPD	DCDSPA	CDGRD
0.75479	-0.76500	-0.01021	0.19626	0.06850	0.01960	0.28436

LANDING PERFORMANCE

LANDING WT	XOB,FT	XROLL,FT	XBRAKE,FT	TOT DIST,FT	FIELD L	VAPPR,KTS
162431.13	1139.08	227.82	2100.50	3467.40	5779.00	134.98
182431.13	1166.42	241.44	2349.13	3756.98	6261.63	143.05
170486.56	1150.05	233.40	2200.61	3584.06	5973.44	138.29

A S S E T   P A R A M E T R I C   A N A L Y S I S

SUMMARY ID NO. 101
NOVEMBER 11 1975

AIRCRAFT MODEL —CL1317-13
I.O.C. DATE —1990
DESIGN SPEED —SUBSONIC

ENGINE I.D. -- 83000
SLS SCALE 1.0 = 35000
NUMBER OF ENGINES = 4.

WING QUARTER CHORD SWEEP = 30.00 DEG
WING TAPER RATIO = 0.300

1 W/S	113.2	113.2	113.2	113.2	112.8	112.8	112.8	112.8	112.4	112.4	112.4	112.4	112.0	112.0	112.0	0.0
2 T/W	0.34	0.34	0.33	0.33	0.34	0.34	0.33	0.33	0.34	0.34	0.33	0.33	0.345	0.340	0.335	0.0
3 AR	9.50	9.50	9.50	9.50	9.50	9.50	9.50	9.50	9.50	9.50	9.50	9.50	9.50	9.50	9.50	0.0
4 T/C	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	0.0
5 RADIUS N. MI	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	0
6 GROSS WEIGHT	179601	179473	179167	179203	179699	179575	179272	179304	179792	179668	179366	179403	179890	179760	179459	0
7 FUEL WEIGHT	20707	20834	20862	21080	20721	20850	20899	21096	20733	20861	20912	21111	20746	20873	20924	0
8 OP. WT. EMPTY	114894	114639	114285	114122	114978	114725	114372	114208	115059	114806	114454	114292	115143	114887	114535	0
9 ZERO FUEL WT.	158894	158639	158285	158122	158978	158725	158372	158208	159059	158806	158454	158292	159143	158887	158535	0
10 THRUST/ENGINE	15490	15255	15005	14784	15499	15263	15014	14792	15507	15271	15021	14800	15515	15279	15029	0
11 ENGINE SCALE	0.443	0.436	0.429	0.422	0.443	0.436	0.429	0.423	0.443	0.436	0.429	0.423	0.443	0.437	0.429	0.0
12 WING AREA	1587.	1585.	1583.	1583.	1593.	1592.	1589.	1590.	1600.	1598.	1596.	1596.	1606.	1605.	1602.	0.
13 WING SPAN	122.8	122.7	122.6	122.6	123.0	123.0	122.9	122.9	123.3	123.2	123.1	123.1	123.5	123.5	123.4	0.0
14 H. TAIL AREA	210.	210.	209.	209.	211.	211.	210.	210.	213.	212.	212.	211.	214.	214.	213.	0.
15 V. TAIL AREA	165.	165.	165.	164.	166.	166.	166.	165.	167.	167.	167.	166.	169.	168.	168.	0.
16 BODY LENGTH	173.2	173.3	173.3	173.5	173.2	173.3	173.3	173.5	173.2	173.3	173.3	173.5	173.2	173.3	173.3	0.0
17 WING FUEL LIMIT	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0
COST DATA—MILLION DOLLARS/AIRCRAFT																
18 FLYAWAY COST	14.037	13.987	13.925	13.888	14.047	13.998	13.936	13.898	14.056	14.007	13.945	13.908	14.066	14.017	13.955	0.0
19 AIRFRAME COST	10.930	10.915	10.889	10.883	10.939	10.924	10.898	10.892	10.948	10.932	10.907	10.901	10.956	10.941	10.915	0.0
20 ENGINE COST	2.606	2.572	2.536	2.504	2.608	2.574	2.538	2.505	2.609	2.575	2.539	2.507	2.610	2.576	2.540	0.0
21 AVIONICS COST	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.0
COST DATA—DIRECT OPERATING COST																
22 $ PER MILE	2.675	2.675	2.671	2.671	2.677	2.676	2.672	2.672	2.678	2.678	2.674	2.674	2.680	2.679	2.675	0.0
23 CENTS/A S MILE	1.338	1.337	1.335	1.335	1.338	1.338	1.336	1.336	1.339	1.339	1.337	1.337	1.340	1.340	1.338	0.0
FLIGHT PATH MISSION CHARACTERISTICS																
24 MISSION SYM(1)	36000	35000	35000	34000	36000	35000	35000	34000	36000	35000	35000	34000	36000	35000	35000	0
25 MISSION SYM(2)	16783	16904	16990	17137	16794	16916	17003	17151	16805	16927	17015	17165	16816	16930	17028	0
CONSTRAINT OUTPUT																
26 CEILING PWR(1)	35997	35732	35365	35098	36013	35748	35380	35113	36029	35763	35396	35128	36045	35779	35411	0
27 TAKEOFF DST(1)	5238	5315	5396	5479	5218	5295	5375	5458	5198	5275	5355	5437	5178	5254	5334	0
28 CLIMB GRAD(1)	0.1750	0.1708	0.1667	0.1626	0.1751	0.1710	0.1669	0.1627	0.1753	0.1712	0.1670	0.1629	0.1755	0.1713	0.1672	0.0
29 TAKEOFF DST(2)	5271	5370	5466	5570	5248	5349	5442	5545	5225	5328	5403	5521	5203	5308	5382	0
30 CLIMB GRAD(2)	0.0991	0.0962	0.0933	0.0905	0.0992	0.0963	0.0935	0.0906	0.0993	0.0965	0.0936	0.0907	0.0995	0.0966	0.0937	0.0
31 AP SPEED-KT 1)	135.8	135.8	135.7	135.6	135.6	135.5	135.5	135.4	135.3	135.3	135.2	135.2	135.1	135.0	135.0	0.0
32 CTOL LNDG D(1)	5830	5825	5820	5815	5816	5811	5806	5801	5802	5797	5792	5787	5788	5783	5779	0
33 AP SPEED-KT(2)	143.9	143.9	143.8	143.8	143.6	143.6	143.6	143.5	143.4	143.3	143.3	143.2	143.1	143.1	143.0	0.0
34 CTOL LNDG D(2)	6317	6312	6309	6304	6301	6296	6293	6288	6285	6281	6277	6272	6269	6265	6261	0
35 AP SPEED-KT(3)	139.0	139.0	139.0	139.0	138.8	138.8	138.8	138.8	138.5	138.5	138.5	138.5	138.3	138.3	138.3	0.0
36 CTOL LNDG D(3)	6020	6018	6016	6015	6005	6004	6002	6000	5991	5989	5987	5986	5976	5975	5973	0

ROC LESS THAN ROCLIM. CLIMB STOPPED. MISSION CONTINUES

LIQUID HYDROGEN---BASIC DESIGN MISSION/200 PASS/ 3000 N MI MISS - *EXTERNAL TANK*

T/C	T/R	AR	LAM	W/S	T/W
10.00	0.40	9.50	30.00	110.6	0.430

C O N F I G U R A T I O N   G E O M E T R Y

WING--	AREA(SQ.FT)	SPAN(FT)	TAPER RATIO	C/4 SWEEP (DEG)	L.E. SWEEP (DEG)	L.E.R/CHORD	
	1674.7	133.45	0.400	30.000	31.901	0.0	
	CR(FT)	CT(FT)	MAC(FT)	CRE(FT)	S WET(SQ.FT)	REF L(FT)	
	20.07	8.03	14.91	18.30	3223.2	14.91	
WING TANK--	CBAR1(FT)	CBAR2(FT)	FTL(FT)	FVWING(CU FT)	FVBOX(CU FT)		
	18.30	8.90	52.10	0.01	0.00		
FUSELAGE--	LENGTH(FT)	S WET(SQ FT)	BWW(FT)	EQUIV D(FT)	SPI(SQ FT)		
	144.70	7580.0	19.58	20.13	316.20		
	BW(FT)	BH(FT)	SBW(SQ FT)	FVE(CU FT)			
	19.58	20.58	7560.00	0.0			
TAIL--	SHT(SQ.FT)	SHTX(SQ.FT)	HT REF L(FT)	SVT(SQ.FT)	SVTX(SQ.FT)	VT REF L(FT)	
	349.22	251.34	8.09	264.34	264.64	14.10	
PROPULSION--	ENG L(FT)	ENG D(FT)	POD L(FT)	POD D(FT)	POD S WET (SQ. FT)	NO. PODS	INLET L(FT)
	8.16	5.63	19.25	6.13	1483.21	4.	0.0
FUEL PODS--	VOL(CU FT)	LENGTH(FT)	SPI(SQ FT)	S WET(SQ FT)	NO PODS		
	6676.41	63.71	181.15	4006.8	2.		

