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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	1,640	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. Illustration 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 deriviation 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 FRI & V_j duct matched @ SLS)	254.5 m/s	(835 ft/sec)
II. Fan Design				
Stages		1		1
Airflow - Wa $\sqrt{\theta_{T_2}}/\delta_{P_2}$	212 kg/sec	(468 lb/sec)	212 kg/sec	(468 lb/sec)
Pressure Ratio		1.51		1.51
Polytropic Efficiency		91%		91%
Diameter	1.26	(49.6 in.)	1.26 m	(49.6 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		0.985		0.986
B. Fan C_v		0.985		0.986
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	1.58 m	(62 in.)		
Overall Length	4.22 m	(166 in.)		
Inlet Highlight Diameter	1.29 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

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

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

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

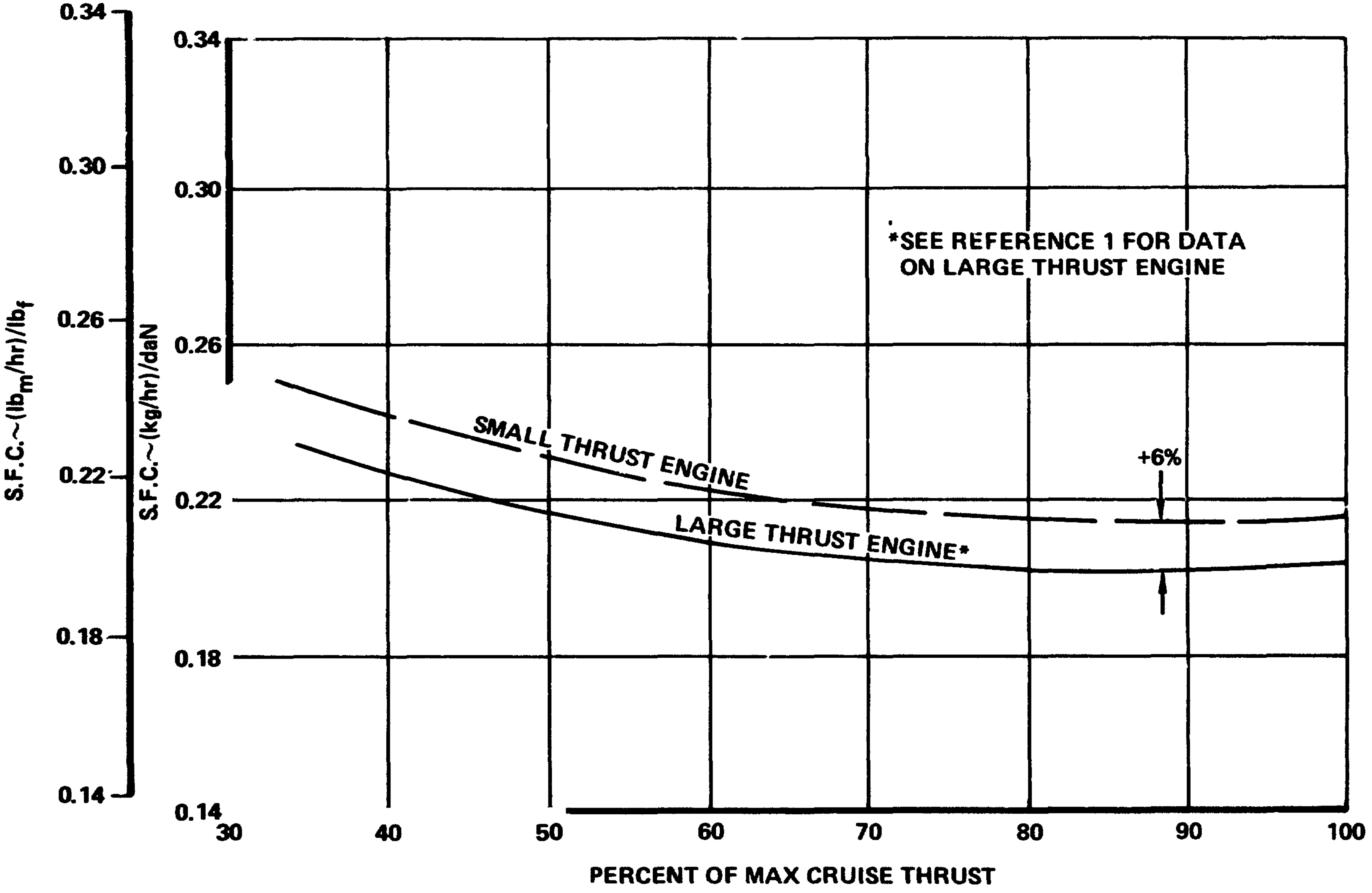


Figure 2. Installed Cruise SFC Versus Percent Maximum Rated Thrust 10,668 m (35,000 ft), Mach 0.85, Standard Day (LH_2 Fueled Engines)

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

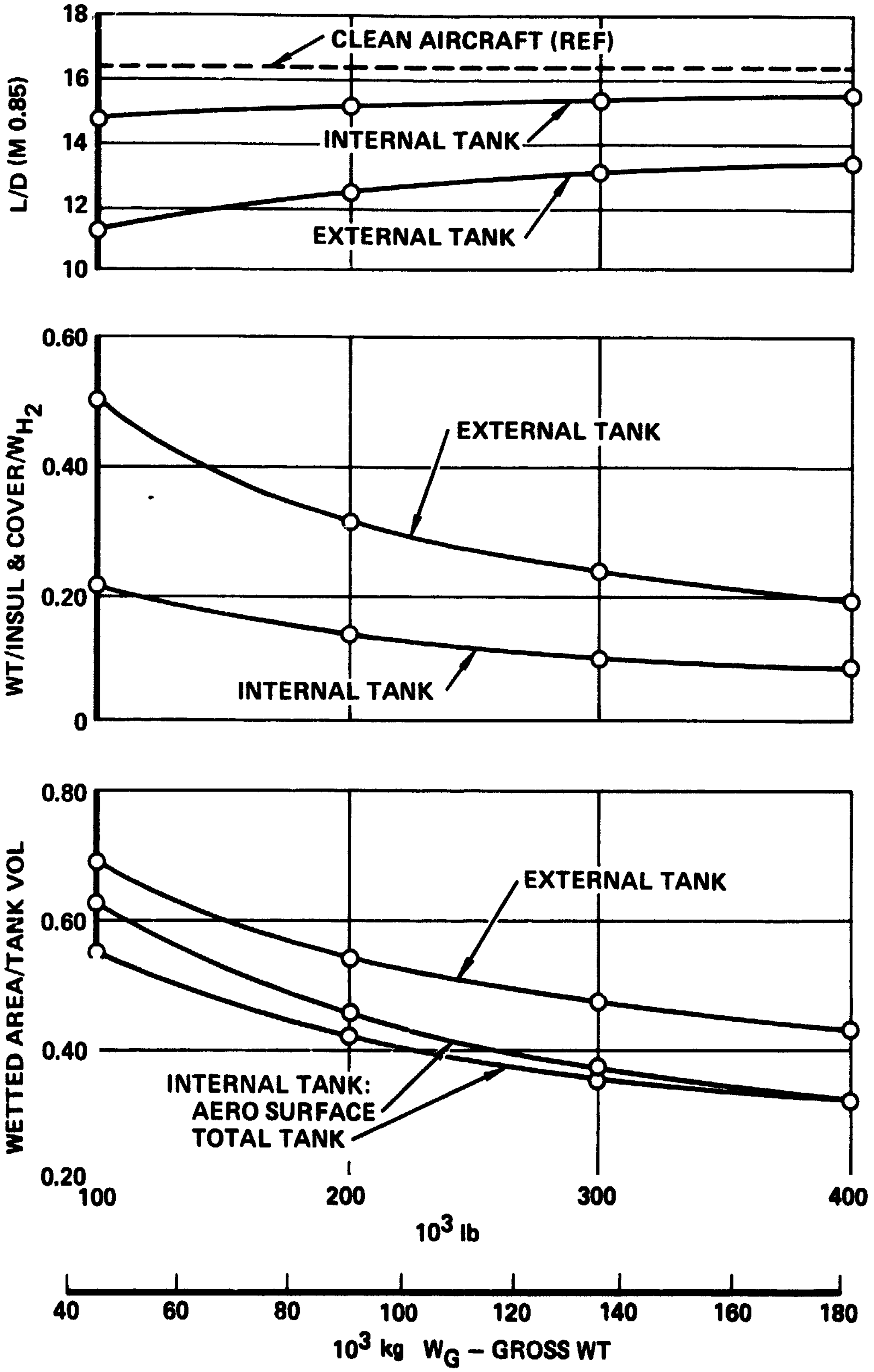


Figure 3. Results of Analysis of Hydrogen Tanks

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.

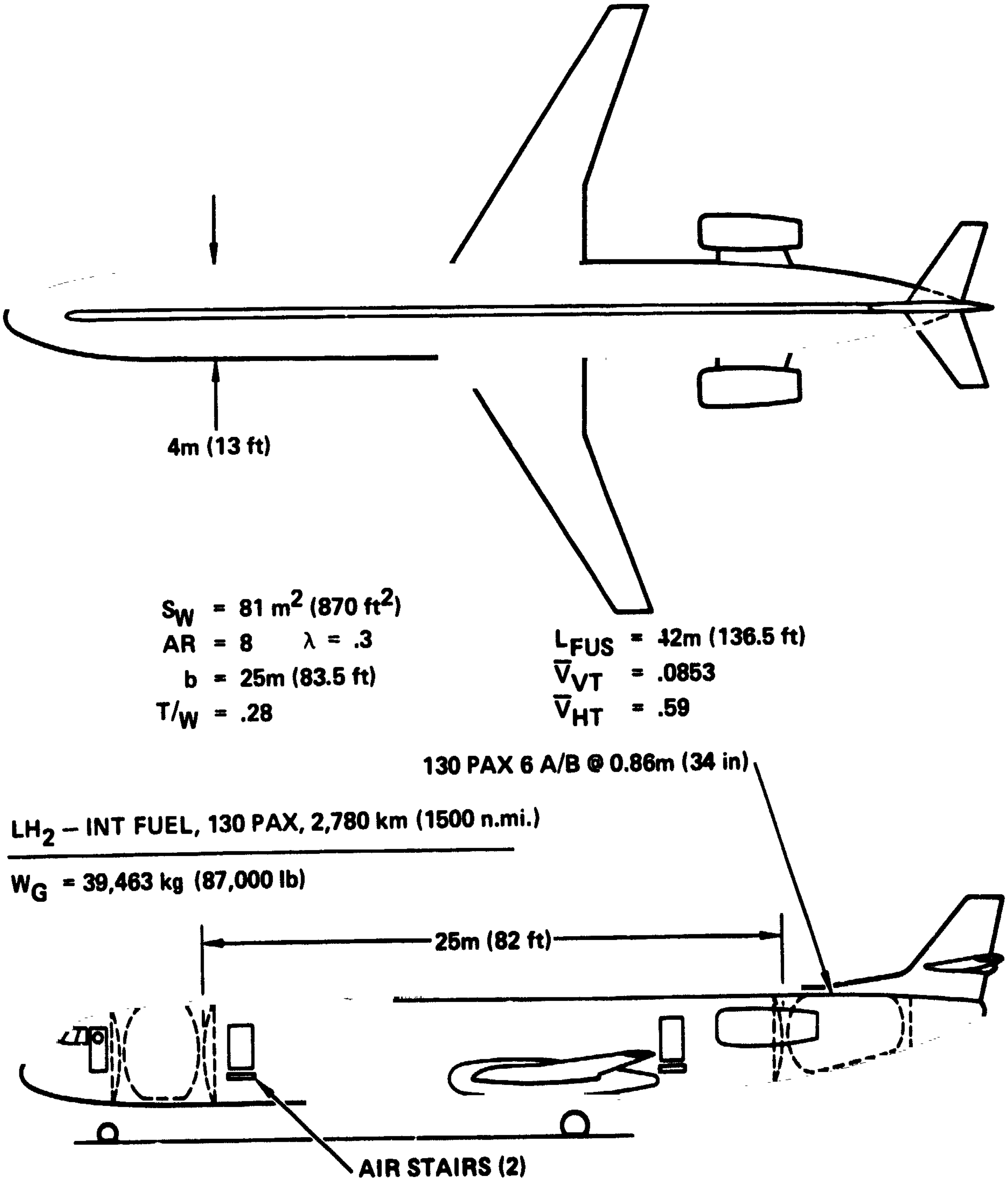
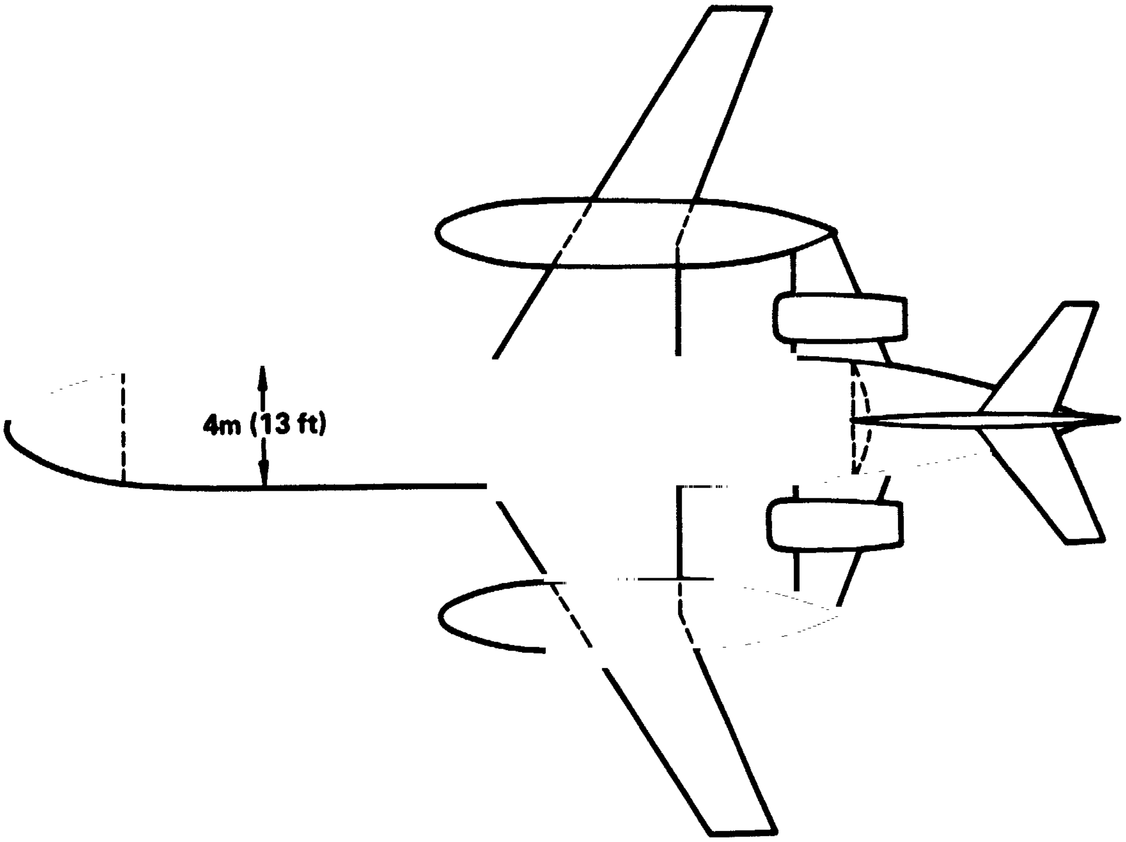


Figure 4. Candidate Configuration - Internal Tanks, Aft Mounted Engines



S_W = 85 m^2 (910 ft^2)

AR = 8 λ = .4

b = 26m (85.5 ft)

T/W - .32 $W/_S$ = 488 kg/m^2 (100 lb/ft^2)

L_{FUS} = 34m (113 ft)

$\overline{V}_{HT}$ = .59

$\overline{V}_{VT}$ = .0858

LH_2 – EXT FUEL, 130 PAX, 2,780 km (1500 n.mi.)

W_G = 48,776 kg (91,000 lb)

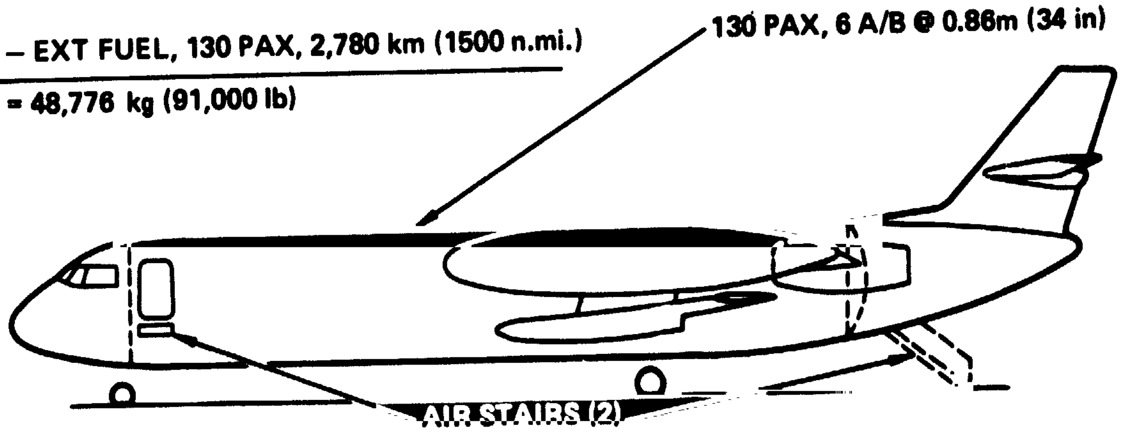


Figure 5. Candidate Configuration - External Tanks, Aft Mounted Engines

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:

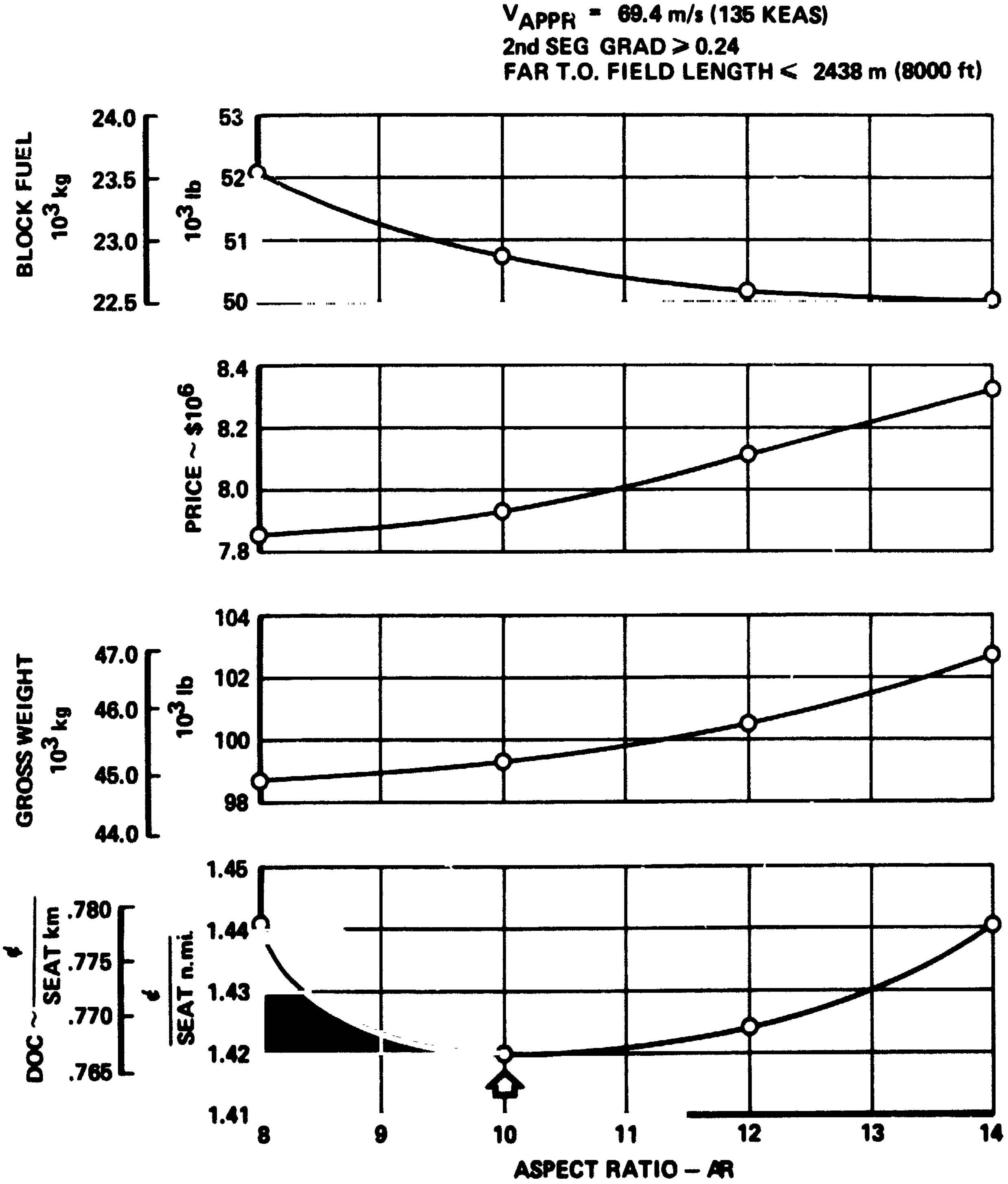


Figure 6. Aspect Ratio Selection - Aircraft No. 1

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., Rohacell 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)	29.11 (95.5)	6.28 (20.6)	3.66 (12.0)
ROOT CHORD M (IN)	4.49 (176.8)	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)	3.19 (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

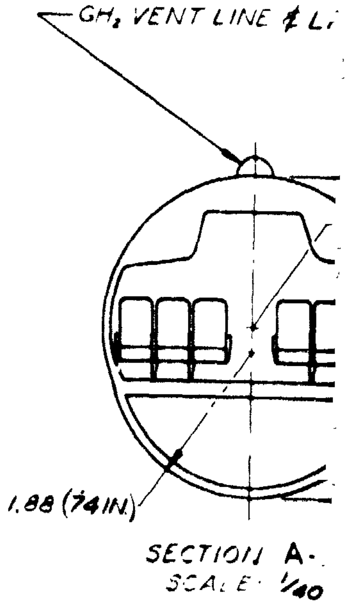
DESIGN GROSS WT. - 44,563 KG. (98,257 LB.)