A-5
Aircraft No. 5
LH_2 External Tank
200 PAX, 3000 n mi range

LIQUID HYDROGEN---BASIC DESIGN MISSION/200 PASS/ 3000 N MI   MISS

T/C	T/R	AR	LAM	W/S	T/W
10.00	0.40	9.50	30.00	110.6	0.430

		POUNDS	O/O	POUNDS	O/O
DESIGN GROSS WEIGHT		207346.	100.00		
FUEL		27229.	13.13		
ZERO FUEL WEIGHT				180117.	
PAYLOAD		44000.	21.22		
OPERATING WEIGHT EMPTY				136117.	65.65
OPERATIONAL ITEMS		7805.	3.76		
STANDARD ITEMS		2541.	1.23		
EMPTY WEIGHT-MFG.				125772.	
WING		19603.	9.45		
TAIL		3312.	1.60		
BODY		24329.	11.73		
LANDING GEAR		8203.	3.96		
FLIGHT CONTROLS		2898.	1.40		
NACELLES		5283.	2.55		
PROPULSION SYSTEM		35540.	17.14		
ENGINE	17727.				
AIR INTAKE	2048.				
EXHAUST	1606.				
COOLING	0.				
OIL SYSTEM (LESS OIL)	11.				
ENGINE CONTROLS	99.				
ENGINE STARTING	306.				
TANKS	7523.				
INSULATION	4973.				
FUEL-PLUMBING	1247.				
INSTRUMENTS		1042.	0.50		
HYDRAULICS		1690.	0.82		
ELECTRICAL		3808.	1.84		
ELECTRONICS		1554.	0.75		
FURNISHINGS AND EQUIP.		14353.	6.92		
AIR CONDITIONING		3122.	1.51		
ANTI-ICING		205.	0.10		
AUXILIARY POWER UNIT		830.	0.40		
MISCELLANEOUS		0.	0.0		
DESIGN RESERVE		0.	0.0		

NO. OF PASSENGERS	200.
NO. OF CREW	8.
STRUCTURAL T/C	12.50
FUEL VOLUME REQD	6505.5
WING FUEL VOLUME AVAILABLE	0.0

ORIGINAL PAGE IS OF POOR QUALITY

MISSION SUMMARY

LIQUID HYDROGEN---BASIC DESIGN MISSION/200 PASS/ 3000 N MI

SEGMENT	INIT ALTITUDE (FT)	INIT MACH NO	INIT WEIGHT (LB)	SEGMT FUEL (LB)	TOTAL FUEL (LB)	SEGMT DIST (N MI)	TOTAL DIST (N MI)	SEGMT TIME (MIN)	TOTAL TIME (MIN)	EXTERN STORE TAB ID	ENGINE THRUST TAB ID	EXTERN F TANK TAB ID	AVG L/D RATIO	AVG SFC (FF/T)
TAKEOFF POWER 1	0.	0.0	207346.	129.	129.	0.	0.	14.0	14.0	0.	-83101.	0.	0.0	0.124
POWER 2	0.	0.0	207217.	148.	277.	0.	0.	1.0	15.0	0.	83401.	0.	0.0	0.100
CLIMB	0.	0.378	207069.	317.	594.	10.	10.	2.3	17.3	0.	83101.	0.	13.37	0.161
ACCEL	10000.	0.456	206752.	118.	712.	5.	16.	0.9	18.2	0.	83101.	0.	10.94	0.184
CLIMB	10000.	0.636	206634.	2316.	3028.	208.	224.	25.6	43.8	0.	83101.	0.	10.35	0.212
CRUISE	36000.	0.850	204318.	17380.	20408.	2526.	2750.	310.9	354.7	0.	-83101.	0.	12.30	0.211
DESCENT	39000.	0.850	186937.	97.	20506.	46.	2796.	5.6	360.5	0.	83301.	0.	9.13	-1.635
DECEL	10000.	0.636	186840.	27.	20533.	6.	2802.	1.1	361.6	0.	83301.	0.	10.60	46.520
DESCENT	10000.	0.456	186813.	173.	20706.	27.	2829.	6.0	367.6	0.	83301.	0.	12.78	0.847
CRUISE	39000.	0.850	186640.	1136.	21842.	171.	3000.	21.0	388.7	0.	-83101.	0.	12.11	0.211
LOITER	1500.	0.241	185504.	195.	22037.	0.	3000.	6.0	394.7	0.	-83101.	0.	14.53	0.153
RESET	0.	0.0	185309.	0.	22037.	0.	3000.	0.0	394.7	0.	0.	0.	0.0	0.0
RESET	0.	0.0	185309.	0.	22037.	-3000.	0.	-394.7	0.0	0.	0.	0.	0.0	0.0
CRUISE	39000.	0.850	185309.	3198.	25235.	0.	0.	60.0	60.0	0.	-83101.	0.	12.13	0.211
RESET	0.	0.0	182111.	0.	25235.	0.	0.	0.0	60.0	0.	0.	0.	0.0	0.0
CLIMB	0.	0.378	182111.	272.	25506.	9.	9.	2.0	62.0	0.	83101.	0.	12.48	0.161
ACCEL	10000.	0.456	181839.	43.	25549.	2.	11.	0.3	62.3	0.	83101.	0.	11.29	0.175
CLIMB	10000.	0.547	181796.	714.	26263.	48.	58.	7.1	69.4	0.	83101.	0.	10.56	0.192
CRUISE	30000.	0.605	181082.	277.	26540.	41.	100.	6.9	76.3	0.	-83101.	0.	13.79	0.184
DESCENT	30000.	0.700	180805.	105.	26645.	37.	137.	5.7	82.0	0.	83301.	0.	10.41	-5.261
DECEL	10000.	0.547	180701.	15.	26659.	3.	140.	0.6	82.6	0.	83301.	0.	11.34	1.700
DESCENT	10000.	0.456	180686.	124.	26783.	20.	161.	4.5	87.1	0.	83301.	0.	12.55	0.889
CRUISE	30000.	0.605	180562.	260.	27043.	39.	200.	6.4	93.5	0.	-83101.	0.	13.77	0.184
LOITER	1500.	0.239	180303.	190.	27233.	0.	200.	6.0	99.5	0.	-83101.	0.	14.46	0.153

TOGWT= 207344.1   ULL A= 27229.1   FUEL F= 27233.0

COST SUMMARY

WING		1274539.00		
TAIL		254304.88		
BODY		2062172.00		
LANDING GEAR		145907.88		
FLIGHT CONTROLS		145557.56		
NACELLES		577160.38		
PROPULSION				
ENGINE	23516.38			
AIR INDUCTION	169304.69			
FUEL SYSTEM	1199342.00			
START SYSTEM	4735.46			
ENGINE CONTROLS	1881.14			
EXH/THRUST REV.	2095.65			
LUBE SYSTEM	2121.73			
TOTAL PROPULSION		1462995.00		
INSTRUMENTS		156409.69		
HYDRAULICS		144608.19		
ELECTRICAL		342249.56		
ELECTRONIC RACKS		95511.06		
FURNISHING		314519.38		
AIR CONDITIONING		250876.50		
ANTI ICING		16457.63		
APU		89171.75		
SYS. INTEGRATION		164037.13		
TOTAL EMPTY MFG. COST			7514463.00	
SUSTAINING ENGINEERI	530796.81			
TECHNICAL DATA	0.0			
PROD. TOOLING MAINT.	698[illegible]6.94			
MISC.	194183.56			
ENG. CHANGE ORDER	0.0			
QUALITY ASSURANCE	729298.63			
AIRFRAME WARRANTY		483382.13		
AIRFRAME FEE		1522653.00		
AIRFRAME COST			11673679.00	
ENGINE WARRANTY		151312.13		
ENGINE FEE		381306.38		
ENGINE COST			3558861.00	
AVIONICS COST			500000.00	
RESEARCH AND DEVELOPMENT			1341131.00	
TOTAL FLY AWAY COST				17073664.66

R AND D

DEVELOPMENT TECHNICAL DATA	11608136.
DESIGN ENGINEERING	257958600.
DEVELOPMENT TOOLING	100268576.
DEVELOPMENT TEST ARTICLE	38974304.
FLIGHT TEST	23594432.
SPECIAL SUPPORT EQUIPMENT	5095502.
DEVELOPMENT SPARES	33897280.
ENGINE DEVLEOPMENT	0.
AVIONICS DEVLEOPMENT	0.
TOTAL R AND D	469395712.

DIRECT OPERATING COST-DOLLARS/N. MILE		O/O
CREW	0.3947	12.14
AIRFRAME LABOR AND BURDEN MAINT.	0.1913	5.88
ENGINE LABOR AND BURDEN MAINT.	0.1067	3.26
AIRFRAME MATERIAL MAINT.	0.1162	3.57
ENGINE MATERIAL MAINT.	0.1409	4.33
FUEL AND OIL	1.1952	36.76
INSURANCE	0.2269	6.98
DEPRECIATION (INCLUDING SPARES)	0.8793	27.05
TOTAL DOC $/N. MILE	3.2510	100.00

RANGE N. MI	835.	1195.	1556.	1917.	2278.	2639.	3000.
DOC C/ASM	1.9925	1.8390	1.7567	1.7054	1.6703	1.6449	1.6255
T8-HR	2.1366	2.8768	3.6170	4.3572	5.0974	5.8377	6.5779
$/TRP	3325.	4397.	5466.	6539.	7610.	8681.	9752.