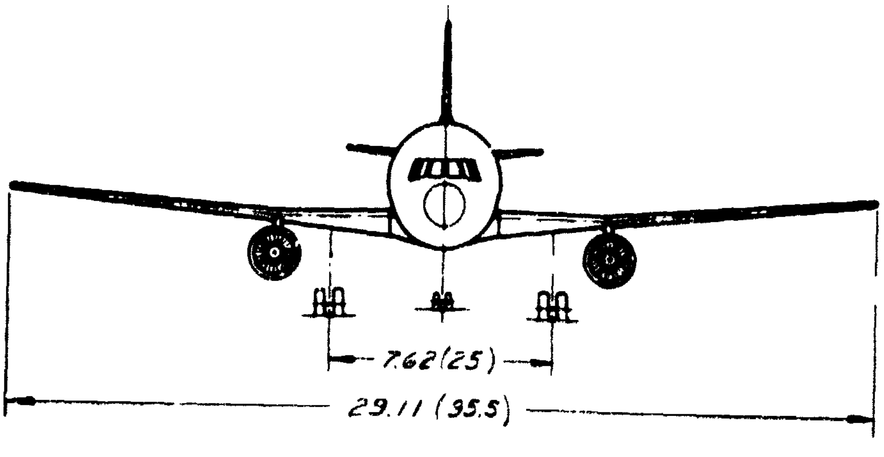
POWER PLANT - (2) TURBOFANS
INSTALLED THRUST EA.) - 75,383 N. (16,943 LB)

PASSENGERS - 130

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

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





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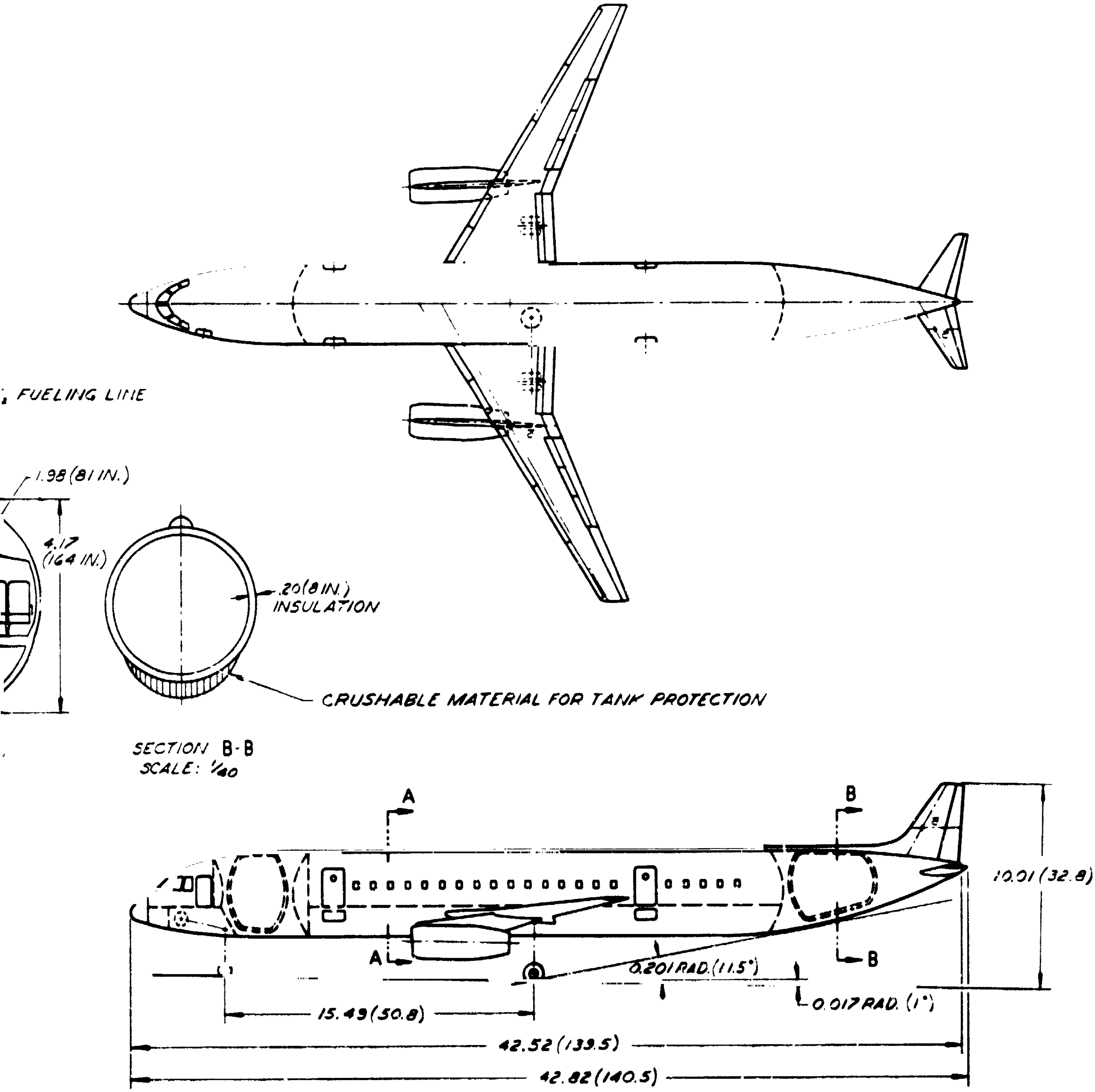

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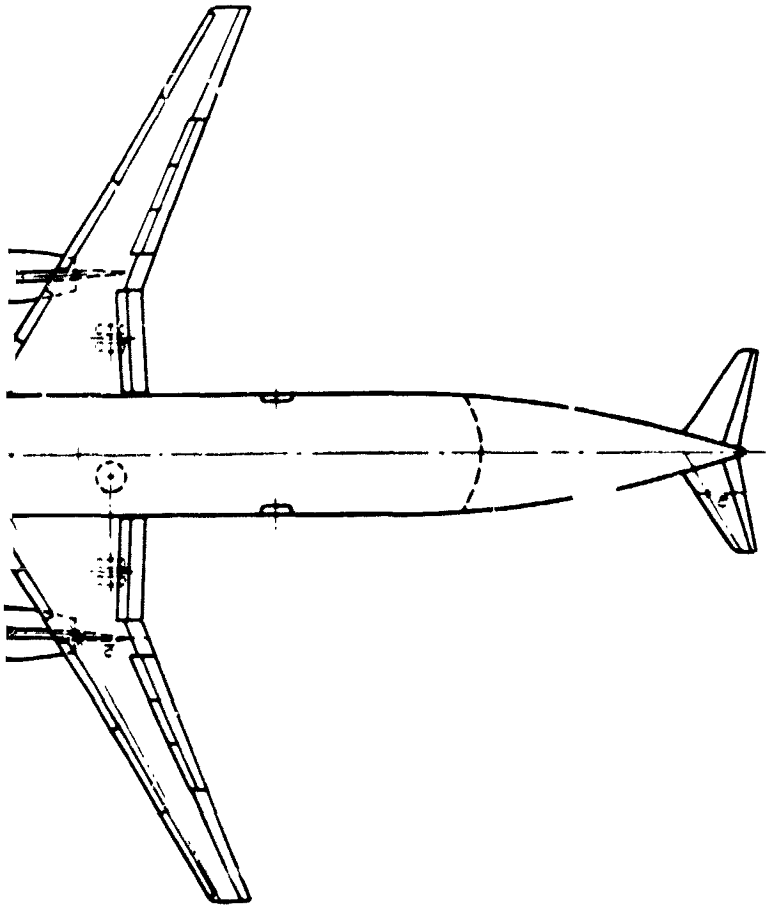
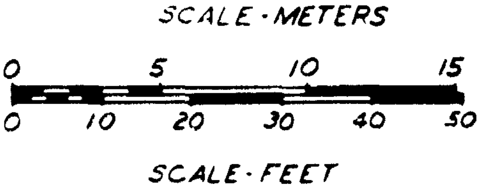
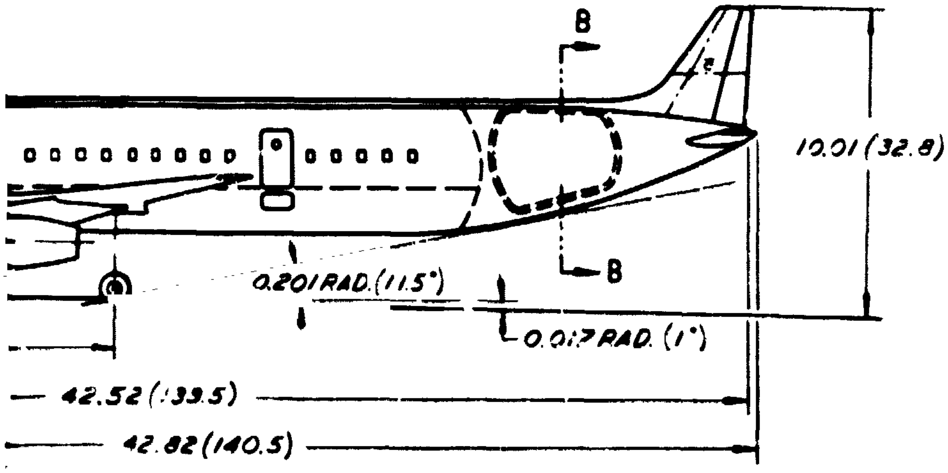




ATERIAL FOR TANK PROTECTION



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NOTE:

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

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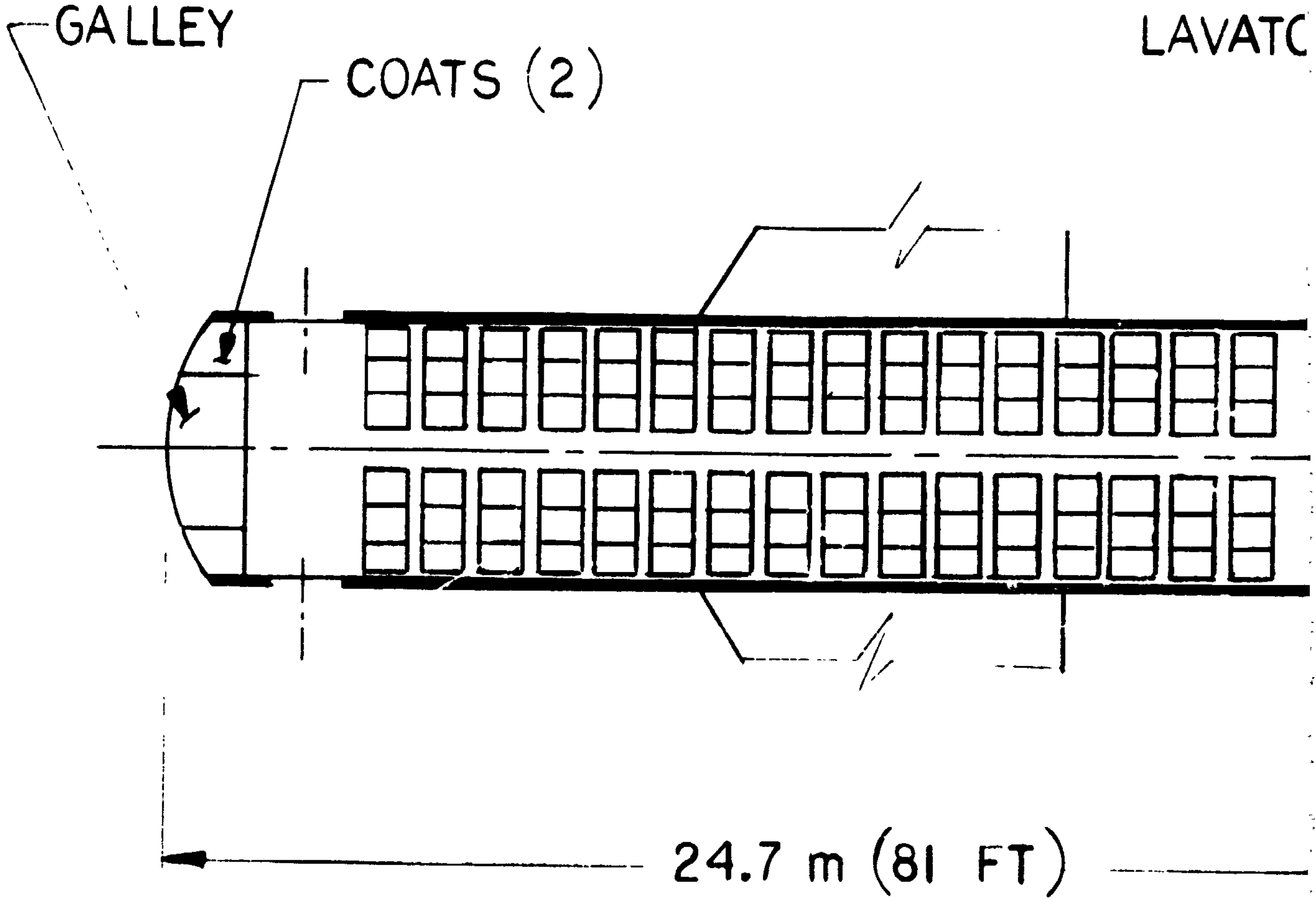


130 PAX, 6 A/B, .86 m (34 IN) SPACING

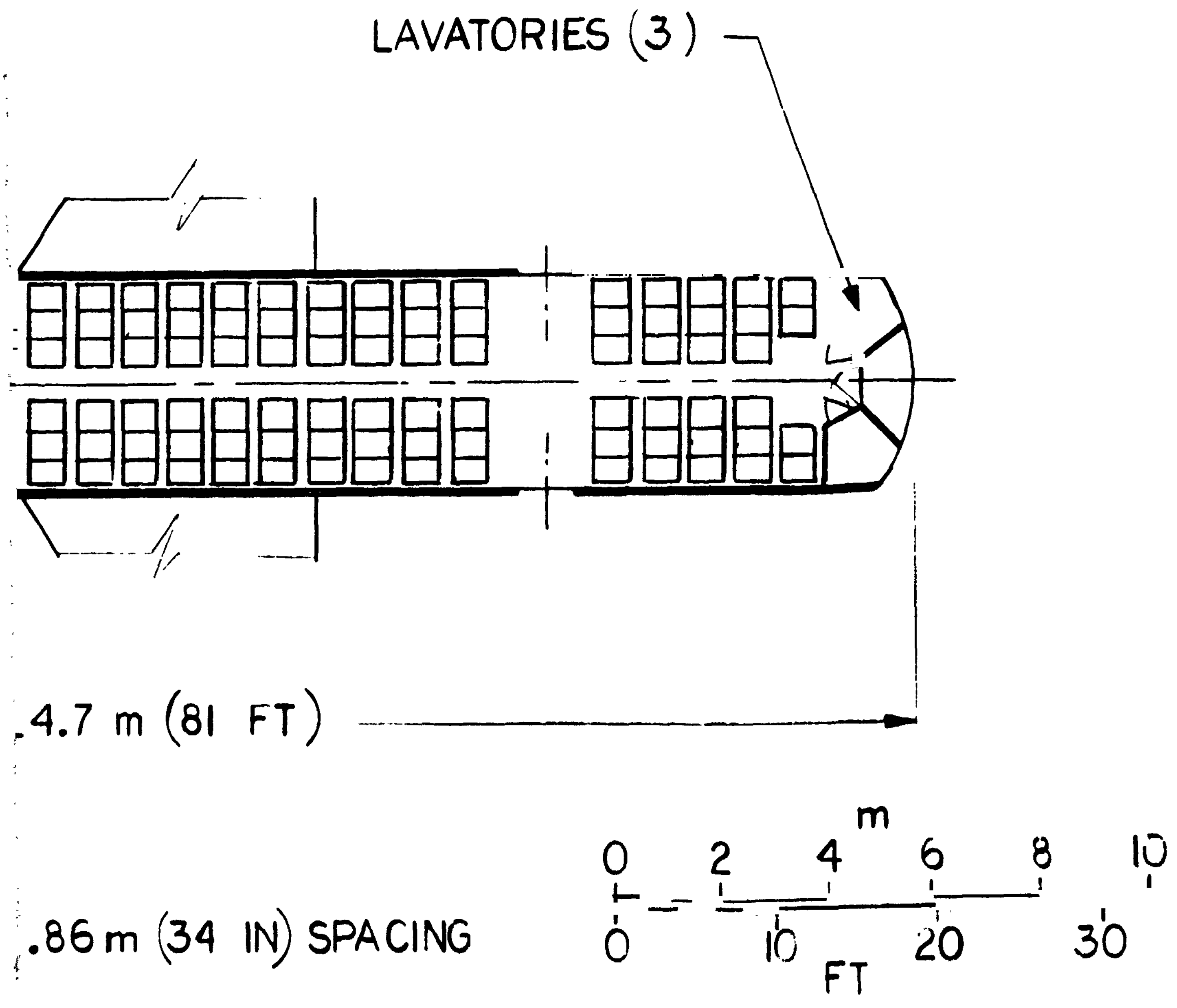


Figure 8. Interior Arrangement: 130 Pax Aircraft

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.

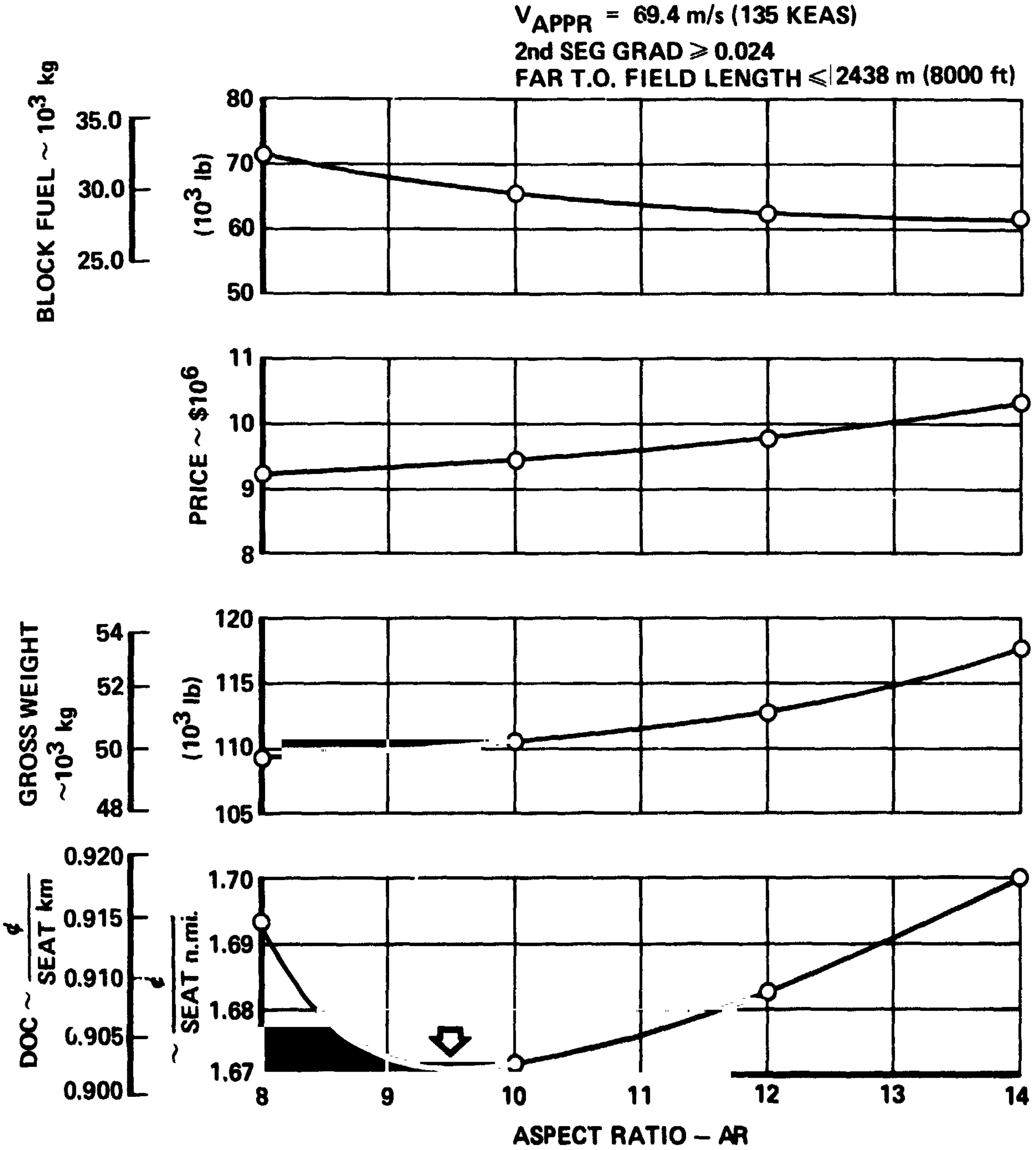


Figure 9. Aspect Ratio Selection - [illegible]rcraft No. 2

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

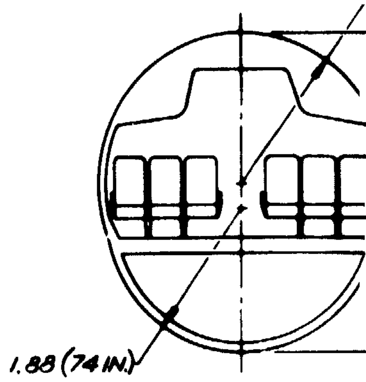
DESIGN GROSS WT. - 49,851 KG. (109,901 LB.)