ASSET PARAMETRIC ANALYSIS

SUMMARY ID NO. 104
NOVEMBER 05 1975

AIRCRAFT MODEL —CL1317-14
I.O.C. DATE —1990
DESIGN SPEED —SUBSONIC

ENGINE I.D. — E3000
SLS SCALE 1.0 = 35000
NUMBER OF ENGINES = 4.

WING QUARTER CHORD SWEEP = 30.00 DEG
WING TAPER RATIO = 0.400

1 W/S	111.2	111.2	111.2	111.2	111.0	11.0	111.0	111.0	110.8	110.8	110.8	110.8	110.6	0.0	0.0	0.0
2 T/W	0.43	0.42	0.42	0.41	0.43	0.42	0.42	0.41	0.430	0.425	0.420	0.415	0.430	0.0	0.0	0.0
3 AR	9.50	9.50	9.50	9.50	9.50	9.50	9.50	9.50	9.50	9.50	9.50	9.50	9.50	0.0	0.0	0.0
4 T/C	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	0.0	0.0	0.0
5 RADIUS N. MI	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	0	0	0
6 GROSS WEIGHT	207122	207177	207178	207202	207196	207251	207255	207260	207271	207327	207331	207357	207346	0	0	0
7 FUEL WEIGHT	27198	27443	27665	27898	27208	27453	27677	27909	27218	27464	27688	27921	27229	0	0	0
8 OP. WT. EMPTY	135924	135734	135512	135304	135988	135797	135577	135370	136052	135862	135643	135436	136117	0	0	0
9 ZERO FUEL WT.	179924	179734	179512	179304	179988	179797	179577	179370	180052	179862	179643	179436	180117	0	0	0
10 THRUST/ENGINE	22265	22012	21753	21497	22273	22020	21761	21505	22281	22028	21769	21513	22289	0	0	0
11 ENGINE SCALE	0.636	0.629	0.622	0.614	0.636	0.629	0.622	0.614	0.637	0.629	0.622	0.615	0.637	0.0	0.0	0.0
12 WING AREA	1863.	1863.	1863.	1863.	1867.	1867.	1867.	1867.	1871.	1871.	1871.	1871.	1875.	0.	0.	0.
13 WING SPAN	133.0	133.0	133.0	133.0	133.2	133.2	133.2	133.2	133.3	133.3	133.3	133.3	133.5	0.0	0.0	0.0
14 H. TAIL AREA	346.	346.	346.	346.	347.	347.	347.	347.	348.	348.	348.	348.	349.	0.	0.	0.
15 V. TAIL AREA	262.	262.	262.	262.	263.	263.	263.	263.	264.	264.	264.	264.	265.	0.	0.	0.
16 BODY LENGTH	144.7	144.7	144.7	144.7	144.7	144.7	144.7	144.7	144.7	144.7	144.7	144.7	144.7	0.0	0.0	0.0
17 WING FUEL LIMIT	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0
COST DATA—MILLION DOLLARS/AIRCRAFT																
18 FLYAWAY COST	17.051	17.010	16.966	16.923	17.056	17.018	16.974	16.931	17.066	17.026	16.982	16.939	17.074	0.0	0.0	0.0
19 AIRFRAME COST	12.995	12.989	12.980	12.973	13.002	12.996	12.987	12.980	13.008	13.003	12.994	12.986	13.015	0.0	0.0	0.0
20 ENGINE COST	3.556	3.521	3.485	3.450	3.557	3.522	3.487	3.451	3.558	3.523	3.488	3.452	3.559	0.0	0.0	0.0
21 AVIONICS COST	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.0	0.0	0.0
COST DATA—DIRECT OPERATING COST																
22 $ PER MILE	3.248	3.253	3.259	3.263	3.249	3.254	3.260	3.265	3.250	3.255	3.261	3.266	3.251	0.0	0.0	0.0
23 CENTS/A S MILE	1.624	1.626	1.630	1.632	1.624	1.627	1.630	1.632	1.625	1.627	1.631	1.633	1.626	0.0	0.0	0.0
FLIGHT PATH MISSION CHARACTERISTICS																
24 MISSION SYM(1)	38000	37000	37000	36000	38000	37000	37000	36000	38000	37000	37000	36000	38000	0	0	0
25 MISSION SYM(2)	22010	22197	22414	22595	22018	22206	22424	22605	22027	22215	22433	22615	22036	0	0	0
CONSTRAINT OUTPUT																
26 CEILING PWR(1)	38325	38116	37798	37575	38335	38126	37808	37585	38345	38135	37817	37594	38354	0	0	0
27 TAKEOFF DST(1)	4256	4303	4350	4398	4250	4295	4342	4384	4243	4287	4334	4381	4235	0	0	0
28 CLIMB GRAD(1)	0.2430	0.2388	0.2345	0.2303	0.2431	0.2389	0.2346	0.2304	0.2432	0.2390	0.2348	0.2305	0.2433	0.0	0.0	0.0
29 TAKEOFF DST(2)	4116	4159	4215	4271	4108	4151	4207	4262	4100	4143	4198	4253	4092	0	0	0
30 CLIMB GRAD(2)	0.1458	0.1428	0.1399	0.1369	0.1459	0.1429	0.1400	0.1370	0.1460	0.1430	0.1401	0.1371	0.1461	0.0	0.0	0.0
31 AP SPEED-KT(1)	135.3	135.3	135.2	135.1	135.2	135.1	135.1	135.0	135.1	135.0	134.9	134.9	135.0	0.0	0.0	0.0

JF FUEL REFERENCE BASELINE DESIGN / 200 PASS / 3000 N MI   FISE   JET A

T/C	T/R	AR	LAM	W/S	T/W
10.00	0.30	9.75	30.00	120.4	0.282

C O N F I G U R A T I O N   G E O M E T R Y

WING--	AREA(SQ.FT)	SPAN(FT)	TAPER RATIO	C/4 SWEEP (DEG)	L.E. SWEEP (DEG)	L.E.X/CHORD	
	1663.6	127.36	0.300	30.000	32.316	0.0	
	CR(FT)	CT(FT)	MAC(FT)	CRE(FT)	S WET(SQ.FT)	REF L(FT)	
	20.10	6.03	14.33	17.92	2782.1	14.33	
WING TANK--	CBAR1(FT)	CBAR2(FT)	FTL(FT)	FVWING(CU FT)	FVBOX(CU FT)		
	17.93	7.05	49.27	797.66	277.05		
FUSELAGE--	LENGTH(FT)	S WET(SQ FT)	BWW(FT)	EQUIV D(FT)	SPI(SQ FT)		
	144.70	7580.0	19.58	20.13	318.20		
	BW(FT)	BH(FT)	SBW(SQ FT)	FVF(CU FT)			
	19.58	20.58	7580.00	99999.00			
TAIL--	SHT(SQ.FT)	SHTX(SQ.FT)	HT REF L(FT)	SVT(SQ.FT)	SVTX(SQ.FT)	VT REF L(FT)	
	296.30	203.11	7.36	221.56	221.56	12.91	
PROPULSION--	ENG L(FT)	ENG D(FT)	POD L(FT)	POD D(FT)	POD S WET (SQ. FT)	NO. PODS	INLET L(FT)
	6.89	4.65	16.25	5.07	1034.05	4.	0.0

A-6
Aircraft No. 6
JET A Fueled
200 PAX, 3000 n mi range
Mach 0.85

JP FUEL REFERENCE BASELINE DESIGN / 200 PASS / 3000 N MI [illegible]

T/C	T/R	AR	LAM	S/A	T/W
10.00	0.20	9.75	30.00	1[illegible]0.4	0.[illegible]

		POUNDS	O/O	POUNDS	O/O
DESIGN GROSS WEIGHT		216924.	100.00		
FUEL		61147.	28.18		
ZERO FUEL WEIGHT				155787.	
PAYLOAD		44000.	20.28		
OPERATING WEIGHT EMPTY				111787.	51.53
OPERATIONAL ITEMS		7778.	3.59		
STANDARD ITEMS		2003.	0.92		
EMPTY WEIGHT-MFG.				102006.	
WING		17172.	7.91		
TAIL		2812.	1.30		
BODY		24434.	11.26		
LANDING GEAR		8542.	3.9		
FLIGHT CONTROLS		3012.	1.39		
NACELLES		3520.	1.63		
PROPULSION SYSTEM		15521.	7.16		
ENGINE	11846.				
AIR INTAKE	1369.				
EXHAUST	1073.				
COOLING	0.				
OIL SYSTEM (LESS OIL)	11.				
ENGINE CONTROLS	66.				
ENGINE STARTING	204.				
TANKS	320.				
INSULATION	0.				
FUEL-PLUMBING	632.				
INSTRUMENTS		1052.	0.48		
HYDRAULICS		1755.	0.81		
ELECTRICAL		3779.	1.74		
ELECTRONICS		1542.	0.71		
FURNISHINGS AND EQUIP.		14353.	6.62		
AIR CONDITIONING		3431.	1.58		
ANTI-ICING		211.	0.10		
AUXILIARY POWER UNIT		830.	0.38		
MISCELLANEOUS		0.	0.0		
DESIGN RESERVE		0.	0.0		