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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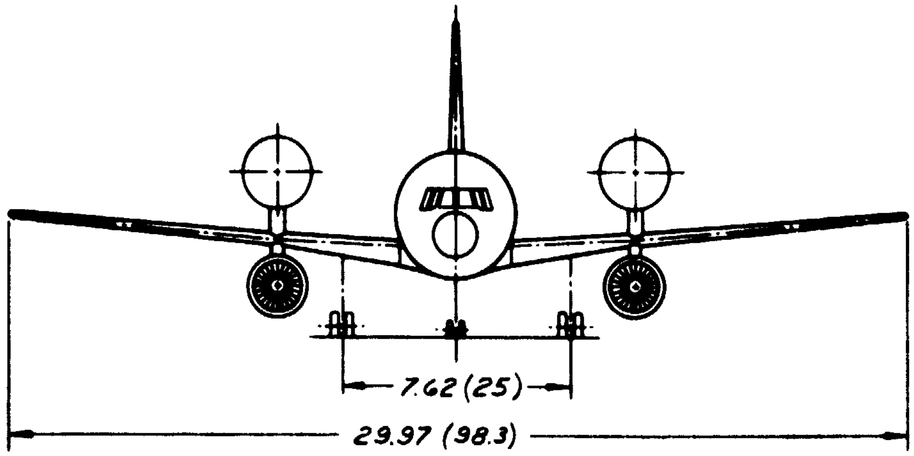

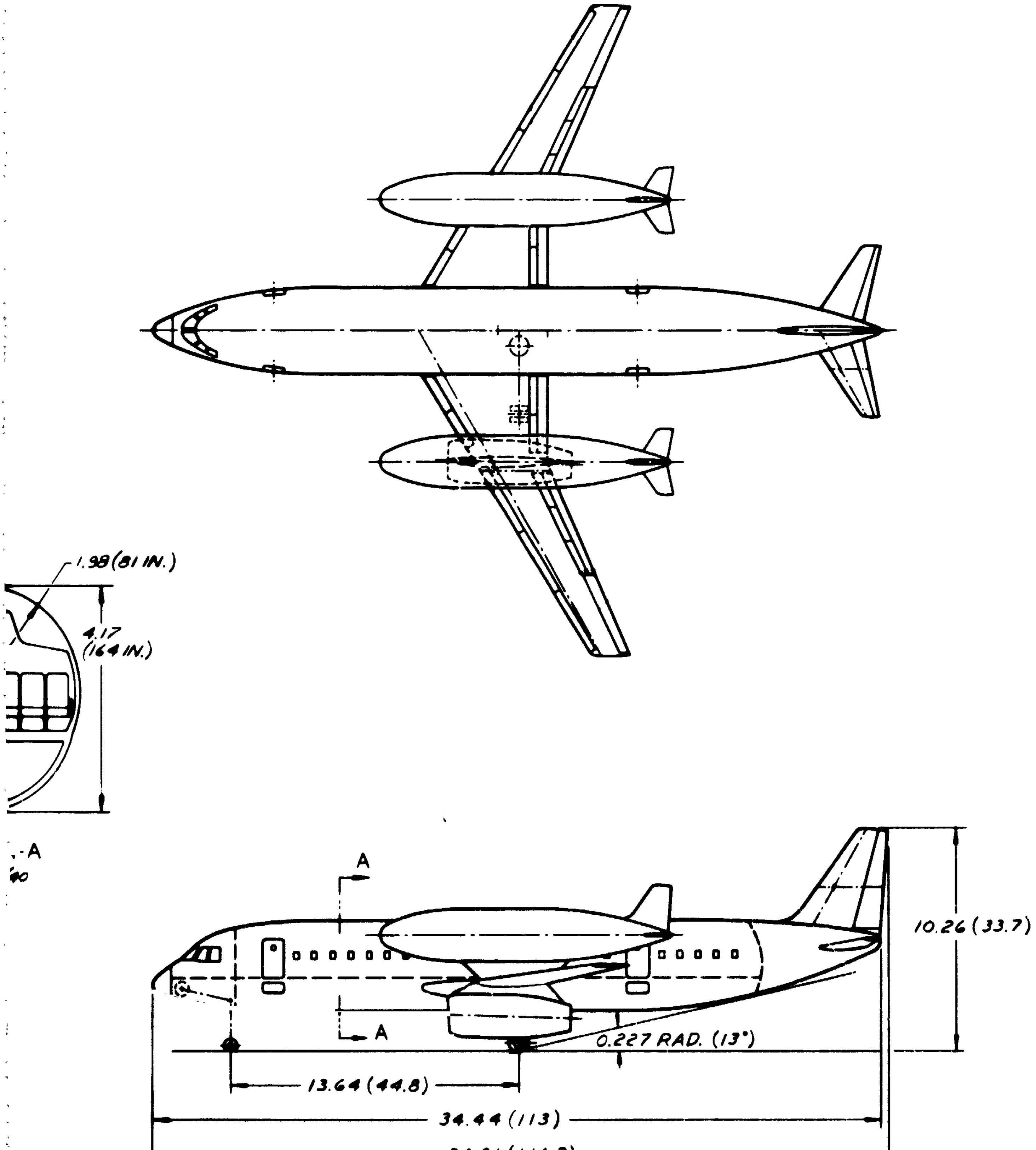

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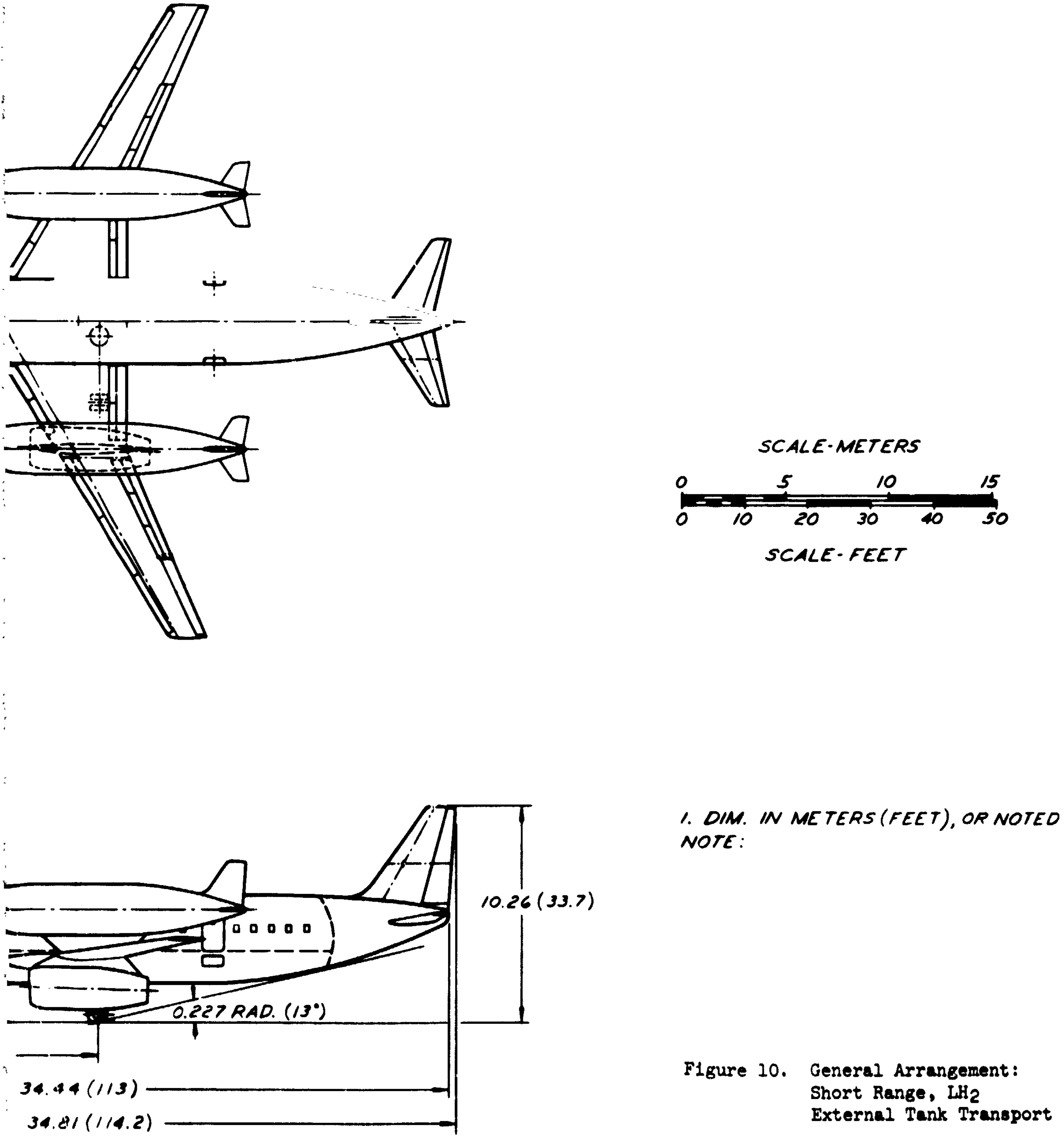


NOTE:

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

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

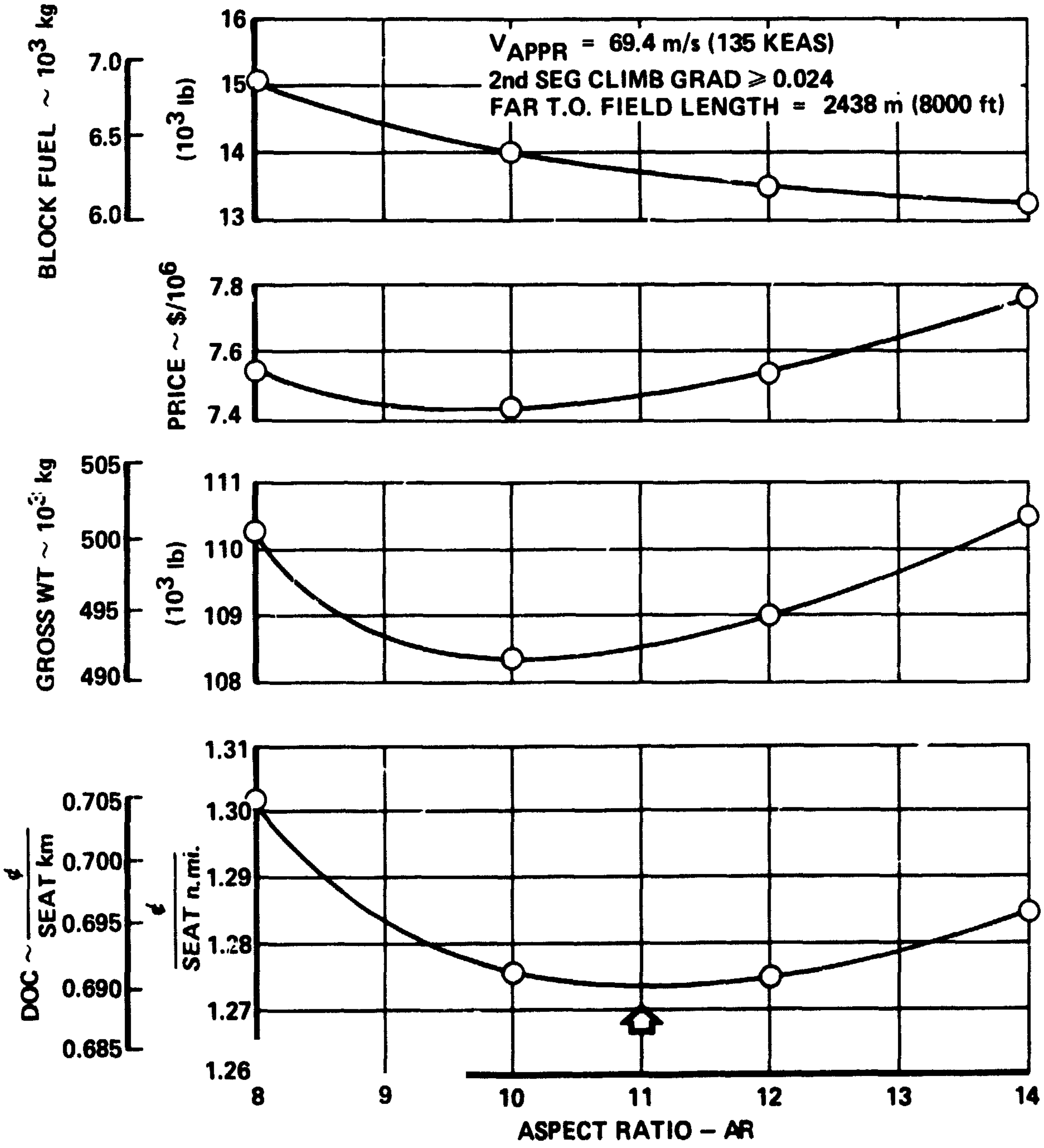


Figure 11. Aspect Ratio Selection - Aircraft No. 3

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)	2.35(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

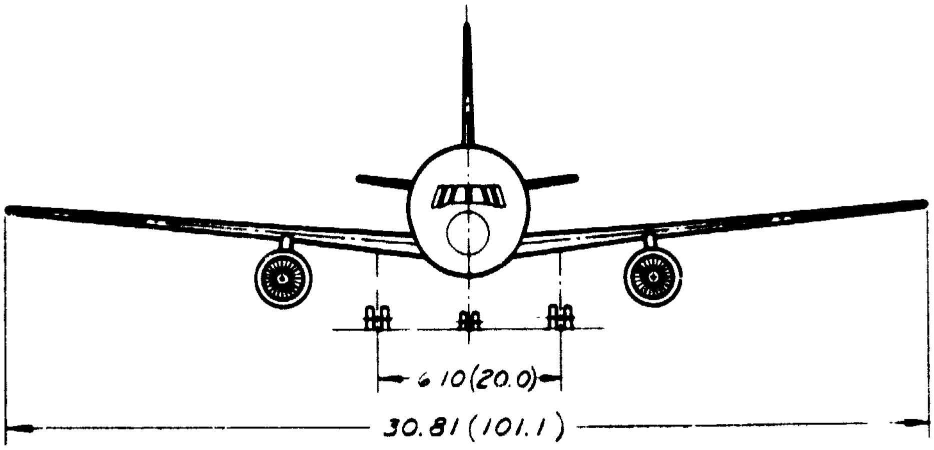
DESIGN GROSS WT. - 49,287 KG. (108,657 LB.)

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.)



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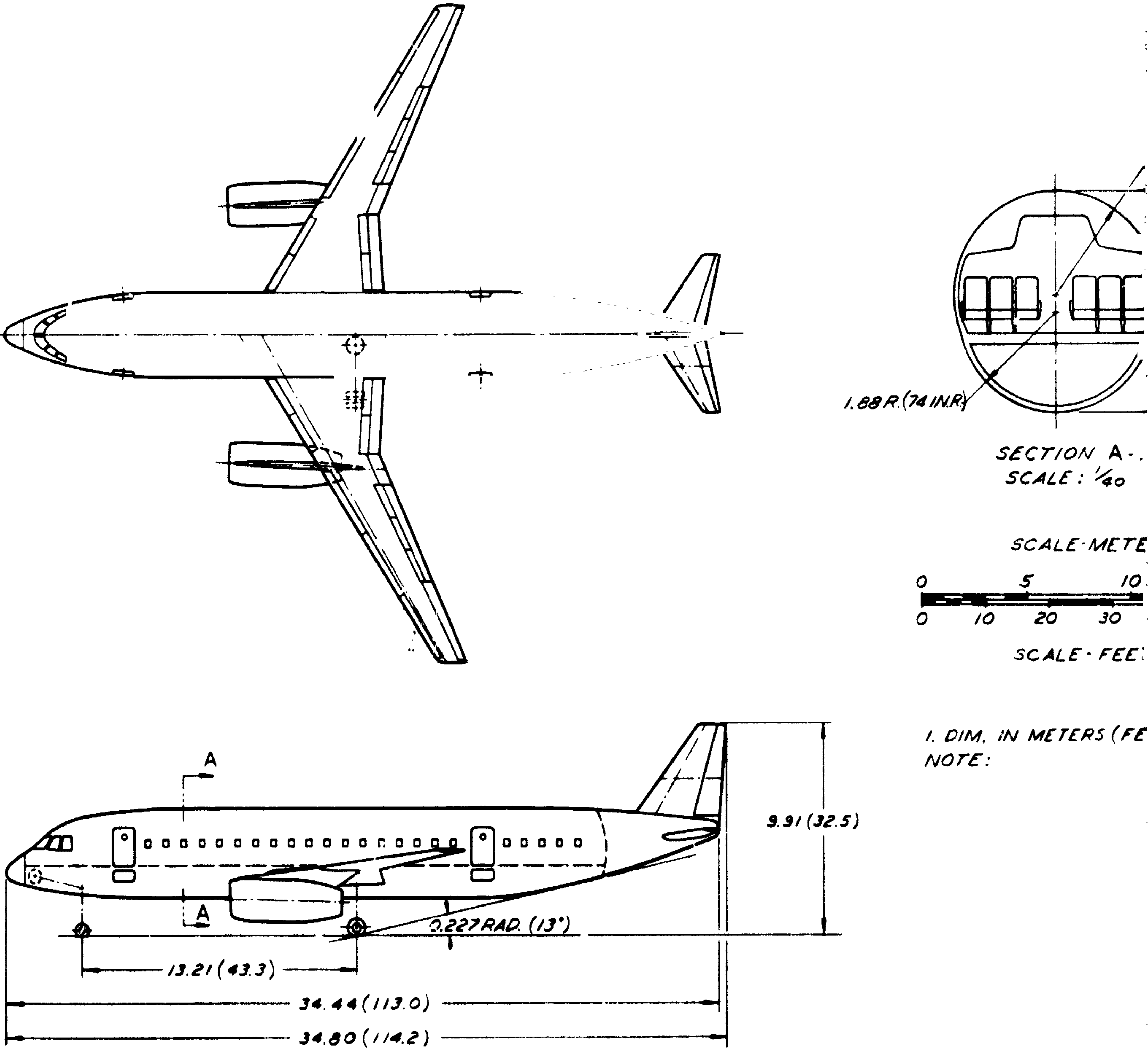

Figure 12. General
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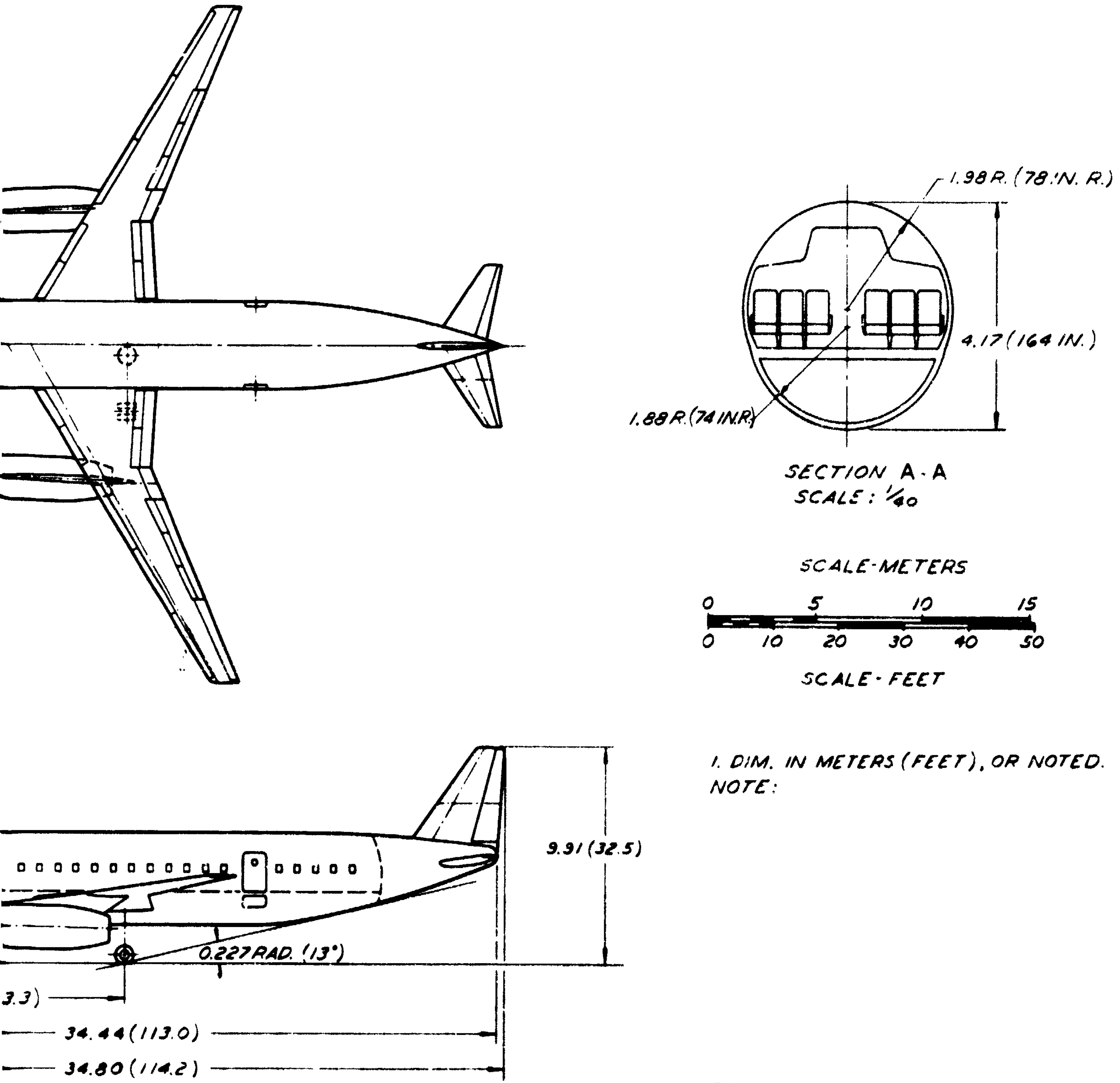

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NOTE:

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 $\left(\frac{\text{Ext}}{\text{Int}}\right)$	Aircraft No. 3 (Jet A)	Ratio $\left(\frac{\text{Jet A}}{\text{Int } LH_2}\right)$
Gross Weight	kg	44,570	49,850	1.118	49,290	1.11
Total Fuel	kg	3,340	4,360	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	1,746	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	$\$10^6$	7.86	9.34	1.19	7.51	0.96
DOC	$\frac{}{\text{seat km}}$	0.763[1]	0.901[1]	1.18	0.689[2]	0.90
Energy Utilization	$\frac{\text{kJ}}{\text{seat km}}$	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		0.616	2.93
Initial Cruise Altitude	ft	38,000	38,000		40,000	
Wing Loading	lb/ft^2	107.8	108.0		117.0	
Thrust/Weight		0.346	0.450	1.3	0.348	1.0
No. Engines		2	2		2	
Thrust Per Engine	lb	16,950	24,730	1.46	18,970	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	135	135		135	
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)

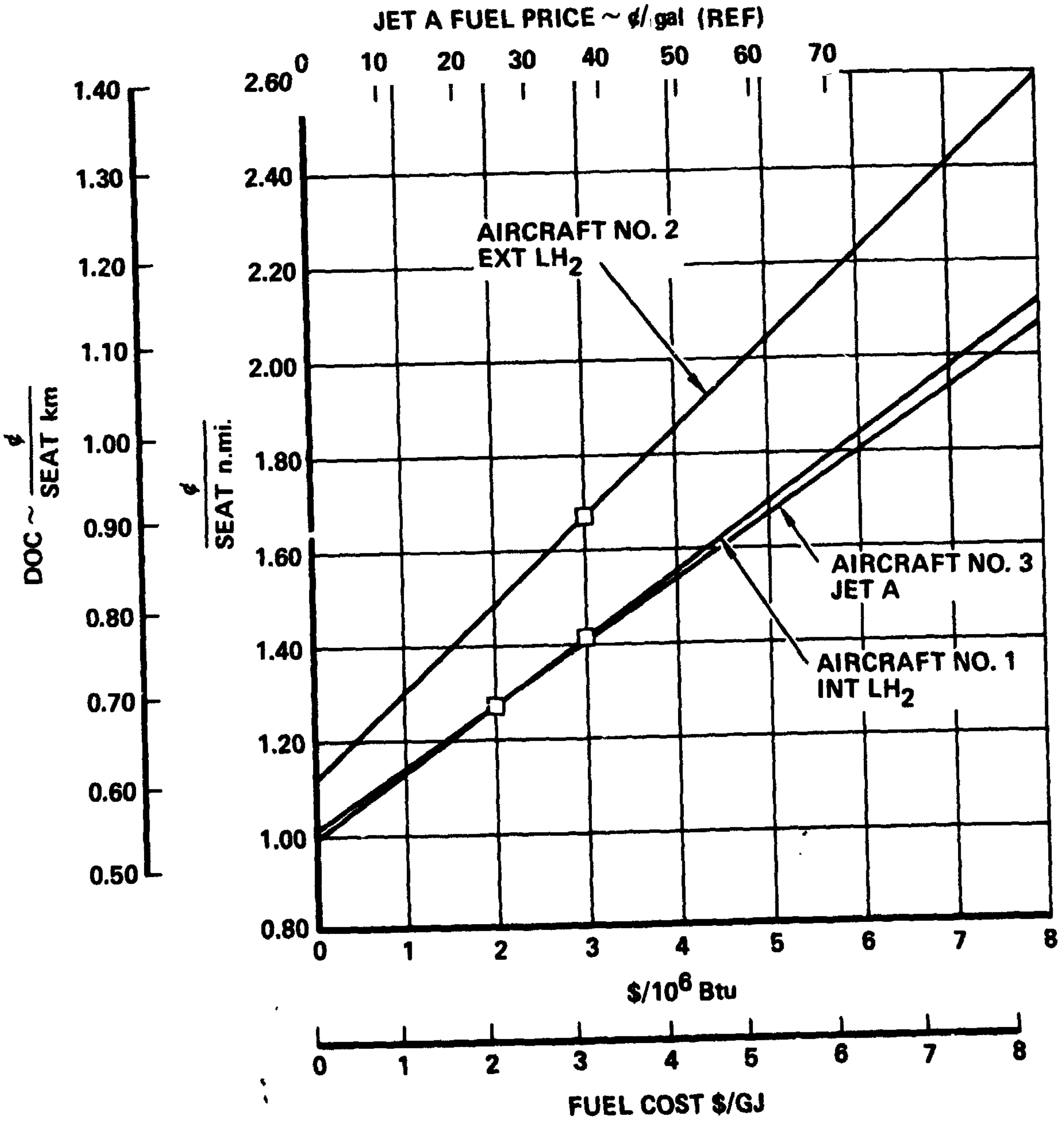


Figure 13. DOC Versus Fuel Cost - 1500 n.mi., 130 Pax Aircraft

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

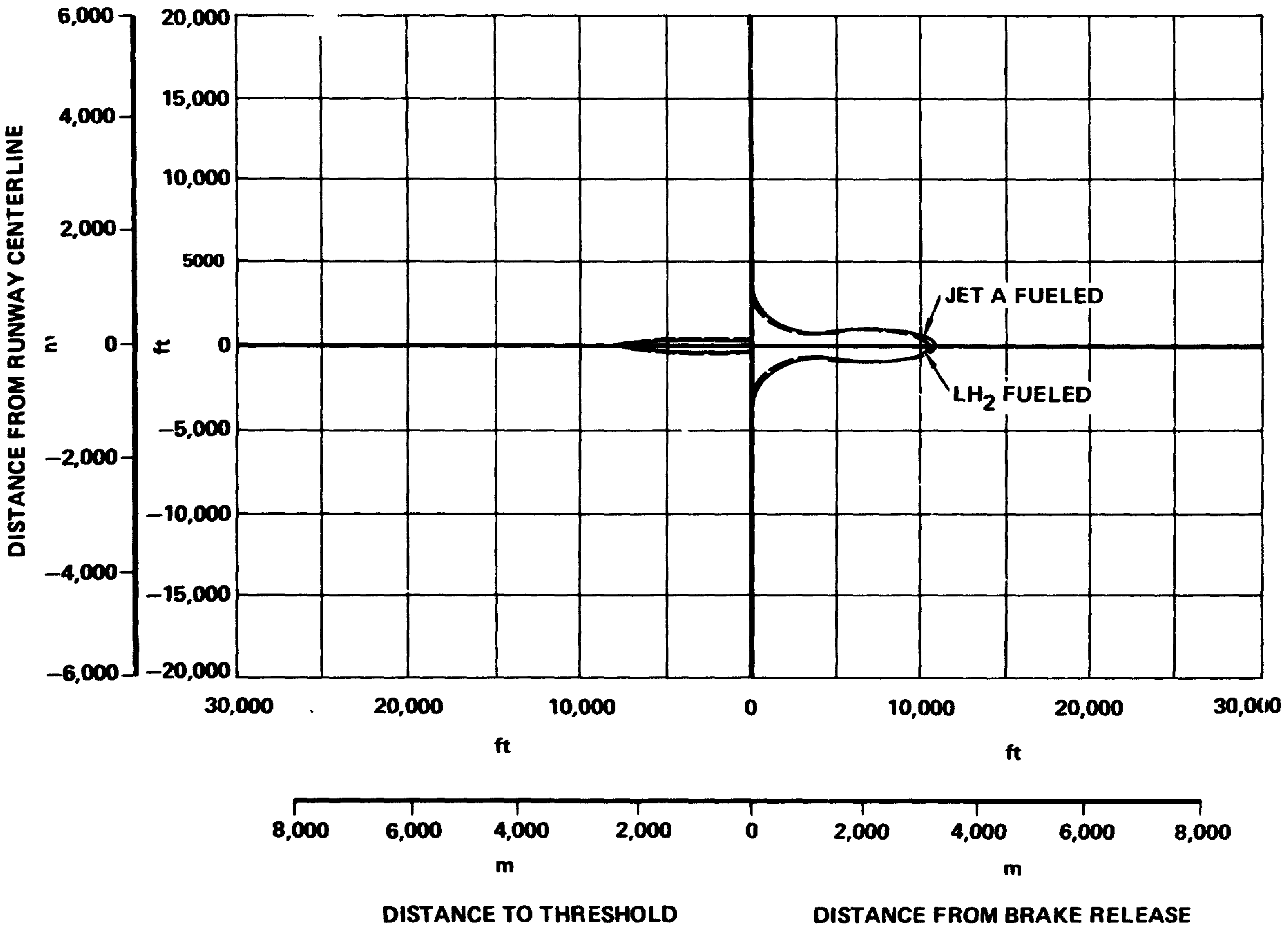


Figure 14. 90 EPNdB Contour Comparison - Short Range Aircraft

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 M² (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

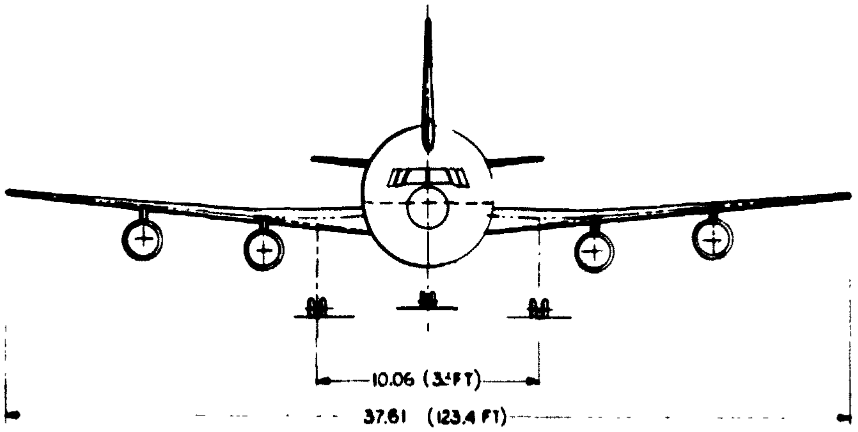
DESIGN GROSS WT. - 81,403 KG. (179,459 LB.)

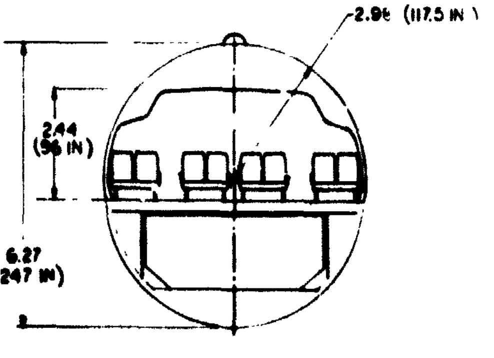
POWER PLANT - (2) TURBOFAN
INSTALLED THRUST (EA.) - 66,849 N. (15,029 LB.)

PASSENGERS - 200

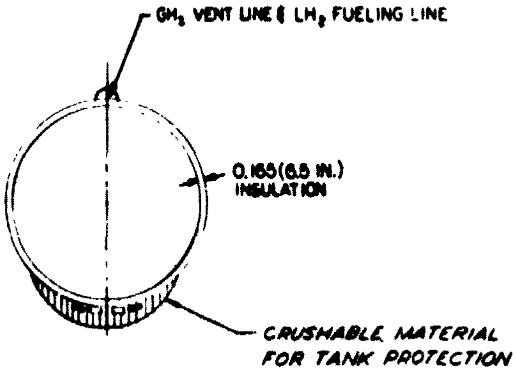
FUEL LH_2 - 9,492 KG (20,924 LB.)

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





SECTION A-A
SCALE 1/90



SECTION B-B
SCALE 1/90

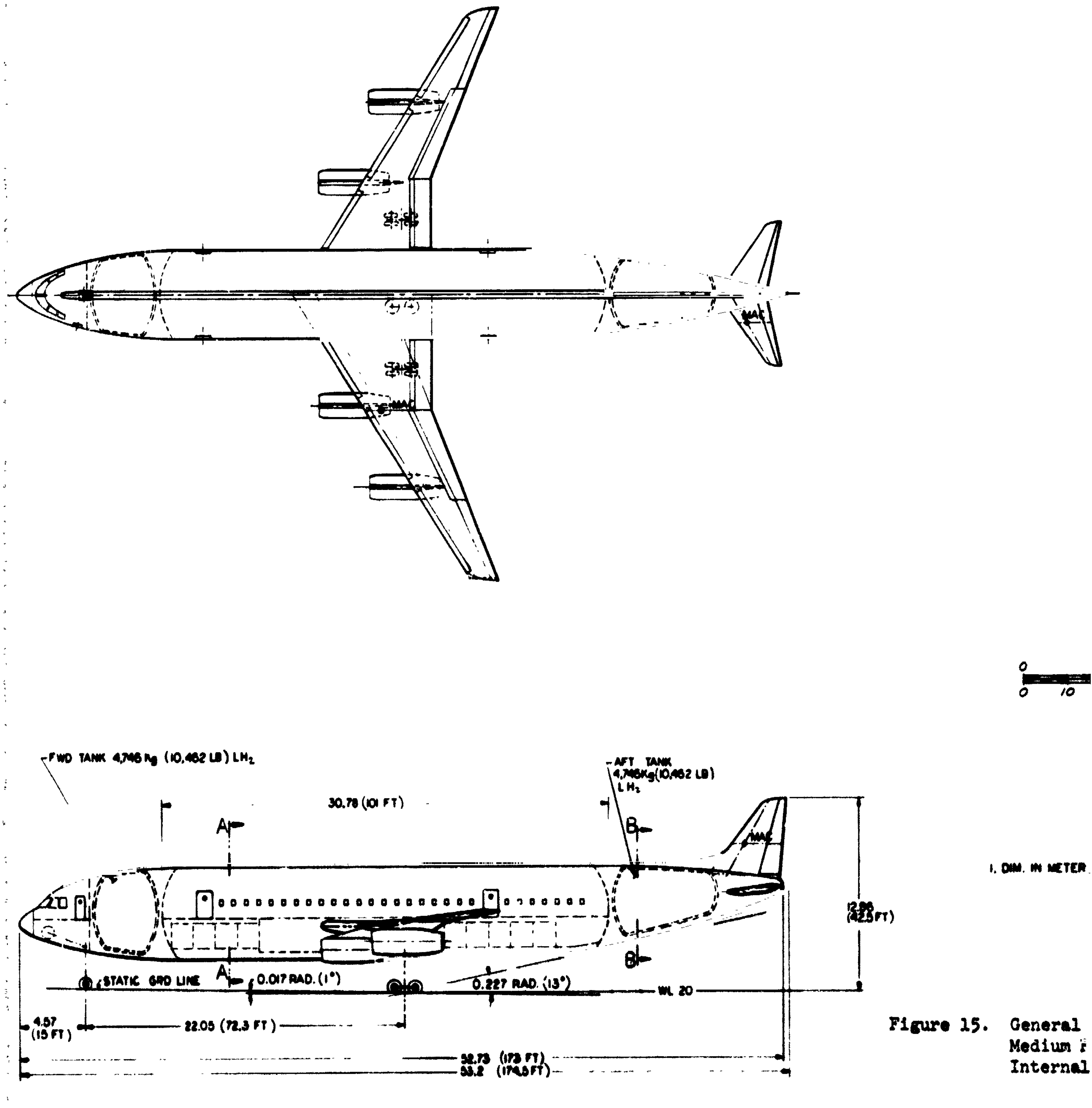
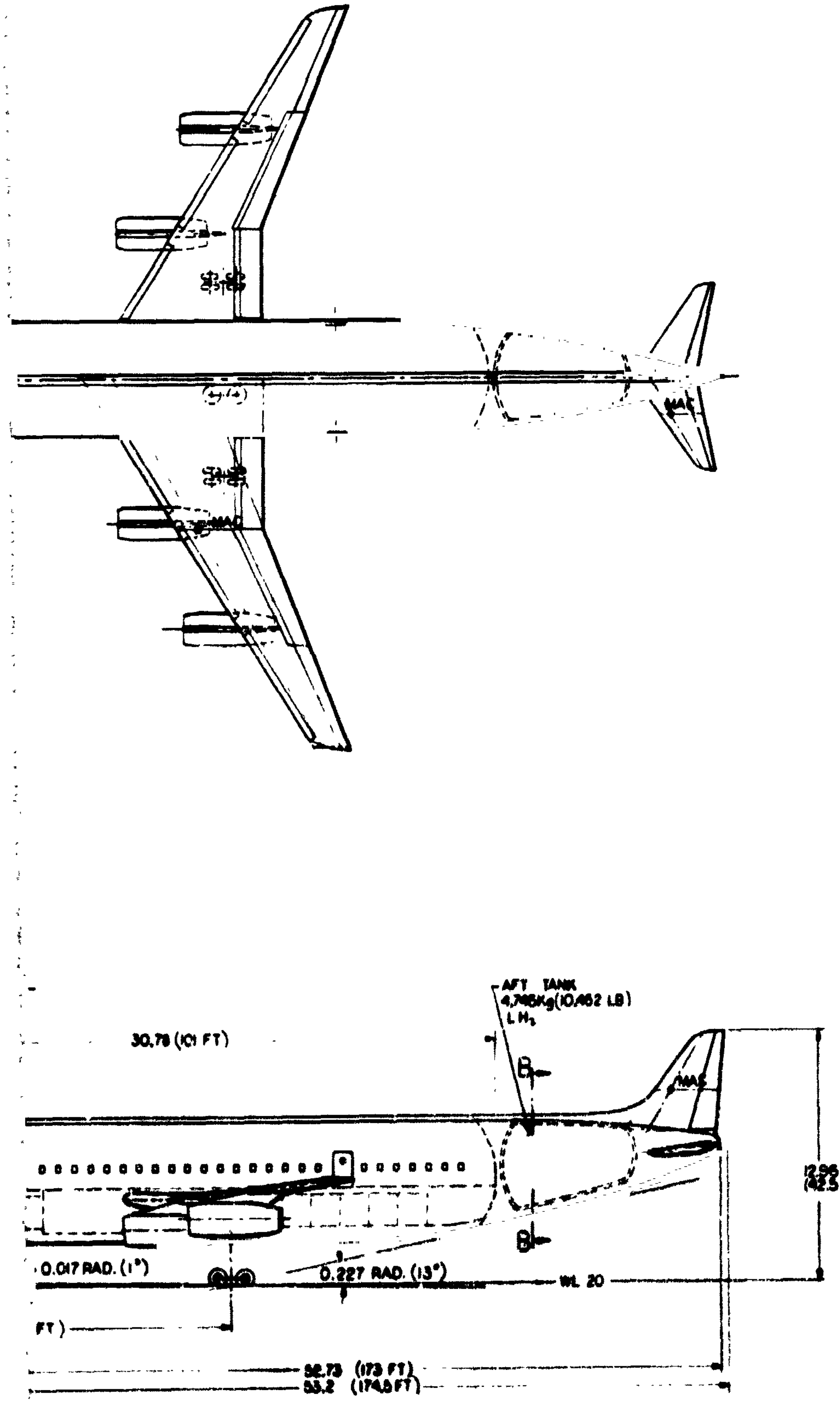