NO. OF PASSENGERS	200.
NO. OF CREW	8.
STRUCTURAL T/C	12.50
FUEL VOLUME REQD	1219.6
WING FUEL VOLUME AVAILABLE	1074.9

MISSION SUMMARY

JP FUEL REFERENCE [illegible] / [illegible] PASS / 5000 NMI MISS

SEGMENT	INIT ALTITUDE (FT)	INIT MACH NO	INIT WEIGHT (LB)	SEGMT FUEL (LB)	TOTAL FUEL (LB)	SEGMT DIST (N MI)	TOTAL DIST (N MI)	SEGMT TIME (MIN)	TOTAL TIME (MIN)	EXTERN STORE TAB ID	ENGINE THROTT TAB ID	EXTERN F TANK TAB ID	AVG L/D RATIO	AVG SFC (FF/T)
TAKEOFF POWER 1	0.	0.0	216924.	332.	332.	0.	0.	14.0	14.0	0.	-81201.	0.	0.0	0.465
POWER 2	0.	0.0	216592.	304.	636.	0.	0.	1.0	15.0	0.	81401.	0.	0.0	0.298
CLIMB	0.	0.370	216288.	1065.	1701.	17.	17.	3.8	18.8	0.	81101.	0.	17.65	0.483
ACCEL	10000.	0.456	215222.	379.	2081.	9.	25.	1.4	20.2	0.	81101.	0.	15.60	0.545
CLIMB	10000.	0.635	214843.	7078.	9159.	303.	328.	37.2	57.4	0.	81101.	0.	14.07	0.623
CRUISE	34000.	0.850	207765.	37622.	46781.	2422.	2750.	297.3	354.7	0.	-81101.	0.	15.28	0.616
DESCENT	38000.	0.850	170143.	247.	47027.	59.	2809.	7.5	362.2	0.	81301.	0.	12.08	-4.680
DECEL	10000.	0.656	169896.	69.	47096.	9.	2818.	1.5	363.7	0.	81301.	0.	14.66	133.291
DESCENT	10000.	0.456	169827.	426.	47522.	34.	2852.	7.7	371.4	0.	81301.	0.	16.43	2.374
CRUISE	38000.	0.850	169401.	2086.	49608.	148.	3000.	18.2	389.6	0.	-81101.	0.	15.68	0.616
LOITER	1500.	0.247	167316.	468.	50076.	0.	3000.	6.0	395.6	0.	-81101.	0.	16.54	0.464
RESET	0.	0.0	166947.	0.	50076.	0.	3000.	0.0	395.6	0.	0.	0.	0.0	0.0
RESET	0.	0.0	166847.	0.	50076.	-3000.	0.	-395.6	0.0	0.	0.	0.	0.0	0.0
CRUISE	38000.	0.850	166847.	6683.	56759.	0.	0.	60.0	60.0	0.	-81101.	0.	15.07	0.616
RESET	0.	0.0	160165.	0.	56759.	0.	0.	0.0	60.0	0.	0.	0.	0.0	0.0
CLIMB	0.	0.378	160165.	719.	57477.	11.	11.	2.5	62.5	0.	81101.	0.	15.93	0.482
ACCEL	10000.	0.456	159446.	110.	57587.	2.	14.	0.4	63.0	0.	81101.	0.	14.57	0.516
CLIMB	10000.	0.447	159336.	1773.	59360.	58.	71.	8.6	71.6	0.	81101.	0.	13.69	0.569
CRUISE	30000.	0.670	157563.	404.	59763.	29.	100.	4.3	75.8	0.	-81101.	0.	15.79	0.571
DESCENT	30000.	0.700	157160.	261.	60024.	48.	148.	7.4	83.2	0.	81301.	0.	13.47	-14.785
DECEL	10000.	0.547	156899.	37.	60061.	4.	153.	0.8	84.0	0.	81301.	0.	14.54	4.778
DESCENT	10000.	0.456	156862.	301.	60362.	26.	178.	5.7	89.6	0.	81301.	0.	15.87	2.492
CRUISE	30000.	0.670	156561.	303.	60665.	22.	200.	3.2	92.8	0.	-81101.	0.	15.75	0.571
LOITER	1500.	0.252	156258.	442.	61106.	0.	200.	6.0	98.8	0.	-81101.	0.	16.37	0.443

TOGWT= 216923.9 FUEL A= 61136.6 FUEL R= 61106.3

COST SUMMARY

WING		1215552.66		
TAIL		[illegible]		
BODY		[illegible]		
LANDING GEAR		[illegible]		
FLIGHT CONTROLS		[illegible]		
NACELLES		[illegible]		
PROPULSION				
ENGINE	[illegible]			
AIR INDUCTION	[illegible]			
FUEL SYSTEM	[illegible]			
START SYSTEM	[illegible]			
ENGINE CONTROLS	[illegible]			
EXH/THRUST REV.	1417.60			
LUBE SYSTEM	[illegible]			
TOTAL PROPULSION		310199.69		
INSTRUMENTS		156551.19		
HYDRAULICS		119482.31		
ELECTRICAL		320281.31		
ELECTRONIC RACKS		55635.19		
FURNISHING		316685.63		
AIR CONDITIONING		277774.69		
ANTI ICING		17065.06		
APU		89533.44		
SYS. INTEGRATION		138754.44		
TOTAL EMPTY MFG. COST			6197359.00	
SUSTAINING ENGINEERI	424183.38			
TECHNICAL DATA	0.0			
PROD. TOOLING MAINT.	556574.13			
MISC.	155180.75			
ENG. CHANGE ORDER	0.0			
QUALITY ASSURANCE	582815.13			
AIRFRAME WARRANTY		395965.50		
AIRFRAME FEE		1247102.00		
AIRFRAME COST			9561118.00	
ENGINE WARRANTY		91336.38		
ENGINE FEE		230167.56		
ENGINE COST			2148231.00	
AVIONICS COST			500000.00	
RESEARCH AND DEVELOPMENT			1116165.00	
TOTAL FLY AWAY COST				13325514.00

R AND D

DEVELOPMENT TECHNICAL DATA	8060272.
DESIGN ENGINEERING	179117184.
DEVELOPMENT TOOLING	117099824.
DEVELOPMENT TEST ARTICLE	31442000.
FLIGHT TEST	27921504.
SPECIAL SUPPORT EQUIPMENT	2149405.
DEVELOPMENT SPARES	24860352.
ENGINE DEVLEOPMENT	0.
AVIONICS DEVLEOPMENT	0.
TOTAL R AND D	390657536.

DIRECT OPERATING COST-DOLLARS/N. MILE		0/0
CREW	0.3956	16.45
AIRFRAME LABOR AND BURDEN MAINT.	0.1666	6.92
ENGINE LABOR AND BURDEN MAINT.	0.1344	5.59
AIRFRAME MATERIAL MAINT.	0.0962	4.00
ENGINE MATERIAL MAINT.	0.1282	5.33
FUEL AND OIL	0.6277	26.09
INSURANCE	0.1775	7.38
DEPRECIATION (INCLUDING SPARES)	0.6794	28.24
TOTAL DOC $/N. MILE	2.4056	100.00

RANGE N. MI	924.	1270.	1616.	1962.	2308.	2654.	[illegible]
DOC C/ASM	1.4635	1.3609	1.3022	1.2642	1.2376	1.2175	[illegible]
TB-HR	2.3458	3.0537	3.7616	4.4696	5.1775	5.8855	[illegible]
$/TRP	2705.	3457.	4209.	4961.	5713.	6465.	[illegible]

ASSET PARAMETRIC ANALYSIS

SUMMARY JOB NO. 101
NOVEMBER OF 1975

AIRCRAFT MODEL --CL1217-15
T.O.C. DATE --1990
DESIGN SPEED --SUBSONIC

ENGINE I.D. -- 31000
CLS SCALE I.D = 45000
NUMBER OF ENGINES = 4.

WING QUARTER CHORD SWEEP = 30.00 DEG
WING TAPER RATIO = 0.300

1 W/S	131.0	131.0	131.0	131.0	130.8	130.8	130.6	130.8	130.6	130.6	130.6	130.6	130.4	130.4	130.4	130.4
2 T/W	0.29	0.29	0.28	[illegible]	0.29	0.29	0.28	0.28	0.29	0.29	0.28	0.28	0.288	0.286	0.284	0.282
3 AR	9.75	9.75	9.75	9.75	9.75	9.75	9.75	9.75	9.75	9.75	9.75	9.75	9.75	9.75	9.75	9.75
4 T/C	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00
5 RADIUS N. MI	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
6 GROSS WEIGHT	217032	216865	216749	216739	217066	216925	216809	216800	217145	216984	216871	216862	217209	217011	216932	216923
7 FUEL WEIGHT	60887	60899	60948	61076	60904	60918	60968	61096	60923	60937	60988	61116	60942	60960	61007	61136
8 OP. WT. EMPTY	112144	111965	111806	111663	112184	112006	111841	111704	112225	112047	111865	111745	112268	112096	111924	111787
9 ZERO FUEL WT.	156144	155965	155806	155663	156184	156006	155841	155704	156225	156047	155863	155745	156266	156096	155924	155787
10 THRUST/ENGINE	15626	15505	15389	15280	15630	15510	15393	15284	15634	15514	15397	15286	15639	15519	15402	15293
11 ENGINE SCALE	0.446	0.443	0.440	0.437	0.447	0.443	0.440	0.437	0.447	0.443	0.440	0.437	0.447	0.443	0.440	0.437
12 WING AREA	1657.	1656.	1655.	1654.	1660.	1658.	1656.	1657.	1663.	1661.	1661.	1661.	1666.	1664.	1664.	1664.
13 WING SPAN	127.1	127.0	127.0	127.0	127.2	127.2	127.1	127.1	127.3	127.3	127.2	127.2	127.4	127.4	127.4	127.4
14 H. TAIL AREA	294.	294.	294.	294.	295.	295.	295.	295.	296.	296.	295.	295.	297.	297.	296.	296.
15 V. TAIL AREA	220.	220.	220.	220.	221.	220.	220.	220.	221.	221.	221.	221.	222.	222.	222.	222.
16 BODY LENGTH	144.7	144.7	144.7	144.7	144.7	144.7	144.7	144.7	144.7	144.7	144.7	144.7	144.7	144.7	144.7	144.7
17 WING FUEL LIMIT	0.879	0.878	0.877	0.875	0.881	0.880	0.879	0.877	0.884	0.882	0.881	0.879	0.886	0.885	0.883	0.881
COST DATA—MILLION DOLLARS/AIRCRAFT																
18 FLYAWAY COST	13.388	13.360	13.333	13.310	13.393	13.365	13.338	13.315	13.398	13.370	13.343	13.320	13.404	13.375	13.349	13.326
19 AIRFRAME COST	10.700	10.686	10.673	10.663	10.705	10.691	10.678	10.668	10.709	10.695	10.683	10.673	10.714	10.700	10.687	10.677
20 ENGINE COST	2.188	2.174	2.160	2.147	2.189	2.174	2.160	2.147	2.189	2.175	2.161	2.148	2.190	2.175	2.161	2.148
21 AVIONICS COST	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500
COST DATA—DIRECT OPERATING COST																
22 $ PER MILE	2.412	2.409	2.406	2.404	2.412	2.409	2.406	2.404	2.413	2.410	2.407	2.405	2.414	2.411	2.408	2.406
23 CENTS/A S MILE	1.206	1.204	1.203	1.202	1.206	1.205	1.203	1.202	1.206	1.205	1.204	1.202	1.207	1.205	1.204	1.203
FLIGHT PATH MISSION CHARACTERISTICS																
24 MISSION SYM(1)	35000	35000	34000	34000	35000	35000	34000	34000	35000	35000	34000	34000	35000	35000	34000	34000
25 MISSION SYM(2)	49747	49823	49911	50025	49762	49827	49927	50042	49777	49853	49944	50059	49793	49871	49960	50076
CONSTRAINT OUTPUT																
26 CEILING PWR(1)	34044	33920	33799	33681	34049	33925	33804	33686	34054	33930	33809	33692	34059	33935	33815	33697
27 TAKEOFF DST(1)	7674	7744	7815	7887	7660	7730	7801	7872	7646	7715	7786	7858	7631	7701	7771	7843
28 CLIMB GRAD(1)	0.1304	0.1289	0.1273	0.1258	0.1305	0.1289	0.1274	0.1258	0.1306	0.1290	0.1274	0.1259	0.1306	0.1291	0.1275	0.1259
29 TAKEOFF DST(2)	7809	7879	7950	8022	7794	7864	7934	8006	7779	7848	7919	7991	7764	7833	7904	7975
30 CLIMB GRAD(2)	0.0689	0.0678	0.0667	0.0656	0.0689	0.0678	0.0667	0.0656	0.0690	0.0679	0.0668	0.0657	0.0690	0.0679	0.0668	0.0658
31 AP SPEED-KT(1)	135.4	135.3	135.3	135.2	135.3	135.2	135.2	135.1	135.2	135.1	135.1	135.0	135.1	135.0	135.0	134.9
32 CTOL LNDG D(1)	5792	5788	5785	5781	5786	5782	5779	5775	5780	5776	5773	5769	5774	5770	5767	5763
33 AP SPEED-KT(2)	143.2	143.2	143.2	143.1	143.1	143.1	143.0	143.0	143.0	143.0	142.9	142.9	142.9	142.9	142.8	142.8
34 CTOL LNDG D(2)	6262	6259	6256	6252	6255	6252	6249	6245	6248	6245	6242	6239	6242	6238	6235	6232
35 AP SPEED-KT(3)	150.3	150.3	150.3	150.3	150.2	150.2	150.2	150.2	150.1	150.1	150.1	150.1	149.9	149.9	149.9	149.9
36 CTOL LNDG D(3)	6706	6705	6704	6704	6698	6698	6697	6696	6691	6690	6690	6689	6684	6684	6682	6682

Appendix A

LIQUID HYDROGEN---BASIC DESIGN MISSION/400 PASS/10000 N MI   MISS   WT. LH_2

T/C	T/R	AR	LAM	W/S	T/W
10.00	0.30	10.00	30.00	117.0	0.268

C O N F I G U R A T I O N   G E O M E T R Y

WING--	AREA(SQ.FT)	SPAN(FT)	TAPER RATIO	C/4 SWEEP (DEG)	L.E. SWEEP (DEG)	L.E.R/CHORD
	5020.2	224.06	0.300	30.000	32.260	0.0
	CR(FT)	CT(FT)	MAC(FT)	CRE(FT)	S WET(SQ.FT)	REF L(FT)
	34.47	10.34	24.57	21.81	9166.4	24.57
WING TANK--	CHAR1(FT)	CHAR2(FT)	FTL(FT)	FVWING(CU FT)	FVAUX(CU FT)	
	31.81	12.09	91.58	0.05	0.00	
FUSELAGE--	LENGTH(FT)	S WET(SQ FT)	BWW(FT)	EQUIV D(FT)	SPI(SQ FT)	
	253.87	18129.6	24.66	26.51	552.00	
	BW(FT)	BH(FT)	SBW(SQ FT)	FVB(CU FT)		
	24.66	26.75	18129.55	36996.96		
TAIL--	SHT(SQ.FT)	SHTX(SQ.FT)	HT REF L(FT)	SVT(SQ.FT)	SVTX(SQ.FT)	VT REF L(FT)
	699.64	522.69	12.71	737.97	737.97	23.03

PROPULSION--	ENG L(FT)	ENG D(FT)	POD L(FT)	POD D(FT)	POD S WET (SQ. FT)	NO. PODS	INLET L(FT)
	10.54	7.45	24.86	8.13	2538.08	4.	0.0

A-7
Aircraft No. 7
LH_2 Internal Tank
400 PAX, 5000 n mi radius
Mach 0.85

LIQUID HYDROGEN---BASIC DESIGN MISSION/400 PASS/10000 N MI [illegible]

T/C	T/R	AR	LAM	W/S	T/W
10.60	0.30	10.00	30.00	117.0	0.2[illegible]

		POUNDS	O/O	POUNDS	O/O
DESIGN GROSS WEIGHT		587366.	100.00		
FUEL		150848.	25.68		
ZERO FUEL WEIGHT				436518.	
PAYLOAD		88000.	14.98		
OPERATING WEIGHT EMPTY				348518.	59.34
OPERATIONAL ITEMS		15460.	2.63		
STANDARD ITEMS		7430.	1.27		
EMPTY WEIGHT-MFG.				325627.	
WING		71380.	12.15		
TAIL		6186.	1.05		
BODY		64242.	10.94		
LANDING GEAR		33466.	5.70		
FLIGHT CONTROLS		7058.	1.20		
NACELLES		9252.	1.58		
PROPULSION SYSTEM		84217.	14.34		
ENGINE	31644.				
AIR INTAKE	3587.				
EXHAUST	2813.				
COOLING	0.				
OIL SYSTEM (LESS OIL)	11.				
ENGINE CONTROLS	174.				
ENGINE STARTING	536.				
TANKS	30962.				
INSULATION	11920.				
FUEL-PLUMBING	3171.				
INSTRUMENTS		1324.	0.23		
HYDRAULICS		4274.	0.73		
ELECTRICAL		5963.	1.02		
ELECTRONICS		2381.	0.41		
FURNISHINGS AND EQUIP.		28400.	4.84		
AIR CONDITIONING		5926.	1.01		
ANTI-ICING		443.	0.08		
AUXILIARY POWER UNIT		1116.	0.19		
MISCELLANEOUS		0.	0.0		
DESIGN RESERVE		0.	0.0		