Figure 15. General
Medium
Internal

FOLDOUT FRAME 2



SCALE·METERS

0 5 10 15

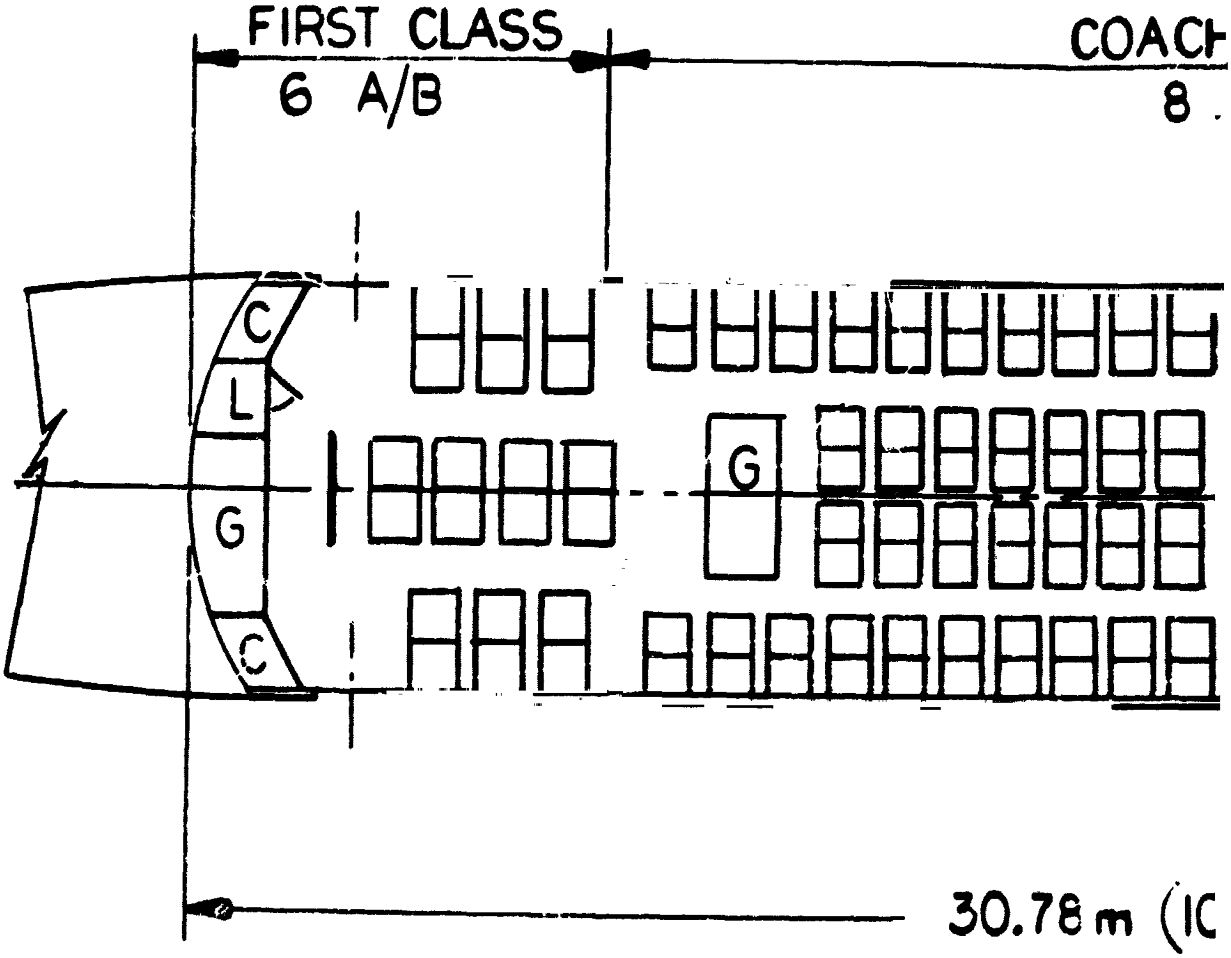
0 10 20 30 40 50

SCALE·FEET

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

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

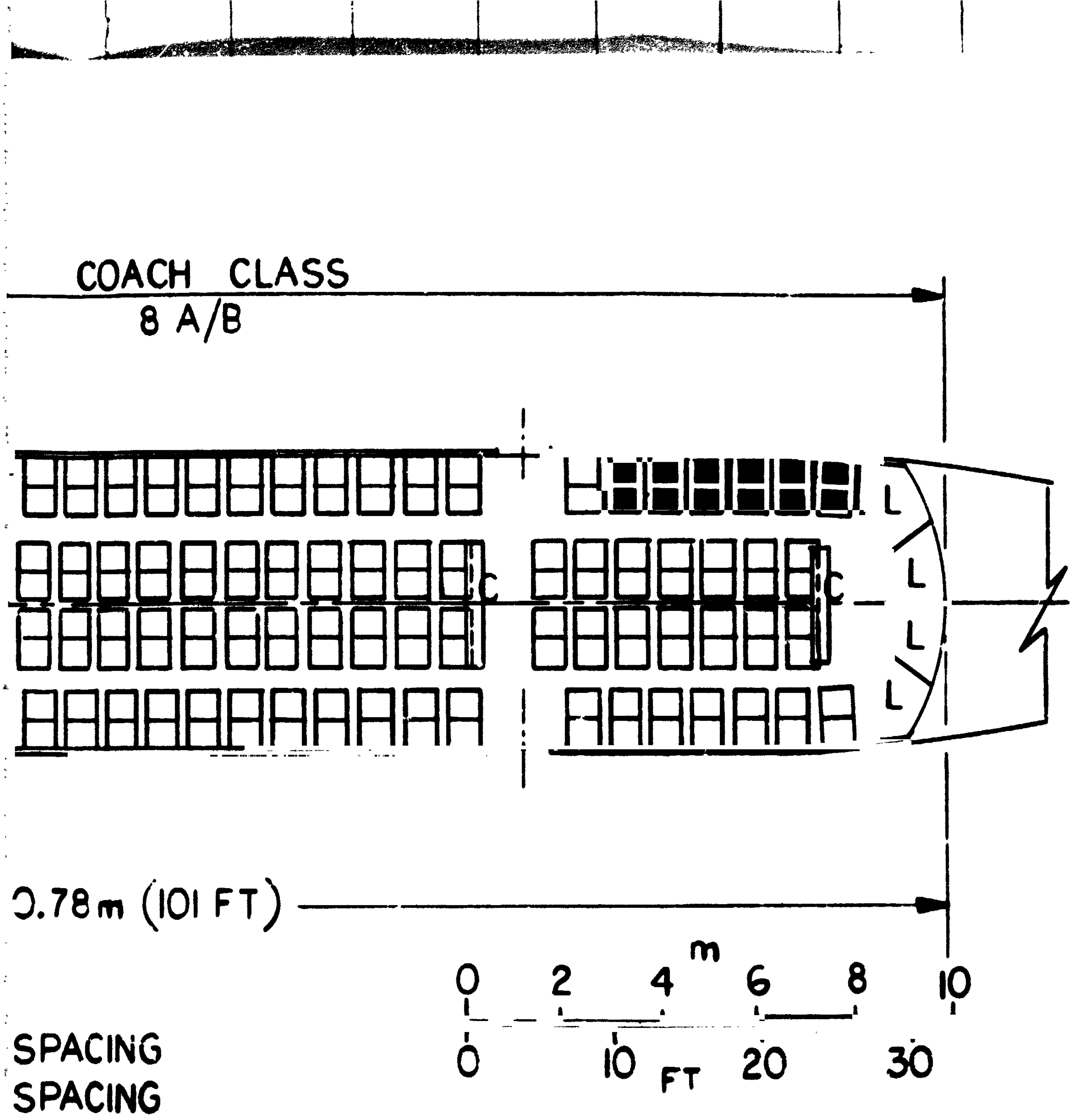


Figure 16. Interior Arrangement: 200 Pax Transport, LH_2 Internal Tank

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.

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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

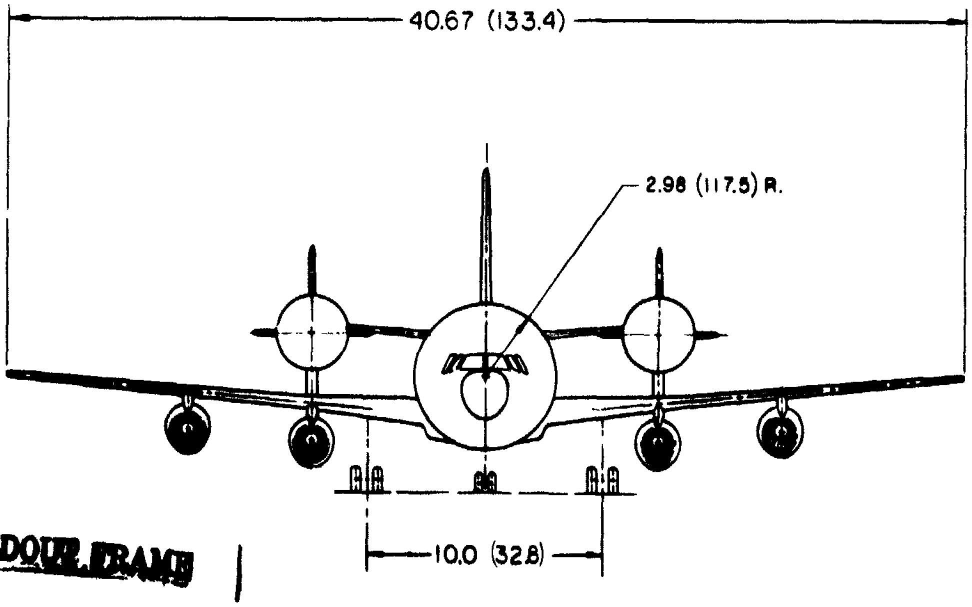
DESIGN GROSS WT. - 94,052 KG (207,346 LB.)

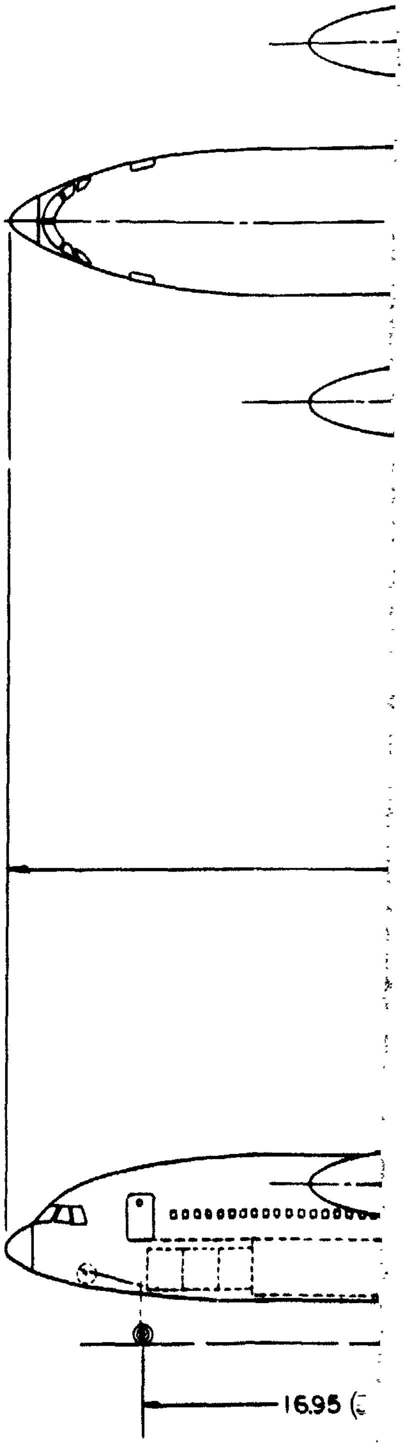
POWER PLANT - 2 TURBOFAN
INSTALLED THRUST (EA.) - 99,141 N. (22,289 LB.)

PASSENGERS - 200

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

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





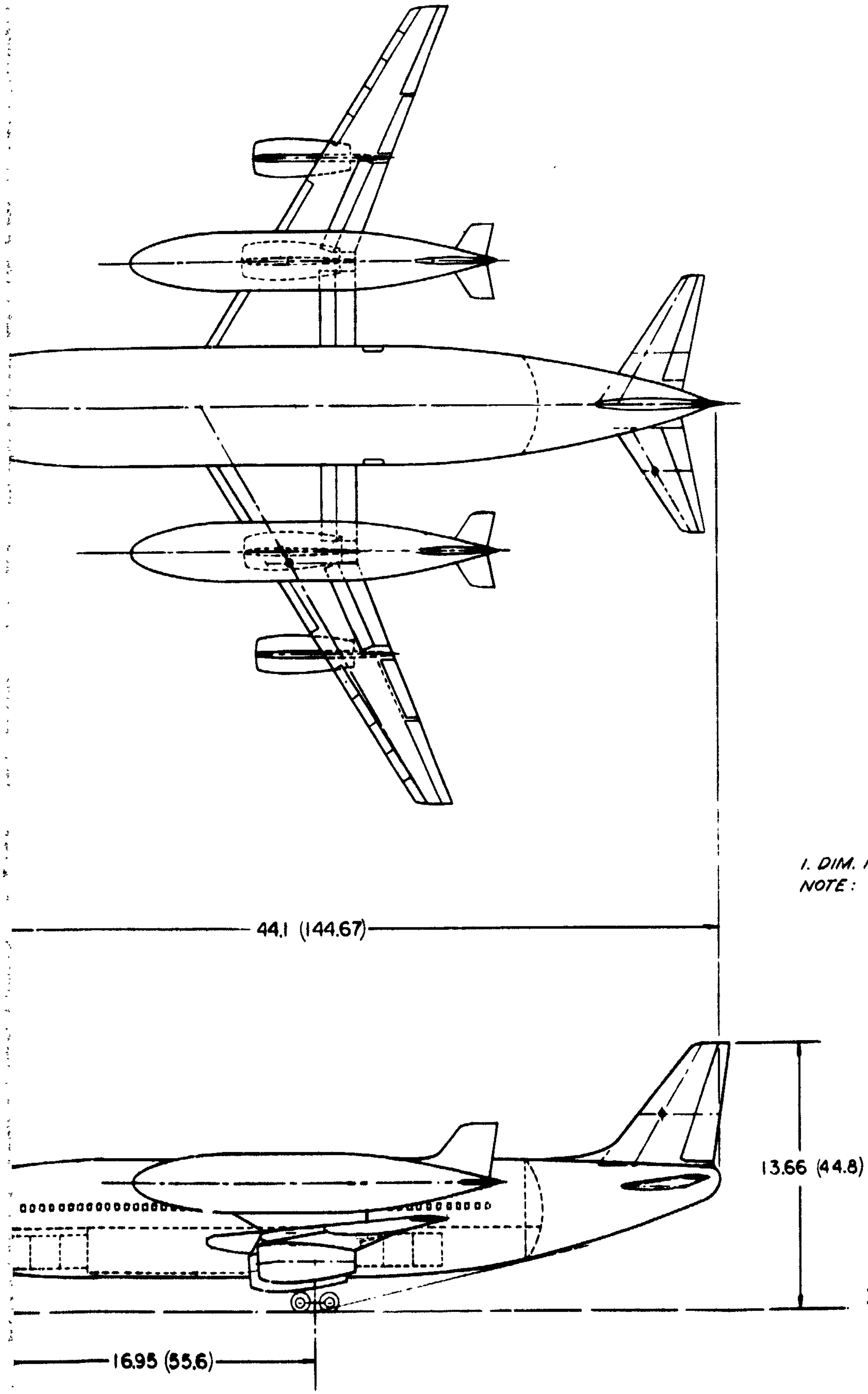
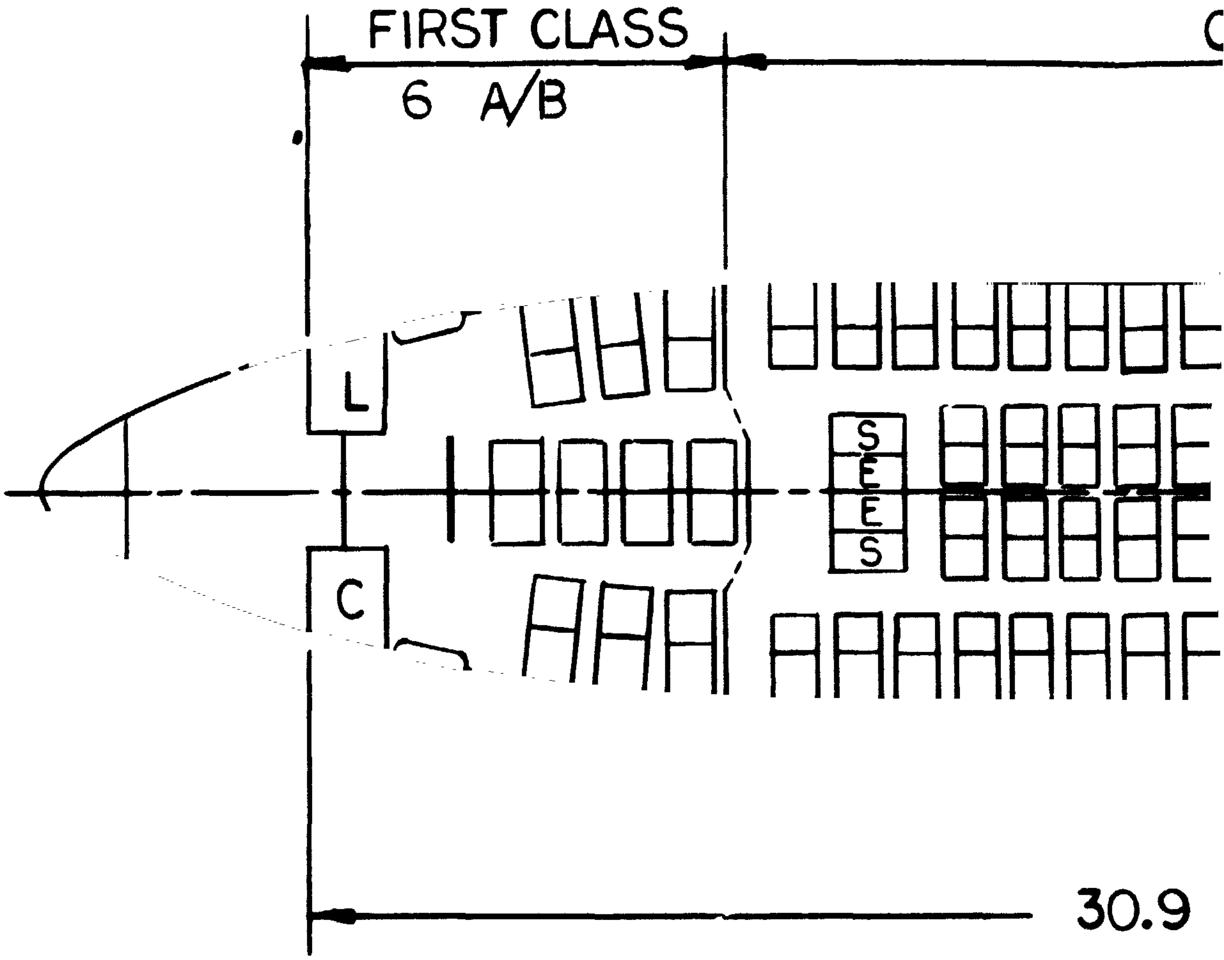