NO. OF PASSENGERS	400.
NO. OF CREW	11.
STRUCTURAL T/C	12.50
FUEL VOLUME REQD	36049.9
WING FUEL VOLUME AVAILABLE	0.0

M I S S I O N   S U M M A R Y

LIQUID HYDROGEN——BASIC DESIGN MISSION/400 PASS/10000 N MI   MISS

SEGMENT	INIT ALTITUDE (FT)	INIT MACH NO	INIT WEIGHT (LB)	SEGMT FUEL (LB)	TOTAL FUEL (LB)	SEGMT DIST (N MI)	TOTAL DIST (N MI)	SEGMT TIME (MIN)	TOTAL TIME (MIN)	EXTERN STORE TAB ID	ENGINE THRUST TAB ID	EXTERN F TANK TAB ID	AVG L/D RATIO	AVG SFC (FF/T)
TAKEOFF POWER 1	0.	0.0	587366.	429.	429.	0.	0.	28.0	28.0	0.	-83101.	0.	0.0	0.117
POWER 2	0.	0.0	586937.	493.	921.	0.	0.	2.0	30.0	0.	83401.	0.	0.0	0.094
CLIMB	0.	0.378	586444.	894.	1815.	17.	17.	3.6	33.6	0.	83101.	0.	19.30	0.152
ACCEL	10000.	0.456	585550.	324.	2140.	9.	26.	1.8	35.4	0.	83101.	0.	16.90	0.173
CLIMB	10000.	0.638	585226.	6799.	8939.	365.	391.	44.7	80.1	0.	83101.	0.	15.33	0.201
CRUISE	34000.	0.850	578427.	57887.	66826.	4358.	4750.	534.3	614.5	0.	-83101.	0.	16.85	0.199
DESCENT	35000.	0.850	520540.	749.	67575.	114.	4864.	19.3	633.7	0.	83301.	0.	16.68	-5.977
CRUISE	36000.	0.850	519790.	1724.	69299.	136.	5000.	16.7	650.4	0.	-83101.	0.	16.66	0.199
LOITER	1500.	0.277	518066.	402.	69701.	0.	5000.	6.0	656.4	0.	-83101.	0.	18.64	0.145
RESET	0.	0.0	517665.	0.	69701.	0.	5000.	0.0	656.4	0.	0.	0.	0.0	0.0
CLIMB	0.	0.378	517665.	756.	70456.	15.	5015.	3.3	659.7	0.	83101.	0.	18.62	0.152
ACCEL	10000.	0.456	516909.	274.	70730.	8.	5022.	1.3	661.0	0.	83101.	0.	15.78	0.173
CLIMB	10000.	0.638	516635.	4737.	75467.	249.	5272.	30.7	691.7	0.	83101.	0.	14.53	0.200
CRUISE	37000.	0.850	511898.	53276.	128743.	4478.	9750.	551.1	*****	0.	-83101.	0.	16.64	0.199
DESCENT	35000.	0.850	458622.	708.	129451.	107.	9857.	18.1	*****	0.	83301.	0.	15.69	-5.807
CRUISE	39000.	0.850	457914.	1610.	131061.	143.	10000.	17.6	*****	0.	-83101.	0.	16.61	0.199
LOITER	1500.	0.259	456303.	356.	131418.	0.	10000.	6.0	*****	0.	-83101.	0.	18.53	0.145
RESET	0.	0.0	455947.	0.	131418.	0.	10000.	0.0	*****	0.	0.	0.	0.0	0.0
RESET	0.	0.0	455947.	0.	131418.	-10000.	0.	******	0.0	0.	0.	0.	0.0	0.0
CRUISE	39000.	0.850	455947.	10415.	141833.	0.	0.	115.0	115.0	0.	-83101.	0.	16.52	0.199
RESET	0.	0.0	445532.	0.	141833.	0.	0.	0.0	115.0	0.	0.	0.	0.0	0.0
CLIMB	0.	0.378	445532.	2311.	144143.	78.	78.	12.7	127.7	0.	83101.	0.	15.70	0.174
CRUISE	30000.	0.650	443222.	1389.	145532.	122.	200.	18.6	146.3	0.	-83101.	0.	17.85	0.181
DESCENT	30000.	0.700	441833.	611.	146143.	90.	290.	16.1	162.4	0.	83301.	0.	16.15	-2.140
CRUISE	30000.	0.650	441222.	1254.	147397.	110.	400.	16.8	179.2	0.	-83101.	0.	17.82	0.181
LOITER	1500.	0.254	439968.	3433.	150829.	0.	400.	60.0	239.2	0.	-83101.	0.	18.50	0.145

COST SUMMARY

WING		4426756.00		
TAIL		464994.38		
FUSY		4285586.00		
LANDING GEAR		765339.69		
FLIGHT CONTROLS		466608.63		
NACELLES		964164.38		
PROPULSION				
ENGINE	36949.56			
AIR INDUCTION	283113.30			
FUEL SYSTEM	3646535.00			
START SYSTEM	8103.43			
ENGINE CONTROLS	3219.21			
EXH/THRUST REV.	3470.08			
LUBE SYSTEM	2645.20			
TOTAL PROPULSION		4187424.00		
INSTRUMENTS		192891.94		
HYDRAULICS		280635.88		
ELECTRICAL		484346.44		
ELECTRONIC RACKS		140677.94		
FURNISHING		603323.88		
AIR CONDITIONING		460603.38		
ANTI ICING		34407.60		
APU		117726.38		
SYS. INTEGRATION		414123.44		
TOTAL EMPTY MFG. COST			19298704.00	
SUSTAINING ENGINEERI	1362116.00			
TECHNICAL DATA	0.0			
PROD. TOOLING MAINT.	1793666.00			
MISC.	498309.25			
ENG. CHANGE ORDER	0.0			
QUALITY ASSURANCE	1871508.00			
AIRFRAME WARRANTY		1241214.00		
AIRFRAME FEE		3909822.00		
AIRFRAME COST			29975296.00	
ENGINE WARRANTY		246150.94		
ENGINE FEE		620300.06		
ENGINE COST			5789471.00	
AVIONICS COST			500000.00	
RESEARCH AND DEVELOPMENT			2627556.00	
TOTAL FLY AWAY COST				38892304.00

R AND D

DEVELOPMENT TECHNICAL DATA	19143248.
DESIGN ENGINEERING	425405696.
DEVELOPMENT TOOLING	240449216.
DEVELOPMENT TEST ARTICLE	100038704.
FLIGHT TEST	54272448.
SPECIAL SUPPORT EQUIPMENT	5104867.
DEVELOPMENT SPARES	75231712.
ENGINE DEVLEOPMENT	0.
AVIONICS DEVLEOPMENT	0.
TOTAL R AND D	919644416.

DIRECT OPERATING COST-DOLLARS/N. MILE		O/O
CREW	0.3854	7.05
AIRFRAME LABOR AND BURDEN MAINT.	0.3592	6.57
ENGINE LABOR AND BURDEN MAINT.	0.1352	2.47
AIRFRAME MATERIAL MAINT.	0.2342	4.28
ENGINE MATERIAL MAINT.	0.2093	3.83
FUEL AND OIL	2.1372	39.11
INSURANCE	0.4163	7.62
DEPRECIATION (INCLUDING SPARES)	1.5885	29.07
TOTAL DOC $/N. MILE	5.4652	100.00

RANGE N. MI	6264.	6887.	7510.	8132.	8755.	9377.	10000.
DOC C/ASM	1.3913	1.3853	1.3802	1.3759	1.3723	1.3691	1.3663
TB-HR	13.7755	15.0478	16.3200	17.5922	18.8645	20.1367	21.4089
$/TRP	34864.	38162.	41460.	44758.	48056.	51354.	54652.

A S S E T   P A R A M E T R I C   A N A L Y S I S

SUMMARY ID NO. 101
SEPTEMBER 05 1975

AIRCRAFT MODEL --CL1317-A
I.O.C. DATE --1990
DESIGN SPEED --SUBSONIC

ENGINE I.D. -- 65000
SLS SCALE 1.0 = 35000
NUMBER OF ENGINES = 4.

WING QUARTER CHORD SWEEP = 30.60 DEG
WING TAPER RATIO = 0.300

1 W/S	116.0	116.0	116.0	116.0	116.5	116.5	116.5	116.5	117.0	117.0	0.0	0.0	0.0	0.0	0.0	0.0
2 T/W	0.27	0.28	0.27	0.27	0.27	0.27	0.27	0.27	0.286	0.288	0.0	0.0	0.0	0.0	0.0	0.0
3 AR	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	0.0	0.0	0.0	0.0	0.0	0.0
4 T/C	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	0.0	0.0	0.0	0.0	0.0	0.0
5 RADIUS N. MI	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	0	0	0	0	0	0
6 GROSS WEIGHT	588518	589005	588486	589077	588242	588109	587615	588230	587369	587365	0	0	0	0	0	0
7 FUEL WEIGHT	151356	151315	150792	150800	151384	151046	150534	150555	151123	150847	0	0	0	0	0	0
8 OP. WT. EMPTY	349162	349690	349694	350277	348858	349063	349080	349675	348246	348518	0	0	0	0	0	0
9 ZERO FUEL WT.	437162	437690	437694	438277	436858	437063	437080	437675	436246	436518	0	0	0	0	0	0
10 THRUST/ENGINE	39136	39463	39722	40057	39118	39403	39664	39999	39060	39353	0	0	0	0	0	0
11 ENGINE SCALE	1.118	1.128	1.135	1.144	1.118	1.126	1.133	1.143	1.116	1.124	0.0	0.0	0.0	0.0	0.0	0.0
12 WING AREA	5073.	5078.	5073.	5078.	5049.	5048.	5044.	5049.	5020.	5020.	0.	0.	0.	0.	0.	0.
13 WING SPAN	225.2	225.3	225.2	225.3	224.7	224.7	224.6	224.7	224.1	224.1	0.0	0.0	0.0	0.0	0.0	0.0
14 H. TAIL AREA	710.	711.	711.	712.	705.	705.	705.	706.	699.	700.	0.	0.	0.	0.	0.	0.
15 V. TAIL AREA	750.	751.	751.	752.	744.	744.	744.	746.	737.	738.	0.	0.	0.	0.	0.	0.
16 BODY LENGTH	254.1	254.1	253.8	253.8	254.2	254.0	253.7	253.7	254.0	253.9	0.0	0.0	0.0	0.0	0.0	0.0
17 WING FUEL LIMIT	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0	0.0	0.0	0.0
COST DATA--MILLION DOLLARS/AIRCRAFT																
18 FLYAWAY COST	38.961	39.019	39.039	39.123	38.969	38.951	38.972	39.058	38.843	38.892	0.0	0.0	0.0	0.0	0.0	0.0
19 AIRFRAME COST	32.679	32.716	32.703	32.745	32.649	32.656	32.644	32.687	32.590	32.603	0.0	0.0	0.0	0.0	0.0	0.0
20 ENGINE COST	5.782	5.803	5.836	5.878	5.760	5.796	5.829	5.871	5.753	5.789	0.0	0.0	0.0	0.0	0.0	0.0
21 AVIONICS COST	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.0	0.0	0.0	0.0	0.0	0.0
COST DATA--DIRECT OPERATING COST																
22 $ PER MILE	5.475	5.481	5.478	5.485	5.470	5.473	5.469	5.476	5.462	5.465	0.0	0.0	0.0	0.0	0.0	0.0
23 CENTS/A S MILE	1.369	1.370	1.369	1.371	1.368	1.368	1.367	1.369	1.365	1.366	0.0	0.0	0.0	0.0	0.0	0.0
FLIGHT PATH MISSION CHARACTERISTICS																
24 MISSION SVM(1)	34000	34000	34000	35000	34000	34000	34000	35000	34000	34000	0	0	0	0	0	0
25 MISSION SVM(2)	131978	131861	131326	131282	131801	131623	131099	131062	131627	131417	0	0	0	0	0	0
CONSTRAINT OUTPUT																
26 CEILING PWR(1)	33774	33983	34128	34276	33763	33970	34115	34265	33751	33958	0	0	0	0	0	0
27 TAKEOFF DST(1)	6909	6848	6789	6730	6943	6881	6822	6762	6976	6914	0	0	0	0	0	0
28 CLIMB GRAD(1)	0.1216	0.1232	0.1248	0.1264	0.1215	0.1231	0.1246	0.1262	0.1213	0.1229	0.0	0.0	0.0	0.0	0.0	0.0
29 TAKEOFF DST(2)	6874	6816	6760	6704	6908	6850	6793	6736	6941	6883	0	0	0	0	0	0
30 CLIMB GRAD(2)	0.0648	0.0660	0.0671	0.0682	0.0647	0.0658	0.0669	0.0681	0.0646	0.0657	0.0	0.0	0.0	0.0	0.0	0.0
31 AP SPEED-KT(1)	134.4	134.4	134.5	134.5	134.7	134.7	134.8	134.8	135.0	135.0	0.0	0.0	0.0	0.0	0.0	0.0
32 CTOL LNDG D(1)	5853	5855	5858	5859	5871	5873	5875	5876	5888	5890	0	0	0	0	0	0
33 AP SPEED-KT(2)	137.0	137.0	137.0	137.0	137.3	137.3	137.3	137.3	137.6	137.6	0.0	0.0	0.0	0.0	0.0	0.0
34 CTOL LNDG D(2)	6008	6010	6013	6013	6027	6028	6031	6032	6045	6047	0	0	0	0	0	0
35 AP SPEED-KT(3)	139.6	139.6	139.6	139.6	139.9	139.9	139.9	139.9	140.2	140.2	0.0	0.0	0.0	0.0	0.0	0.0
36 CTOL LNDG D(3)	6168	6168	6169	6177	6187	6187	6168	6188	6205	6206	0	0	0	0	0	0

JP FUEL REFERENCE BASELINE DESIGN / 400 PASS /10000 N MI   MT?S   JET A

T/C	T/R	AR	LAM	W/S	T/W
10.00	0.30	11.00	30.00	129.3	0.[illegible]

C O N F I G U R A T I O N   G E O M E T R Y

WING--

AREA(SQ.FT)	SPAN(FT)	TAPER RATIO	C/4 SWEEP (DEG)	L.E. SWEEP (DEG)	L.E.R/CHORD
7125.0	279.96	0.300	30.000	32.059	0.0

CR(FT)	CT(FT)	MAC(FT)	CKE(FT)	S WET(SQ.FT)	REF L(FT)
39.15	11.75	27.91	37.24	13982.9	27.91

WING TANK--

CFAR1(FT)	CFAR2(FT)	CTL(FT)	FVWING(CU FT)	FVBDY(CU FT)
37.24	13.73	120.04	8178.20	1194.63

FUSELAGE--

LENGTH(FT)	S WET(SQ FT)	BWW(FT)	EQUIV D(FT)	SPT(SQ FT)
225.00	14435.0	19.58	19.56	301.10

HW(FT)	BH(FT)	SBW(SQ FT)	FVF(CU FT)
19.58	19.58	14435.00	99449.00

TAIL--

SHT(SQ.FT)	SHTX(SQ.FT)	HT REF L(FT)	SVT(SQ.FT)	SVTX(SQ.FT)	VT REF L(FT)
757.05	611.96	13.01	762.62	762.62	23.92

PROPULSION--

ENG L(FT)	ENG D(FT)	POD L(FT)	POD D(FT)	POD S WET (SQ. FT)	NO. PODS	INLET L(FT)
11.70	8.37	27.59	9.12	3163.69	4.	0.0

A-8
Aircraft No. 8
JET A Fueled
400 PAX, 5000 n mi radius
Mach 0.85

JP FUEL REFERENCE BASELINE DESIGN / 400 PASS /10000 N MI   MISS

T/C	T/W	AR	LAM	W/S	T/W
10.00	0.30	11.00	30.00	139.[illegible]	0.200

		POUNDS	O/O	POUNDS	O/O
DESIGN GROSS WEIGHT		992517.	100.00		
FUEL		523996.	52.79		
ZERO FUEL WEIGHT				468521.	
PAYLOAD		88000.	8.87		
OPERATING WEIGHT EMPTY				380521.	38.34
OPERATIONAL ITEMS		15499.	1.56		
STANDARD ITEMS		13875.	1.40		
EMPTY WEIGHT-MFG.				351146.	
WING		106437.	10.72		
TAIL		7013.	0.71		
BODY		54378.	5.48		
LANDING GEAR		53142.	5.35		
FLIGHT CONTROLS		11054.	1.11		
NACELLES		11[illegible].	1.19		
PROPULSION SYSTEM		5300[illegible].	5.34		
ENGINE	39788.				
AIR INTAKE	4597.				
EXHAUST	3605.				
COOLING	0.				
OIL SYSTEM (LESS OIL)	11.				
ENGINE CONTROLS	223.				
ENGINE STARTING	686.				
TANKS	2222.				
INSULATION	0.				
FUEL-PLUMBING	1879.				
INSTRUMENTS		1532.	0.15		
HYDRAULICS		7029.	0.71		
ELECTRICAL		6085.	0.61		
ELECTRONICS		2420.	0.24		
FURNISHINGS AND EQUIP.		28400.	2.86		
AIR CONDITIONING		6982.	0.70		
ANTI-ICING		696.	0.07		
AUXILIARY POWER UNIT		1116.	0.11		
MISCELLANEOUS		0.	0.0		
DESIGN RESERVE		0.	0.0		
NO. OF PASSENGERS		400.			
NO. OF CREW		11.			
STRUCTURAL T/C		12.50			
FUEL VOLUME REQD		10454.8			
WING FUEL VOLUME AVAILABLE		9372.8			