Figure 17. General Arrangement: Medium Range, LH_2 External Tank Transport



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

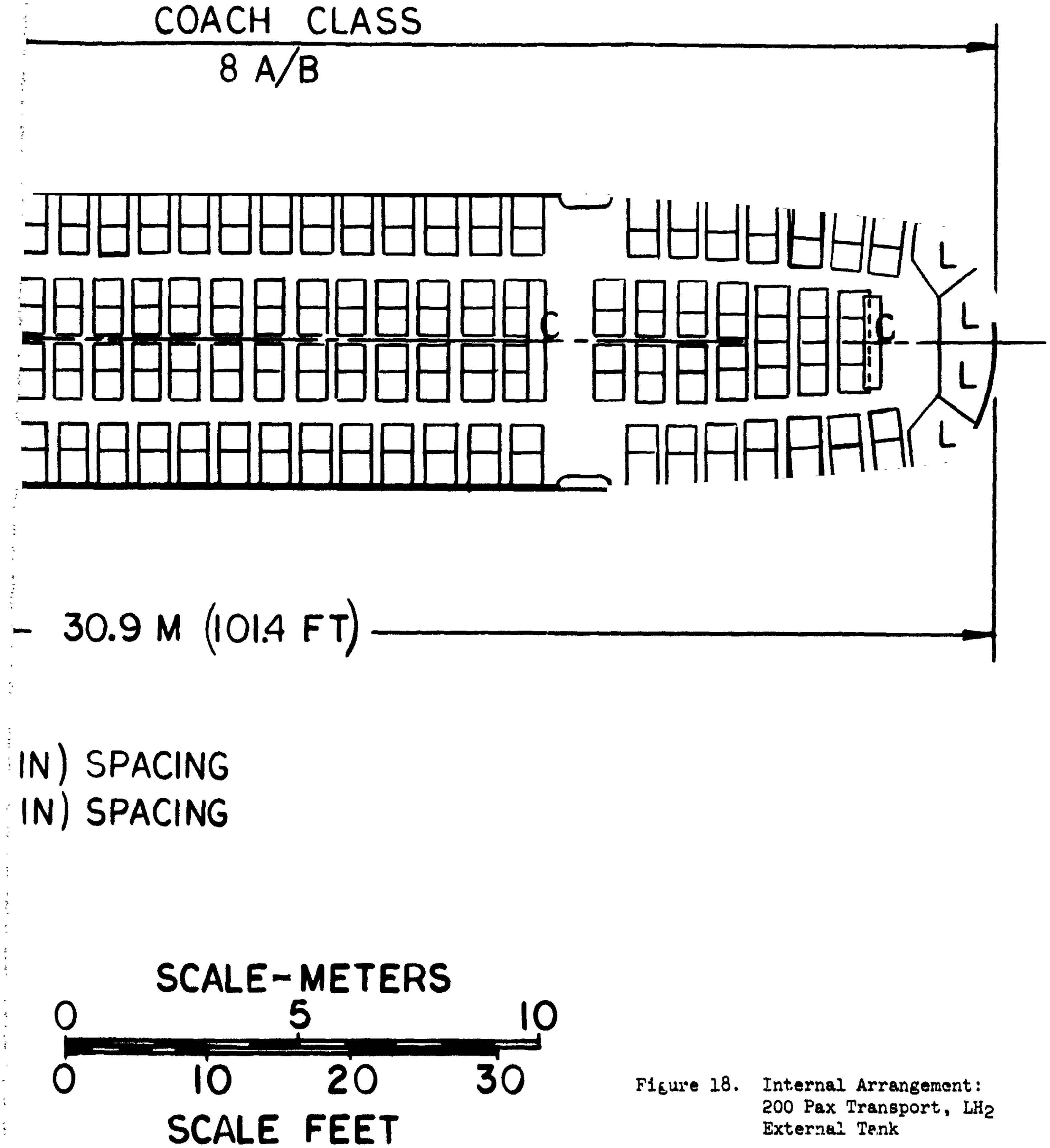


Figure 18. Internal Arrangement: 200 Pax Transport, LH_2 External Tank

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

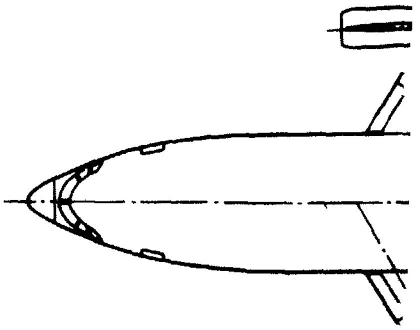
DESIGN GROSS WT. - 98,396 KG. (216,923 LB.)

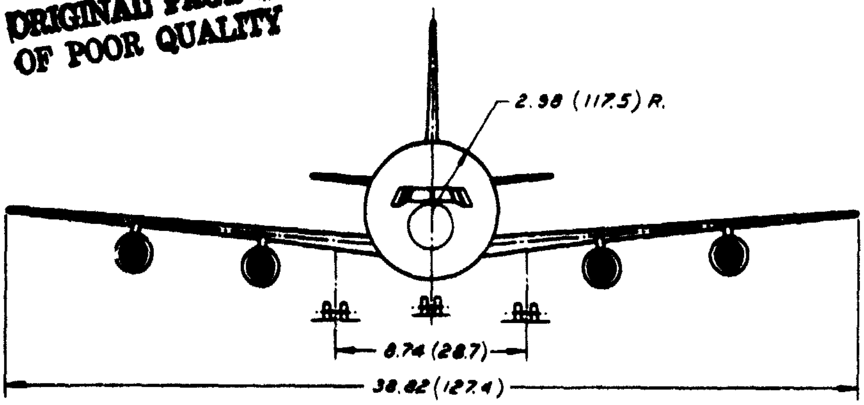
POWER PLANT - (2) TURBOFANS
INSTALLED THRUST (EA.) - 68,023 N. (15,293 LB.)

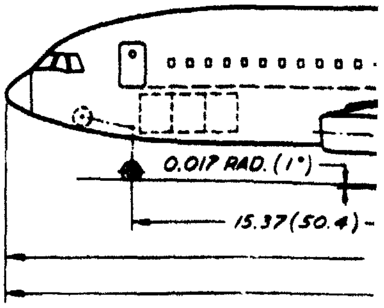
PASSENGERS - 200

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

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







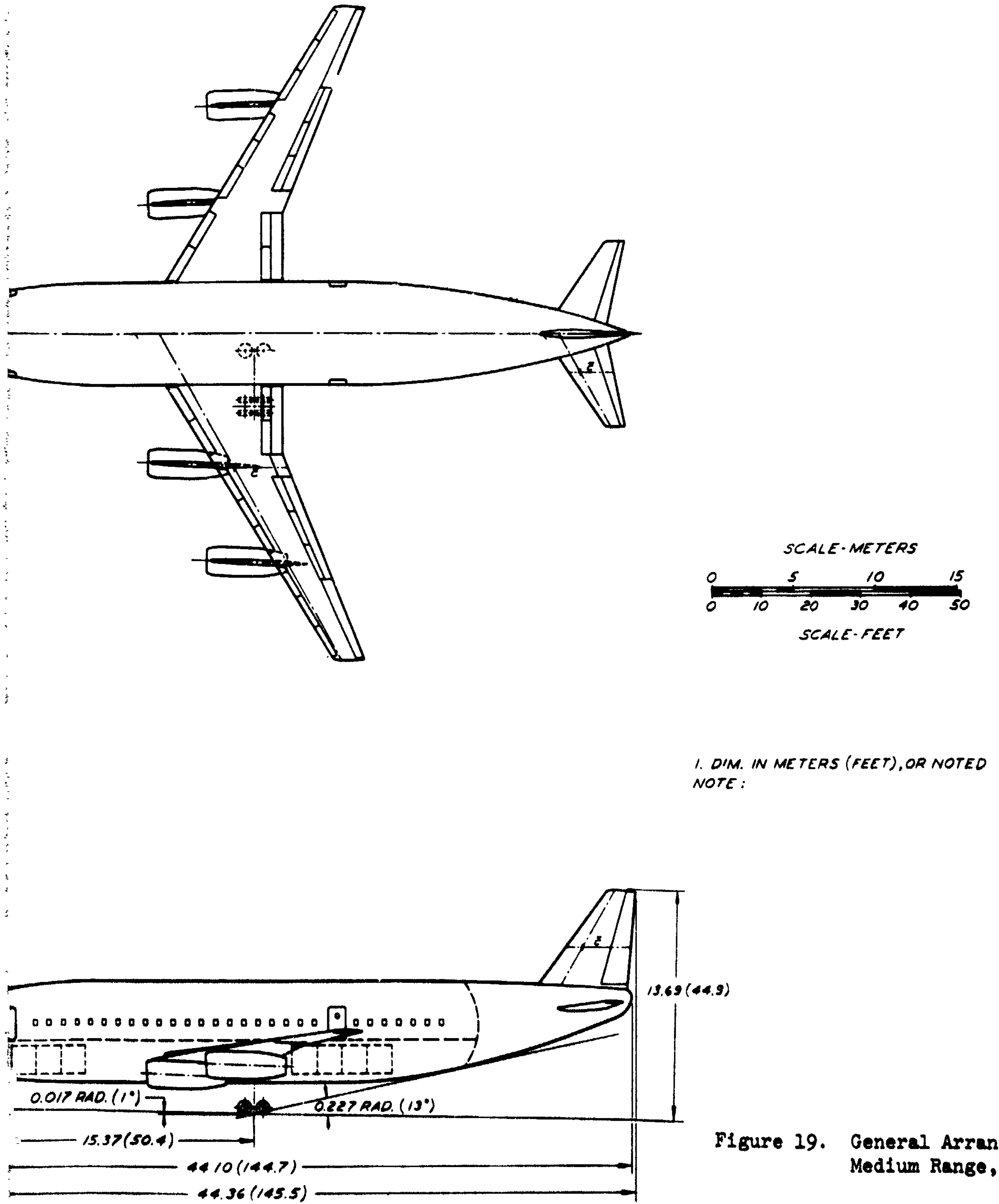


Figure 19. General Arrangement:
Medium Range, Jet Fuel

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: $\frac{(Ext.)}{(Int.)}$	Aircraft No. 6 (Jet A)	Ratio: $\frac{(Jet\ A)}{(Int.\ LH_2)}$
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

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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	$\frac{¢}{\text{seat n.mi}}$	1.338[1]	1.626[1]	1.22	1.203[2]	0.90
Energy Utilization	$\frac{\text{Btu}}{\text{seat n.mi.}}$	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)

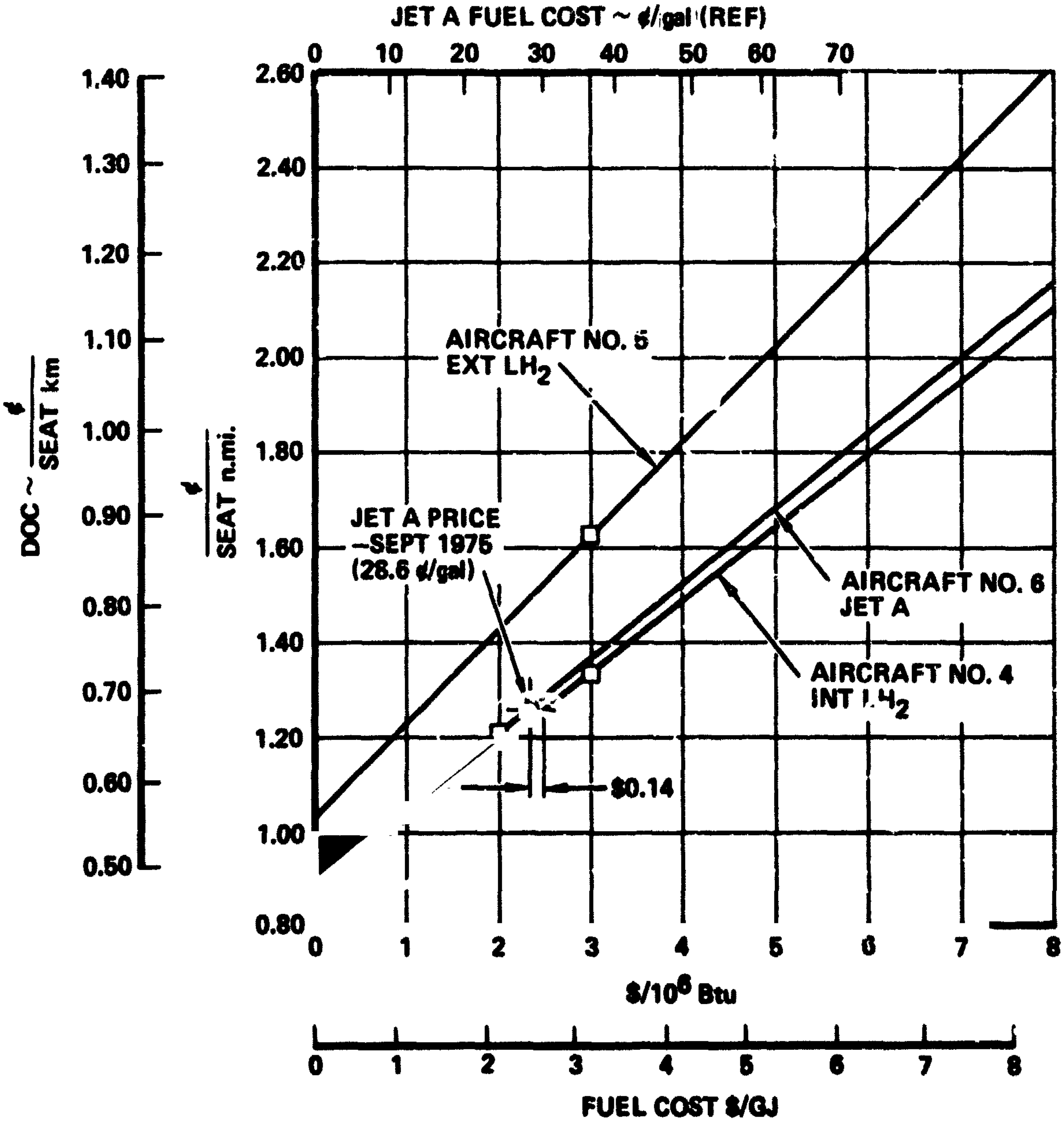


Figure 20. DOC Versus Fuel Cost - 3000 n.mi., 200 Pax Aircraft

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	7.05
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

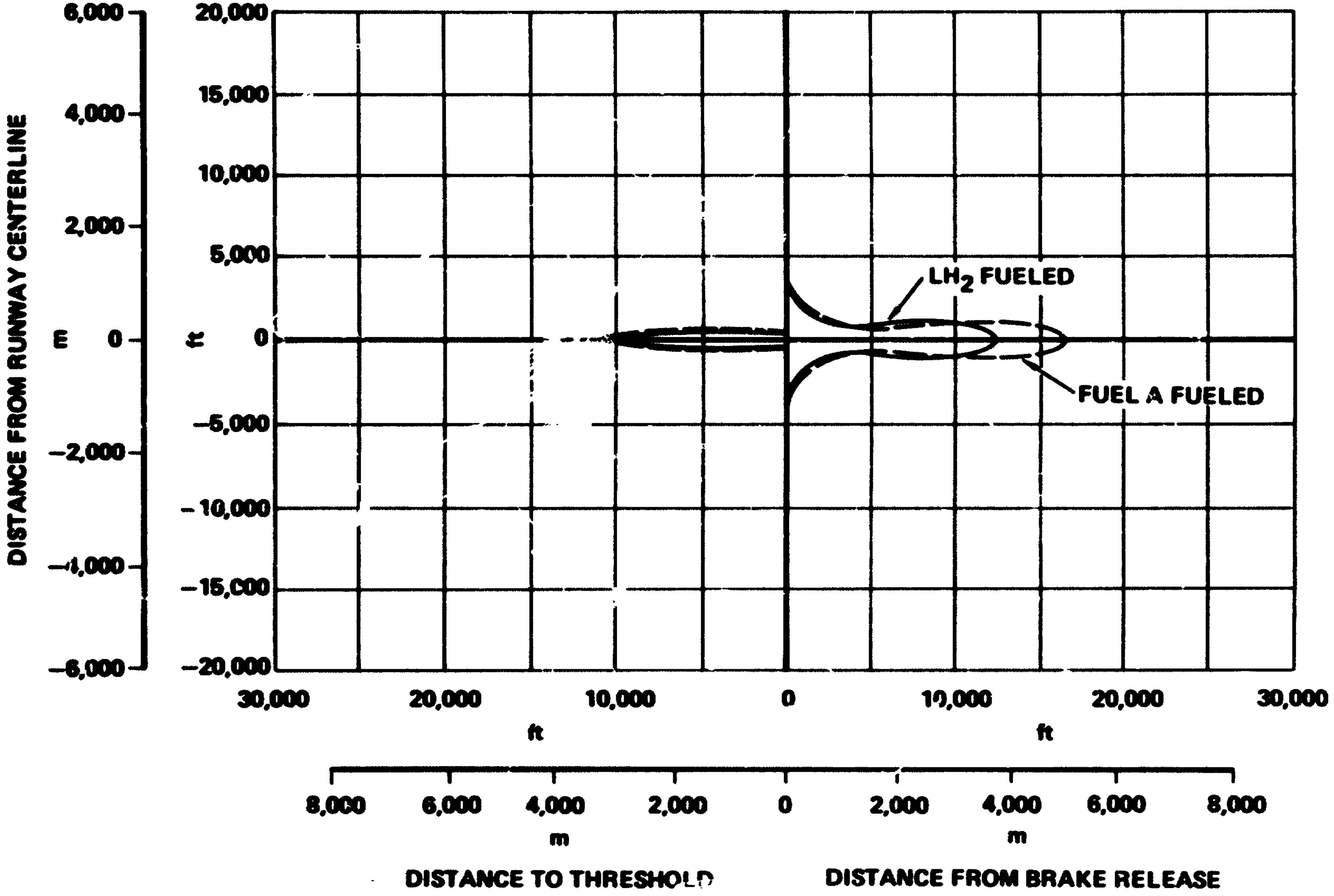


Figure 21. 90 EPNdB Contour Comparison - Medium Range Aircraft

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
11.58	W/S – kg/m^2	575	571	569	565
	T/W – N/kg	0.33	0.32	0.31	0.29
	DOC – $\frac{\text{¢}}{\text{seat km}}$	.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
	2nd Seg. Grad.	0.079	0.0823	0.085	0.085
	V(Appr.) – m/s	69	69	69	69
10.97	W/S – kg/m^2	575	573	570	566
	T/W – N/kg	0.31	0.30	0.29	0.27
	DOC – $\frac{\text{¢}}{\text{seat km}}$	.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
	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
10.36	W/S – kg/m^2	576	574	571	568
	T/W – N/kg	0.29	0.28	0.27	0.25
	DOC – $\frac{\text{¢}}{\text{seat km}}$	.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
	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
9.75	W/S – kg/m^2	578	575	574	570
	T/W – N/kg	0.27	0.26	0.25	0.24
	DOC – $\frac{\text{¢}}{\text{seat km}}$	.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
	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
9.14	W/S – kg/m^2	579	577	575	571
	T/W – N/kg	0.256	0.25	0.24	0.233
	DOC – $\frac{\text{¢}}{\text{seat km}}$	.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
	2nd Seg. Grad.	0.0364	0.043	0.045	0.0525
	V(Appr.) m/s	69	69	69	69
8.53	W/S – kg/m^2	580	578	577	572
	T/W – N/kg	0.25	0.247	0.235	0.23
	DOC – $\frac{\text{¢}}{\text{seat km}}$	.775	.768	.780	.798
	W_G – kg	276,520	276,240	282,590	292,570
	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 – $\frac{¢}{\text{Seat n.mi.}}$	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 – $\frac{¢}{\text{Seat n.mi.}}$	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 – $\frac{¢}{\text{Seat n.mi.}}$	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 – $\frac{¢}{\text{Seat n.mi.}}$	1.4243	1.415	1.42	1.462
	W_G – lb	602,800	604,300	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 – $\frac{¢}{\text{Seat n.mi.}}$	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 – $\frac{¢}{\text{Seat n.mi.}}$	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

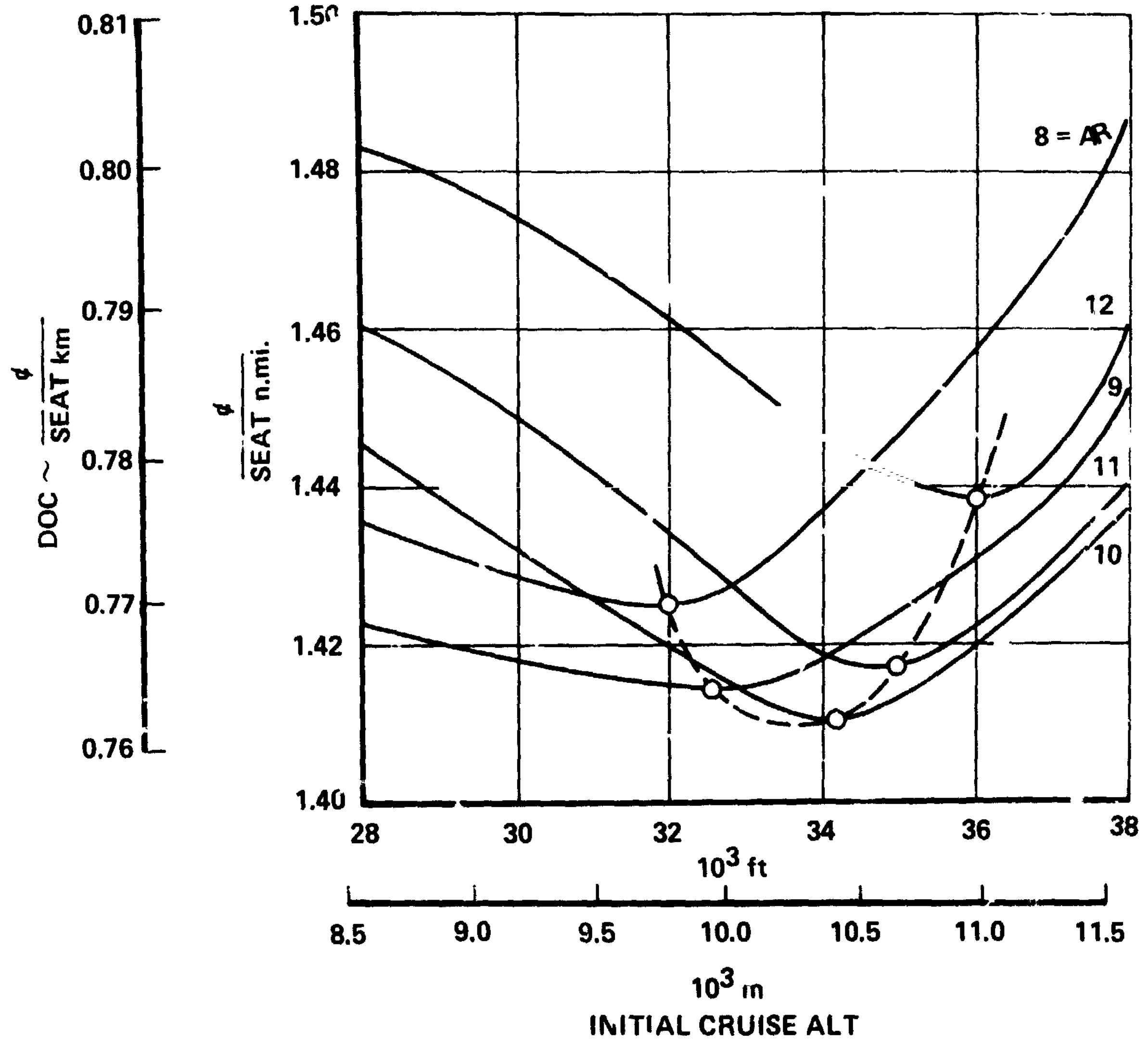


Figure 22. Effect of Aspect Ratio and Initial Cruise Altitude on Direct Operating Cost of the Long Range LH_2 Aircraft

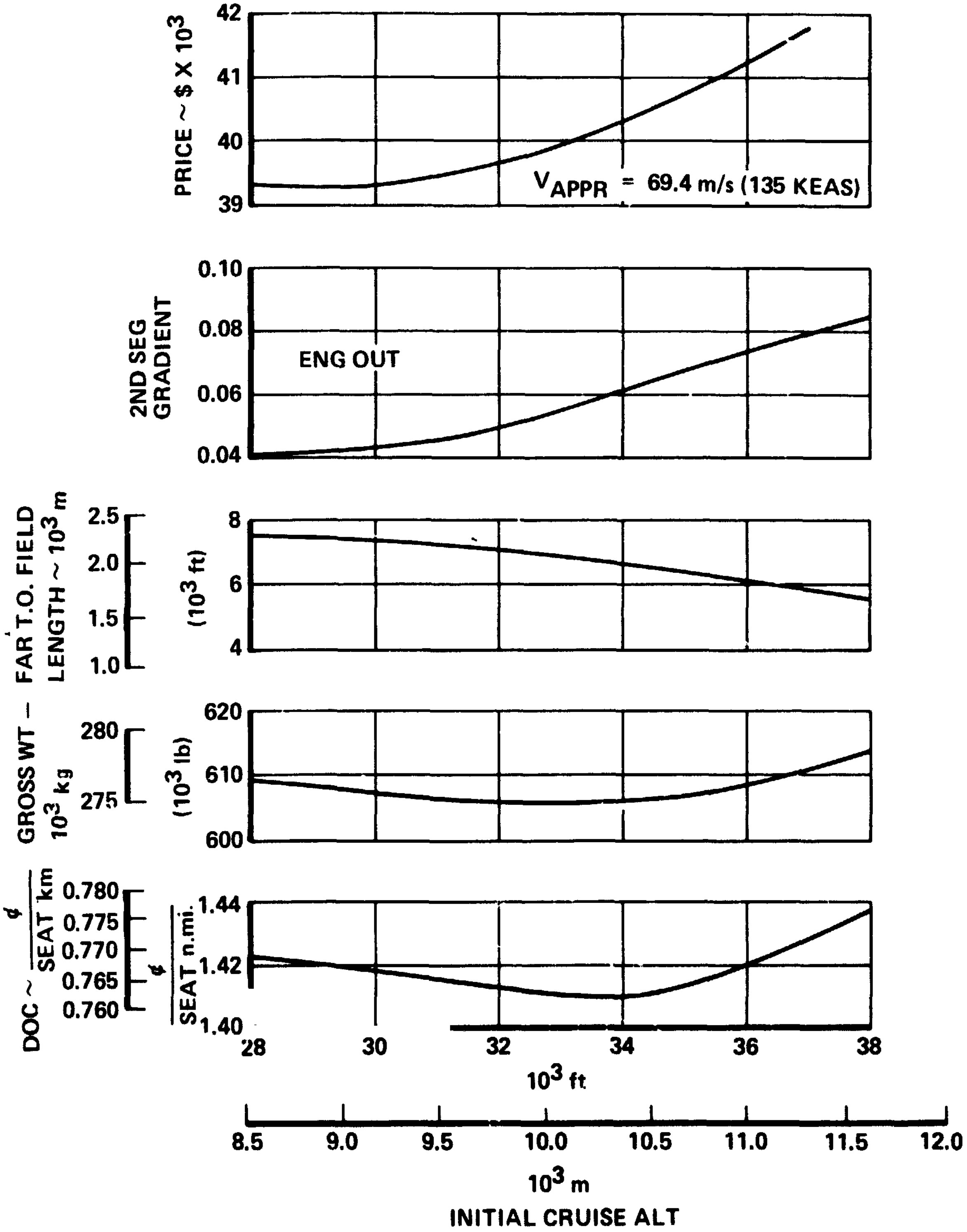


Figure 23. Effect of Initial Cruise Altitude on Performance and Cost of the Long Range LH_2 Aircraft

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 M (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

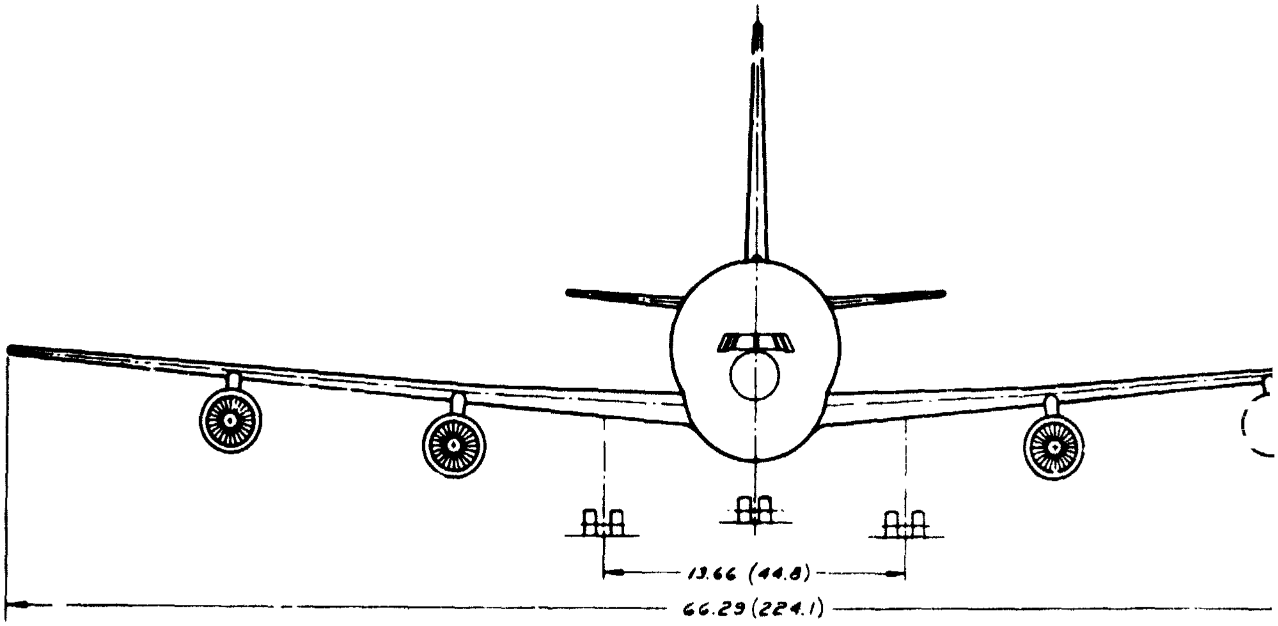
DESIGN GROSS WT - 266.429 KG (587,365 LB.)

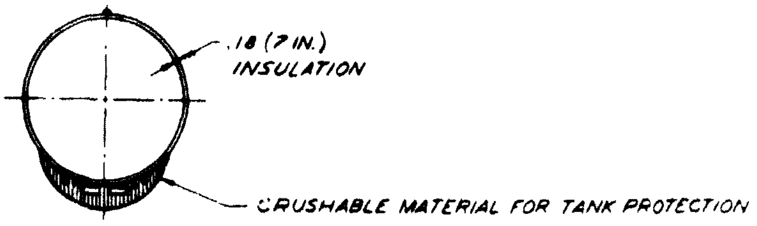
POWER PLANT - (2) TURBOFANS
INSTALLED THRUST (EA.) - 175,[illegible] N (39,353 LB.)

PASSENGERS - 400

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

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





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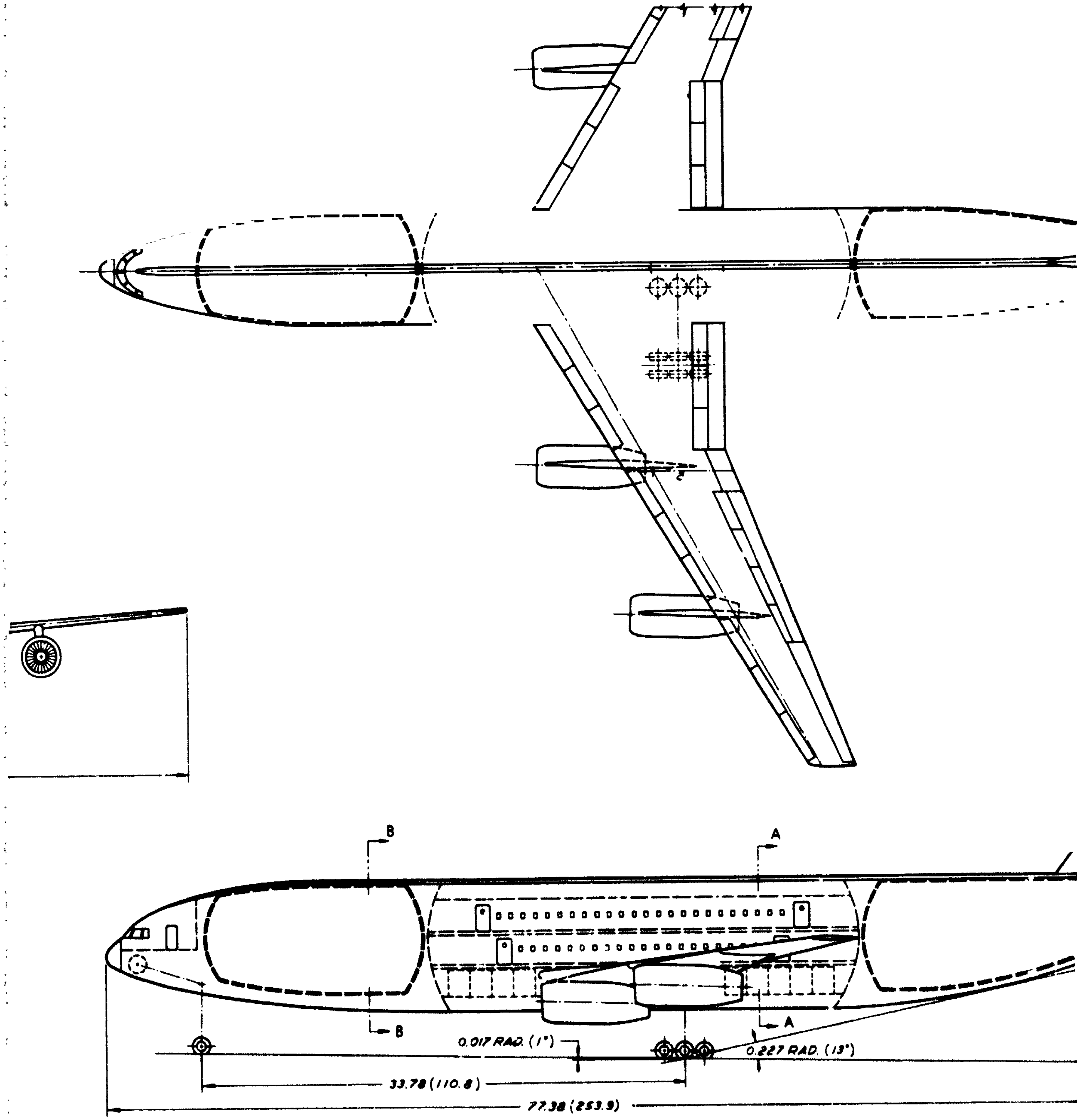

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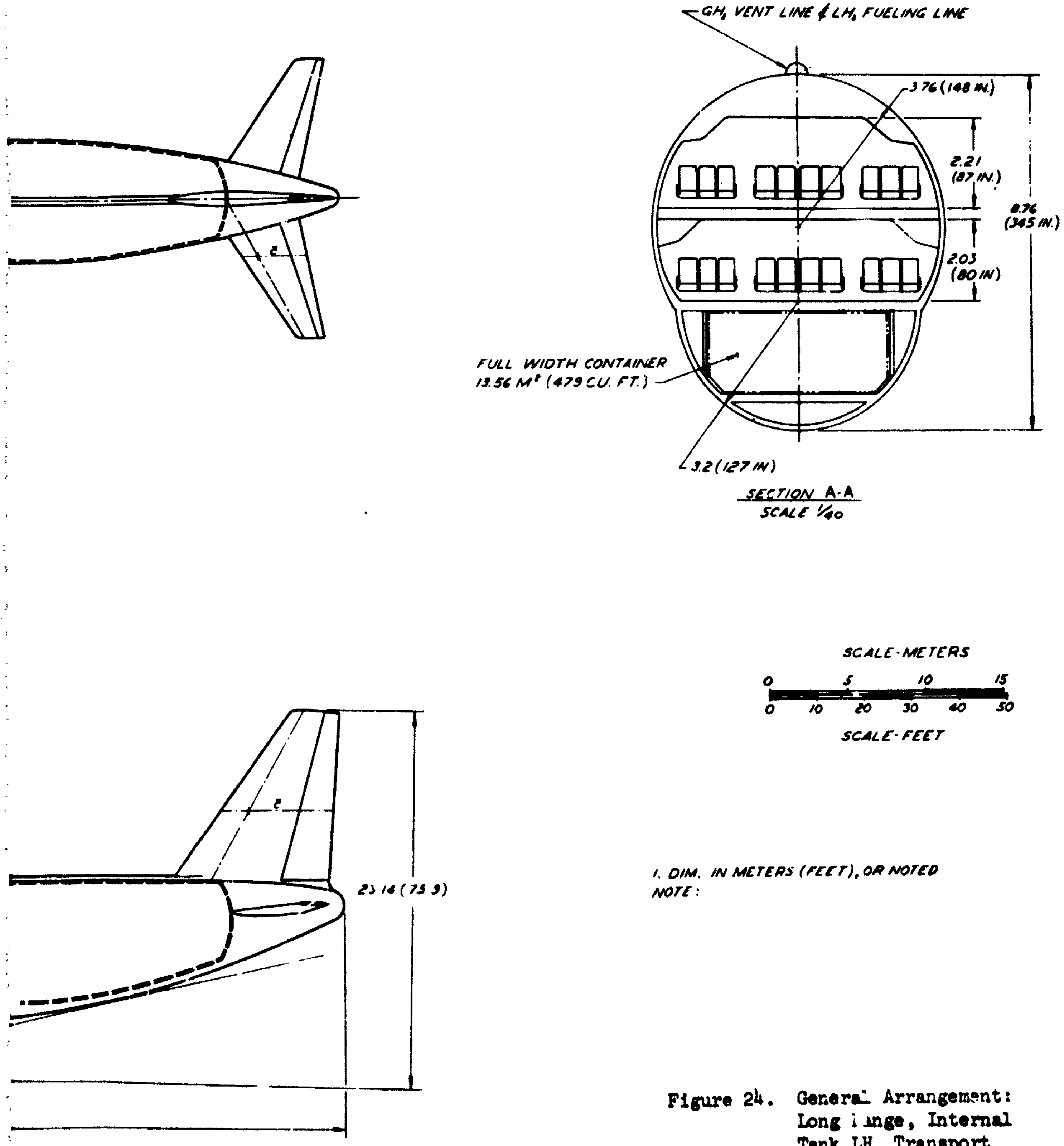
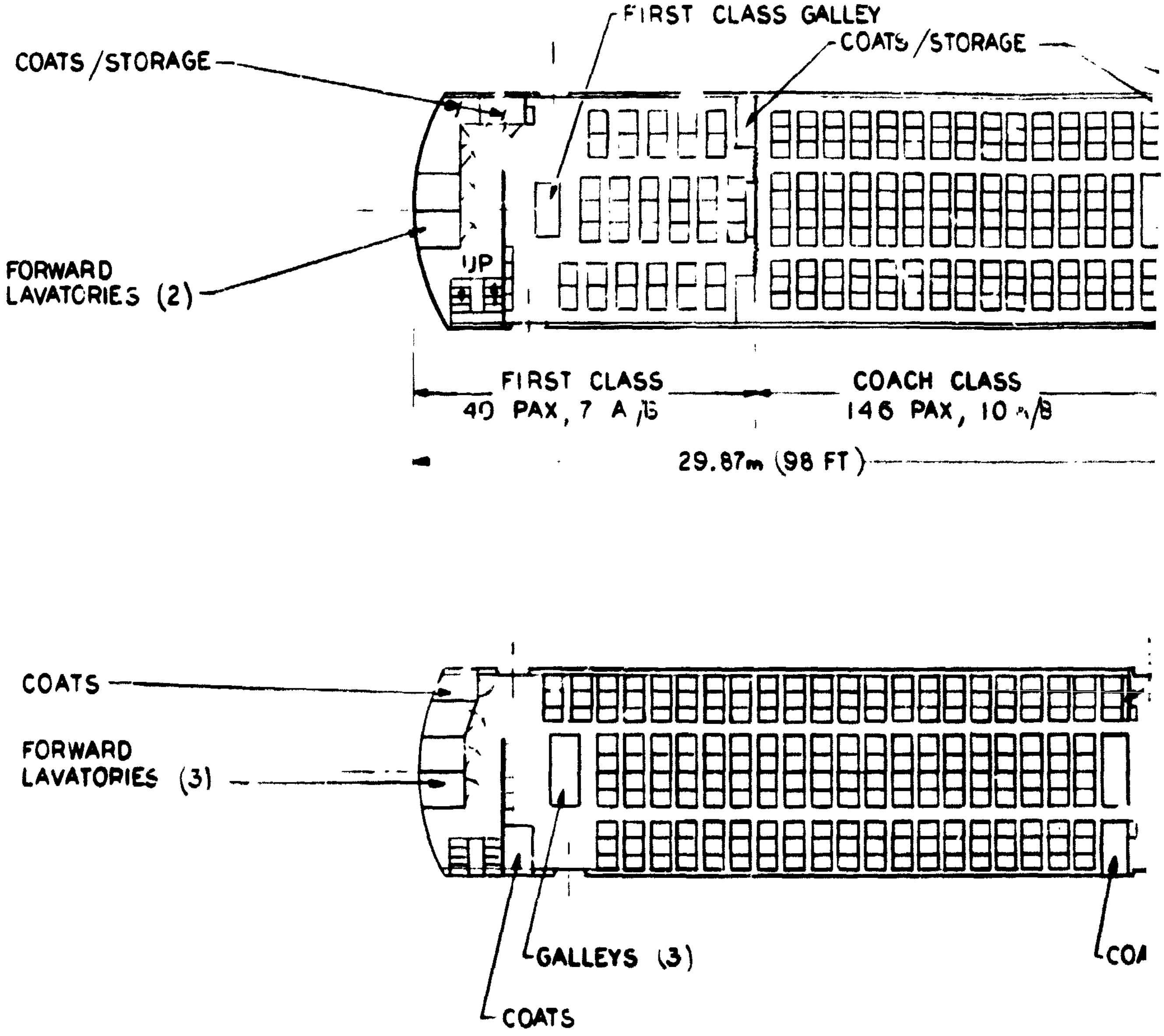
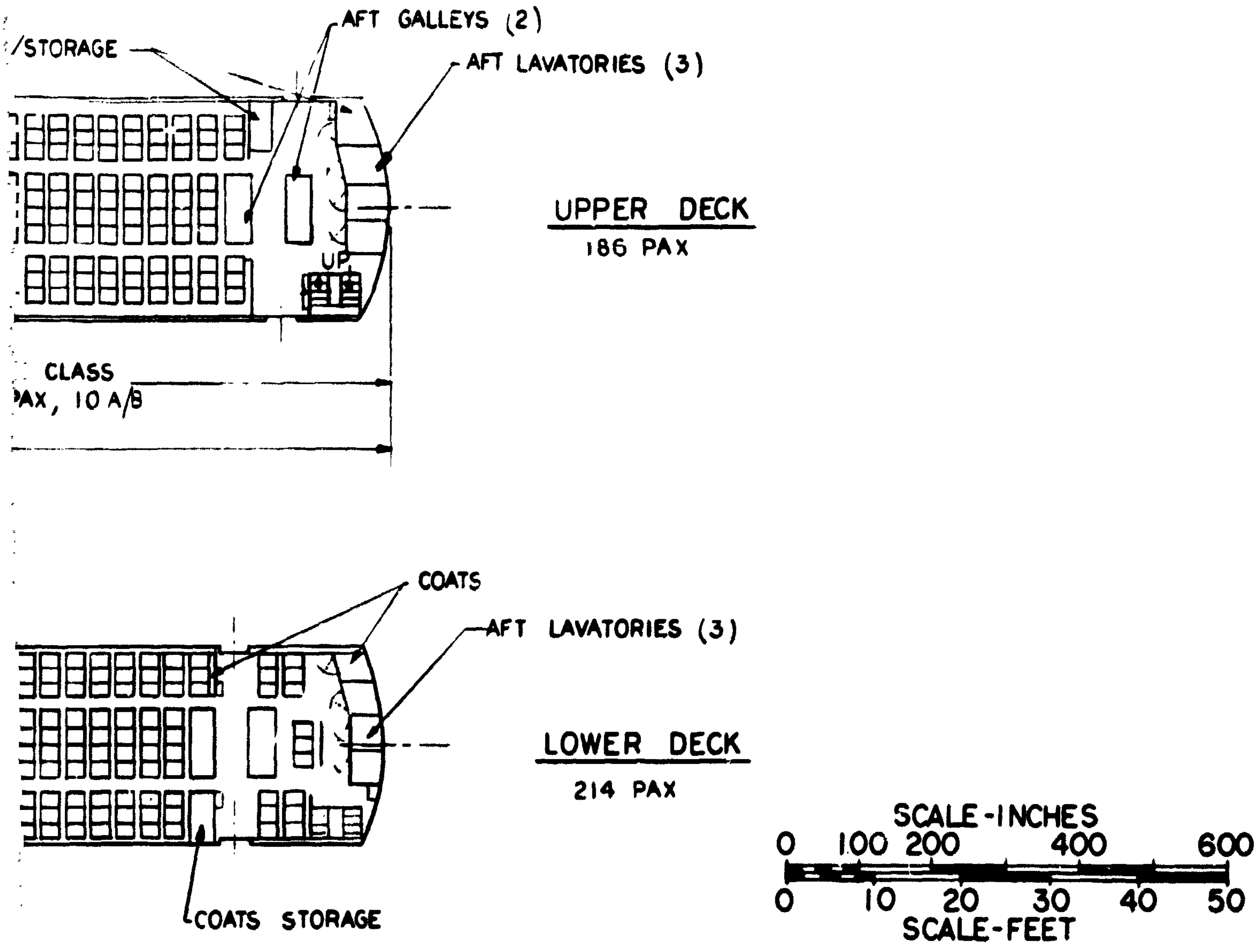