M I S S I O N   S U M M A R Y

JP FUEL REFERENCE BASELINE DESIGN / ACC PASS /10000 N MI   MISS

SEGMENT	INIT ALTITUDE (FT)	INIT MACH NO	INIT WEIGHT (LB)	SEGMT FUEL (LB)	TOTAL FUEL (LB)	SEGMT DIST (N MI)	TOTAL DIST (N MI)	SEGMT TIME (MIN)	TOTAL TIME (MIN)	EXTERN STORE TAB ID	ENGINE THRUST TAB ID	EXTERN F TANK TAB ID	AVG L/D RATIO	AVG SFC (FF/T)
TAKEOFF POWER 1	0.	0.0	992517.	2030.	2030.	0.	0.	28.0	28.0	0.	-81101.	0.	0.0	0.438
POWER 2	0.	0.0	990487.	1861.	3891.	0.	0.	2.0	30.0	0.	81401.	0.	0.0	0.281
CLIMB	0.	0.378	988626.	4798.	8689.	25.	25.	5.5	35.5	0.	81101.	0.	23.10	0.455
ACCEL	10000.	0.456	983828.	1644.	10333.	12.	37.	2.0	37.6	0.	81101.	0.	21.73	0.513
CLIMB	10000.	0.638	982184.	24894.	35226.	327.	364.	40.2	77.8	0.	81101.	0.	19.33	0.509
CRUISE	33000.	0.850	957290.	217250.	252476.	4386.	4750.	537.0	614.8	0.	-81101.	0.	20.26	0.583
DESCENT	35000.	0.850	740040.	3177.	255654.	137.	4887.	23.1	637.9	0.	81301.	0.	19.92	-16.090
CRUISE	38000.	0.850	736862.	4903.	260557.	113.	5000.	13.9	651.8	0.	-81101.	0.	20.09	0.581
LOITER	1500.	0.284	731960.	1531.	262088.	0.	5000.	6.0	657.8	0.	-81101.	0.	21.71	0.455
RESET	0.	0.0	730429.	0.	262088.	0.	5000.	0.0	657.8	0.	0.	0.	0.0	0.0
CLIMB	0.	0.378	730429.	3119.	265207.	16.	5016.	3.6	661.4	0.	81101.	0.	22.07	0.456
ACCEL	10000.	0.456	727309.	1071.	266278.	6.	5024.	1.3	662.7	0.	81101.	0.	18.94	0.513
CLIMB	10000.	0.638	726239.	19267.	285545.	301.	5325.	37.2	699.9	0.	81101.	0.	17.80	0.384
CRUISE	39000.	0.850	706971.	166276.	451821.	4425.	9750.	544.6	*****	0.	-81101.	0.	19.73	[illegible]
DESCENT	35000.	0.850	540695.	2757.	454578.	116.	9866.	19.8	*****	0.	81301.	0.	17.03	-15.707
CRUISE	44000.	0.850	537938.	4405.	458983.	134.	10000.	16.5	*****	0.	-81101.	0.	19.54	[illegible]
LOITER	1500.	0.240	533533.	1164.	460147.	0.	10000.	6.0	*****	0.	-81101.	0.	21.43	[illegible]
RESET	0.	0.0	532369.	0.	460147.	0.	10000.	0.0	*****	0.	0.	0.	0.0	0.0
RESET	0.	0.0	532369.	0.	460147.	-10000.	0.	******	0.0	0.	0.	0.	0.0	0.0
CRUISE	44000.	0.850	532369.	36114.	496261.	0.	0.	140.0	140.0	0.	-81101.	0.	19.39	[illegible]
RESET	0.	0.0	496255.	0.	496261.	0.	0.	0.0	140.0	0.	0.	0.	0.0	0.0
CLIMB	0.	0.378	496255.	6664.	502926.	58.	58.	9.6	149.6	0.	81101.	0.	16.23	[illegible]
CRUISE	30000.	0.590	489591.	4919.	507845.	142.	200.	24.2	173.8	0.	-81101.	0.	20.87	[illegible]
DESCENT	30000.	0.700	484671.	2273.	510117.	93.	293.	16.8	190.6	0.	81301.	0.	16.70	[illegible]
CRUISE	30000.	0.585	482399.	3668.	513785.	107.	400.	18.4	209.0	0.	-81101.	0.	20.89	[illegible]
LOITER	[illegible]	0.227	478730.	10573.	524358.	0.	400.	60.0	269.0	0.	-81101.	0.	21.36	[illegible]

ORIGINAL PAGE IS OF POOR QUALITY

COST SUMMARY

WING		7126194.00		
TAIL		525466.06		
BODY		4440094.00		
LANDING GEAR		1247071.00		
FLIGHT CONTROLS		729862.50		
NACELLES		1231147.00		
PROPULSION				
ENGINE	49686.31			
AIR INDUCTION	361535.00			
FUEL SYSTEM	706728.06			
START SYSTEM	10367.02			
ENGINE CONTROLS	4118.45			
EXH/THRUST REV.	4427.78			
LUBE SYSTEM	2039.29			
TOTAL PROPULSION		1138900.00		
INSTRUMENTS		222690.06		
HYDRAULICS		460357.25		
ELECTRICAL		492865.00		
ELECTRONIC PACKS		142506.75		
FURNISHING		601854.69		
AIR CONDITIONING		541269.00		
ANTI ICING		53978.34		
APU		117556.63		
SYS. INTEGRATION		444130.31		
TOTAL EMPTY MFG. COST			19516400.00	
SUSTAINING ENGINEERI	1336214.00			
TECHNICAL DATA	0.0			
PROD. TOOLING MAINT.	1759556.00			
MISC.	488833.00			
ENG. CHANGE ORDER	0.0			
QUALITY ASSURANCE	1835917.00			
AIRFRAME WARRANTY		1246844.00		
AIRFRAME FEE		3927558.00		
AIRFRAME COST			30111280.00	
ENGINE WARRANTY		250173.36		
ENGINE FEE		630436.62		
ENGINE COST			5884078.00	
AVIONICS COST			500000.00	
RESEARCH AND DEVELOPMENT			3490829.00	
TOTAL FLY AWAY COST				39986160.00

R AND D	
DEVELOPMENT TECHNICAL DATA	22709904.
DESIGN ENGINEERING	504664832.
DEVELOPMENT TOOLING	420066048.
DEVELOPMENT TEST ARTICLE	99036192.
FLIGHT TEST	94250336.
SPECIAL SUPPORT EQUIPMENT	6055977.
DEVELOPMENT SPARES	75007344.
ENGINE DEVLEOPMENT	0.
AVIONICS DEVLEOPMENT	0.
TOTAL R AND D	1221789952.

DIRECT OPERATING COST-DOLLARS/N. MILE		O/O
CREW	0.3860	7.21
AIRFRAME LABOR AND BURDEN MAINT.	0.3766	7.03
ENGINE LABOR AND BURDEN MAINT.	0.2379	4.44
AIRFRAME MATERIAL MAINT.	0.2416	4.51
ENGINE MATERIAL MAINT.	0.3204	5.98
FUEL AND OIL	1.7283	32.28
INSURANCE	0.4288	8.01
DEPRECIATION (INCLUDING SPARES)	1.6353	30.54
TOTAL DOC $/N. MILE	5.3549	100.00

RANGE N. MI	6240.	6867.	7493.	8120.	8747.	9373.	10000.
DOC C/ASM	1.3521	1.3488	1.3461	1.3438	1.3419	1.3402	1.3387
TB-HR	13.7740	15.0527	16.3313	17.6100	18.8886	20.1673	21.4459
$/TRP	33748.	37048.	40349.	43649.	46949.	50249.	53549.

A S S E T   P A R A M E T R I C   A N A L Y S I S

SUMMARY ID NO. 200
SEPTEMBER 11 1975

AIRCRAFT MODEL —CL317-9
I.O.C. DATE —1990
DESIGN SPEED —SUBSONIC

ENGINE I.D. -- F1000
SLS SCALE 1.0 = 35000
NUMBER OF ENGINES = 4.

WING QUARTER CHORD SWEEP = 30.00 DEG
WING TAPER RATIO = 0.300

1 W/S	139.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2 T/W	0.20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3 AR	11.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4 T/C	10.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
* RADIUS N. MI	10000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6 GROSS WEIGHT	992516	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7 FUEL WEIGHT	523996	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8 OP. WT. EMPTY	380520	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9 ZERO FUEL WT.	468520	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10 THRUST/ENGINE	49625	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11 ENGINE SCALE	1.418	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12 WING AREA	7125.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
13 WING SPAN	280.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14 H. TAIL AREA	757.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
15 V. TAIL AREA	763.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
16 BODY LENGTH	225.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17 WING FUEL LIMIT	0.897	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
COST DATA—MILLION DOLLARS/AIRCRAFT																
18 FLYAWAY COST	39.986	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19 AIRFRAME COST	33.602	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20 ENGINE COST	5.884	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21 AVIONICS COST	0.500	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
COST DATA—DIRECT OPERATING COST																
22 $ PER MILE	5.355	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23 CENTS/A S MILE	1.339	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FLIGHT PATH MISSION CHARACTERISTICS																
24 MISSION SYM(1)	33000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25 MISSION SYM(2)	460147	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CONSTRAINT OUTPUT																
26 CEILING PWR(1)	31424	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27 TAKEOFF DST(1)	11973	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28 CLIMB GRAD(1)	0.0759	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
29 TAKEOFF DST(2)	11686	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30 CLIMB GRAD(2)	0.0342	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
31 AP SPEED-KT(1)	135.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
32 CTOL LNDG D(1)	5867	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
33 AP SPEED-KT(2)	136.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
34 CTOL LNDG D(2)	5979	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
35 AP SPEED-KT(3)	153.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
36 CTOL LNDG D(3)	7056	0		0	0	0	0	0	0	0	0	0	0	0	0	0

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