Figure 24. General Arrangement: Long Range, Internal Tank LH_2 Transport



SEATING ARRANGEMENT

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



RANGEMENT

= 400

/.96 m (38 IN) SPACING

/.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

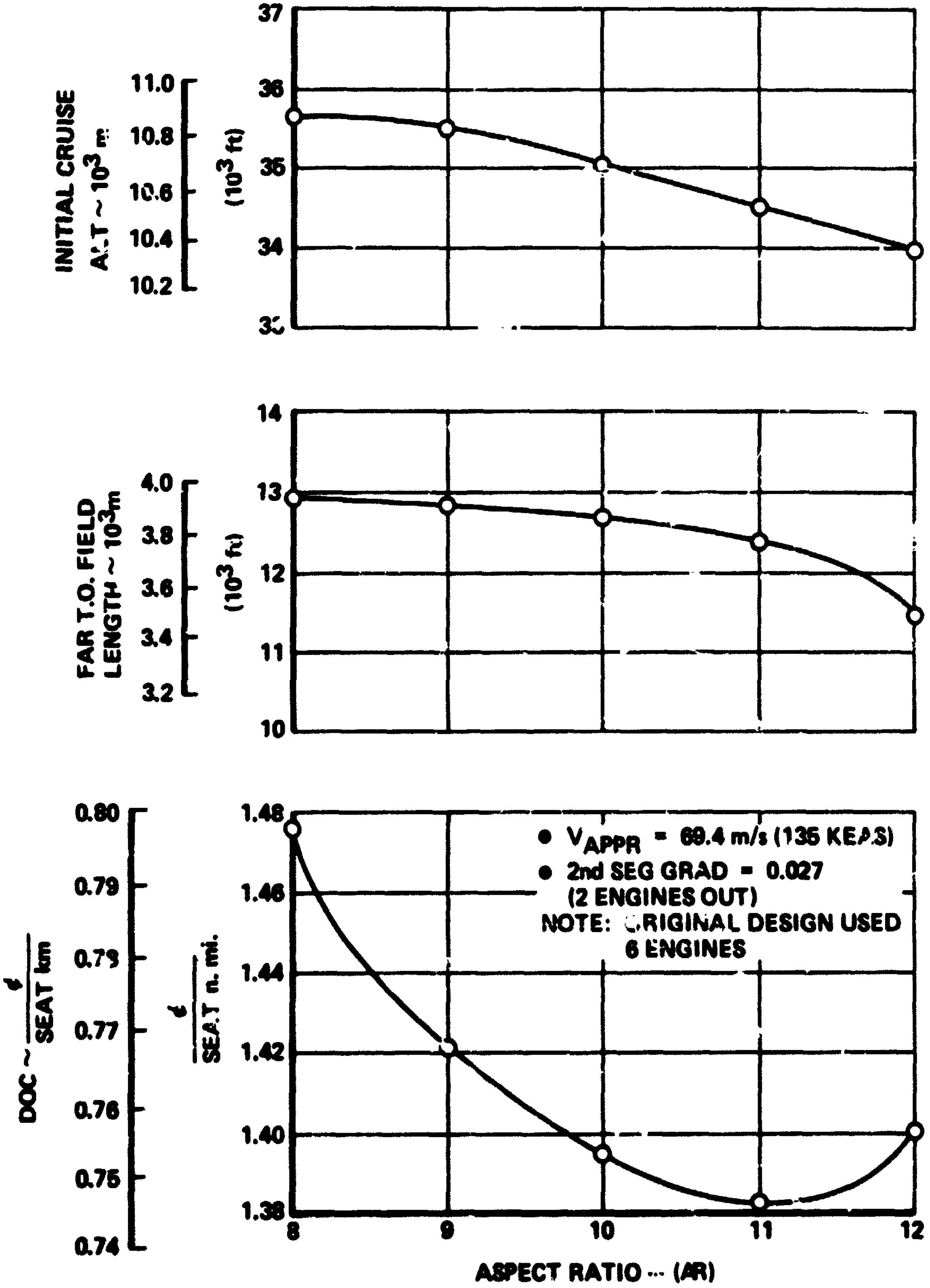


Figure 26. Aspect Ratio Selection for Long Range Jet A Aircraft

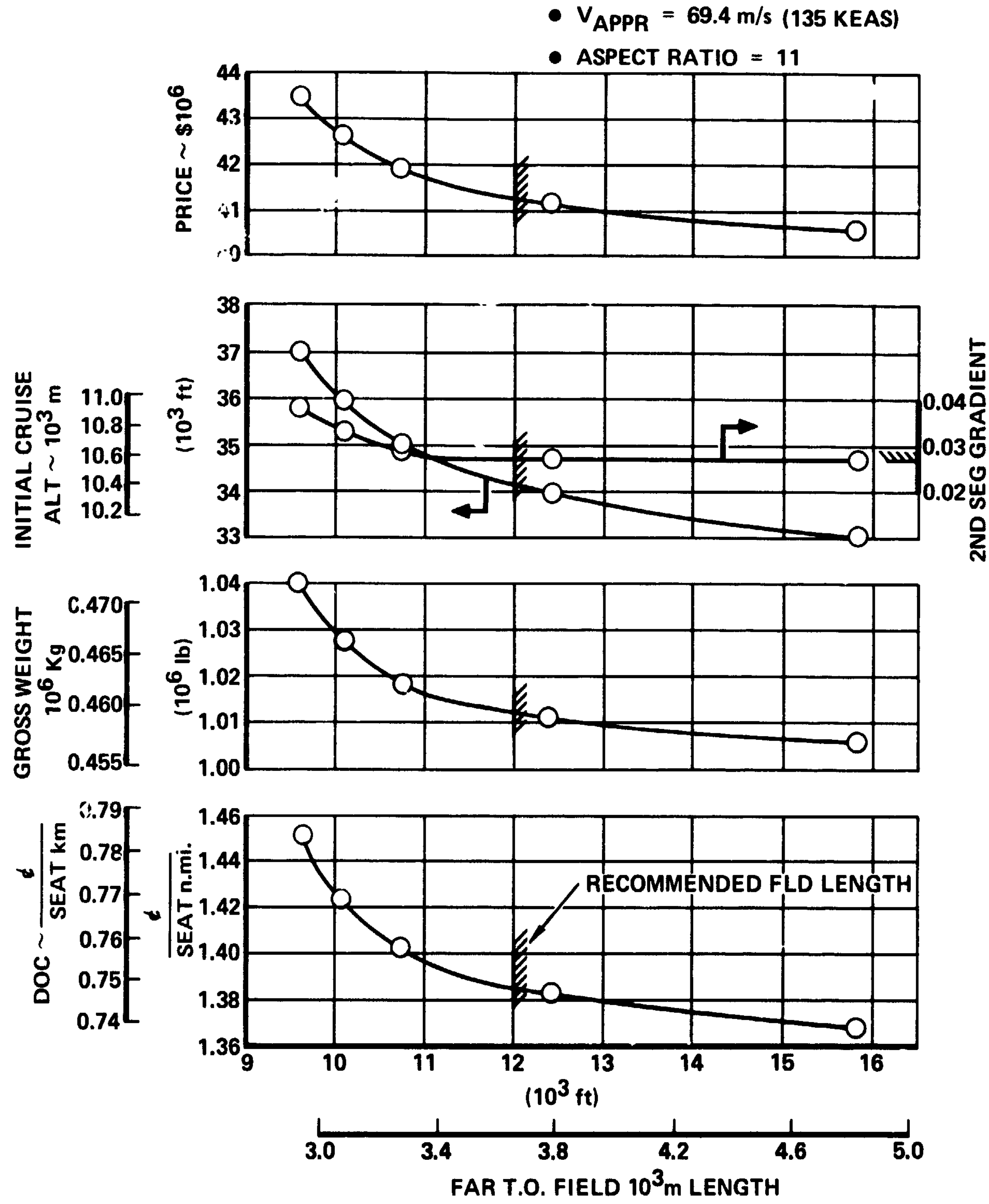


Figure 27. Recommended Field Length for the Long Range, Jet A Aircraft

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.	(312)	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.	(13,120)	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 80 (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

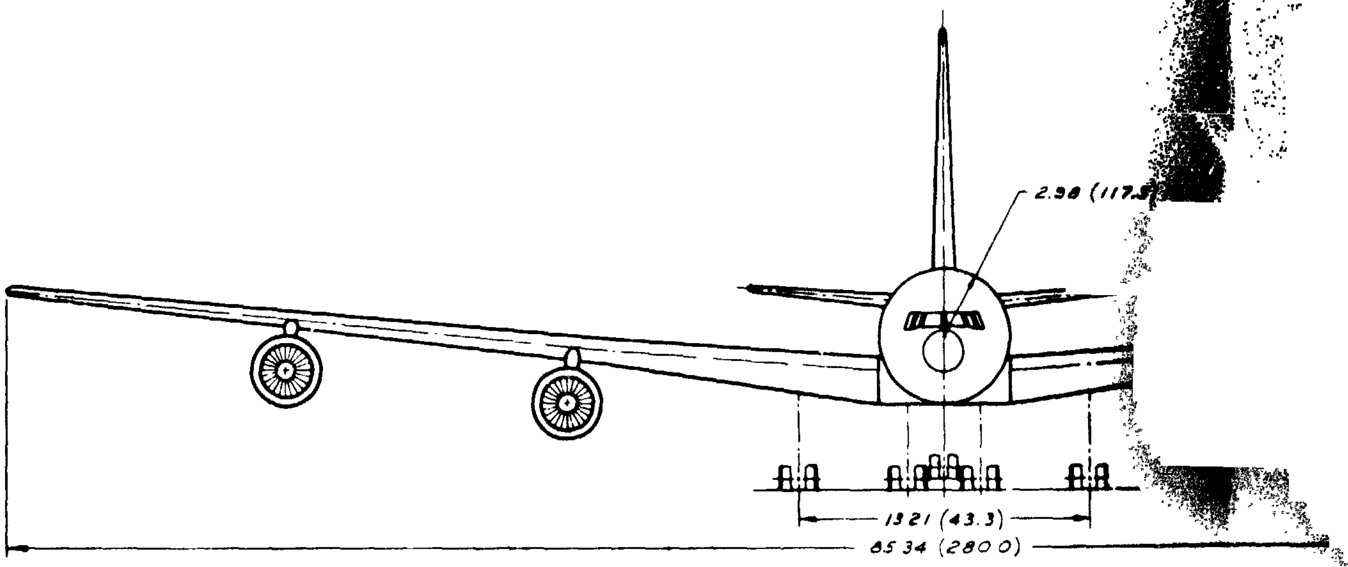
DESIGN GROSS WT - 450,206 KG (99[illegible],517 LB)

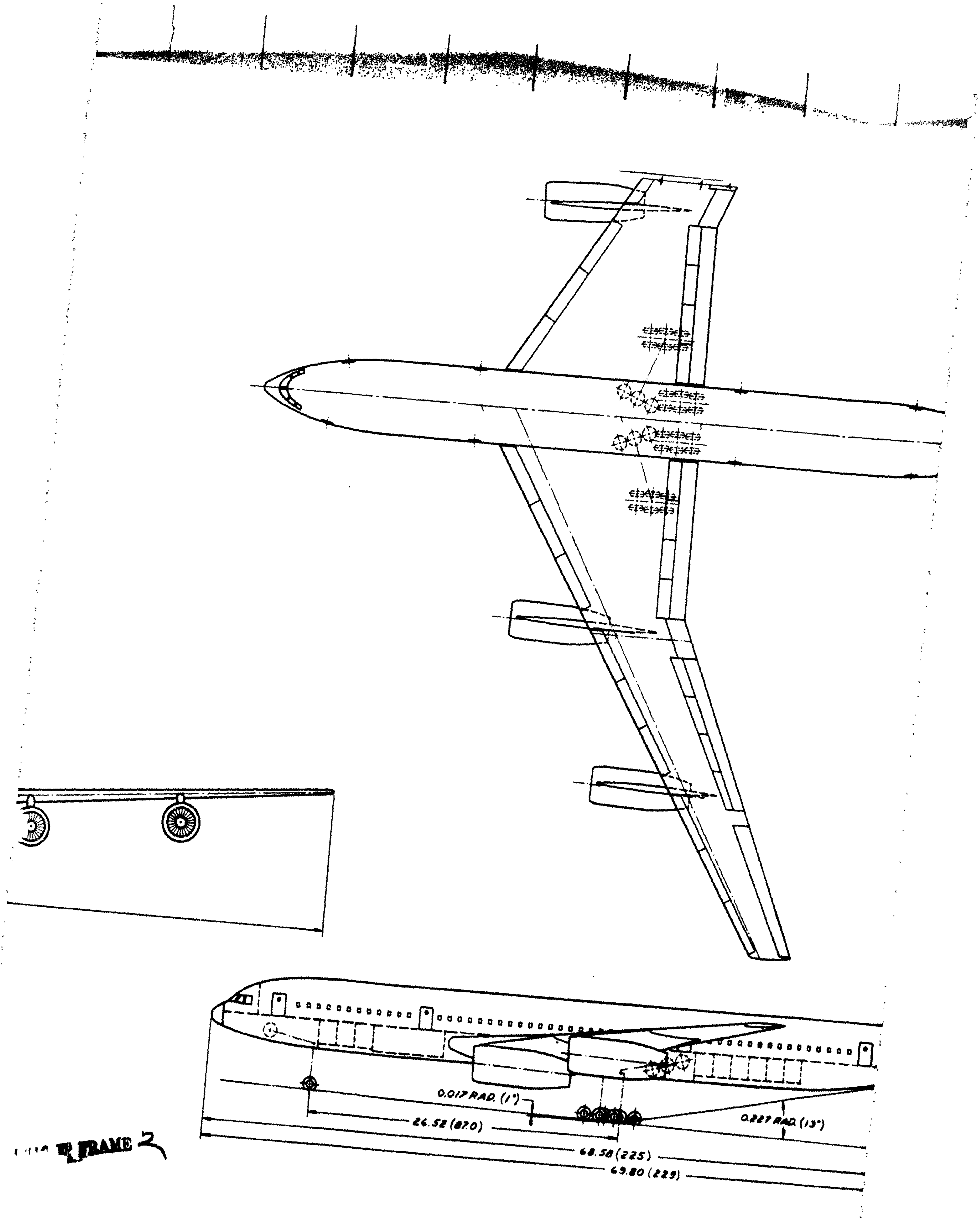
POWER PLANT - (4) TUROFANS
INSTALLED THRUST (EA) - 220,723 N (49,625 LB.)

PASSENGERS - 400

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

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





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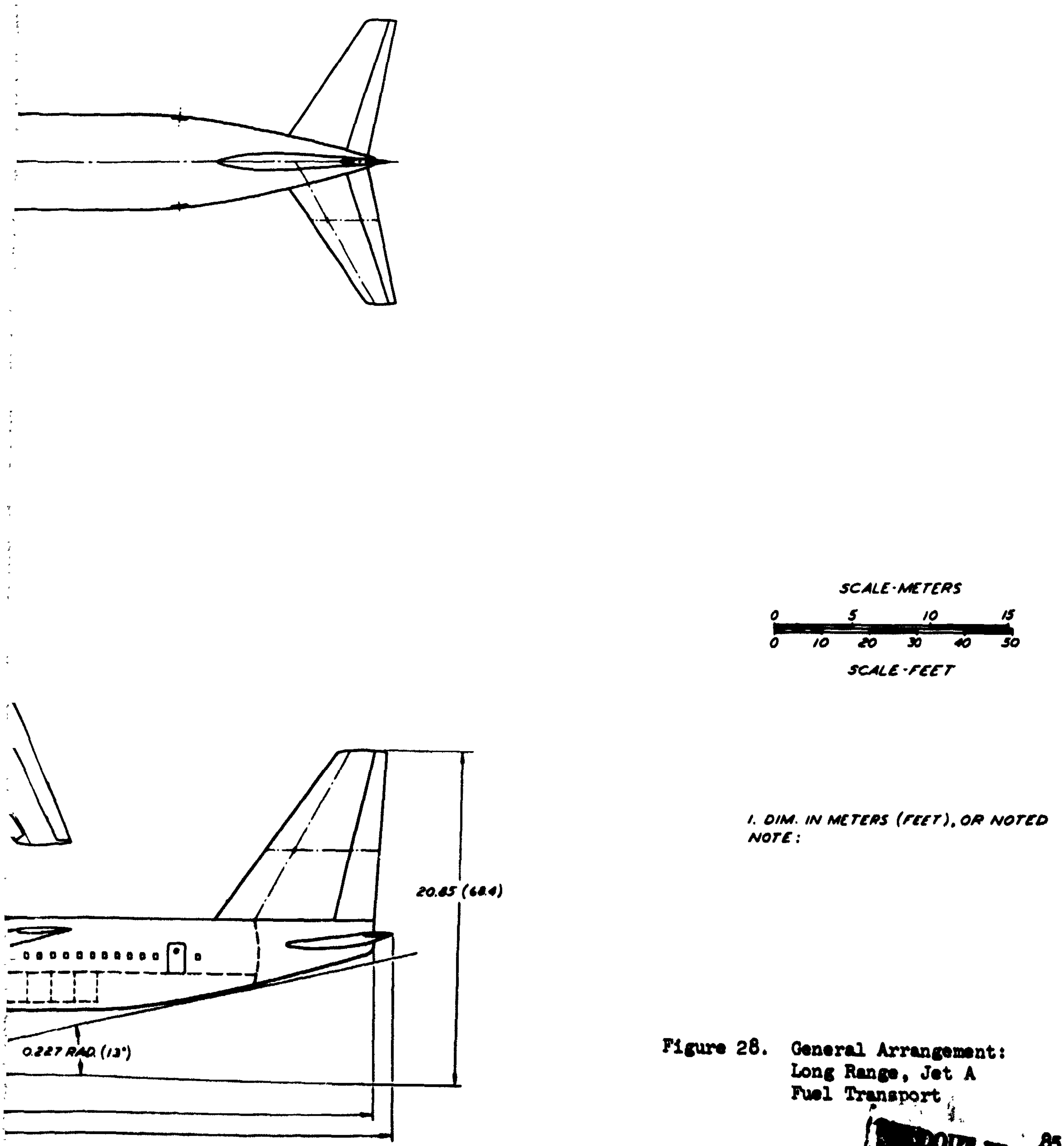
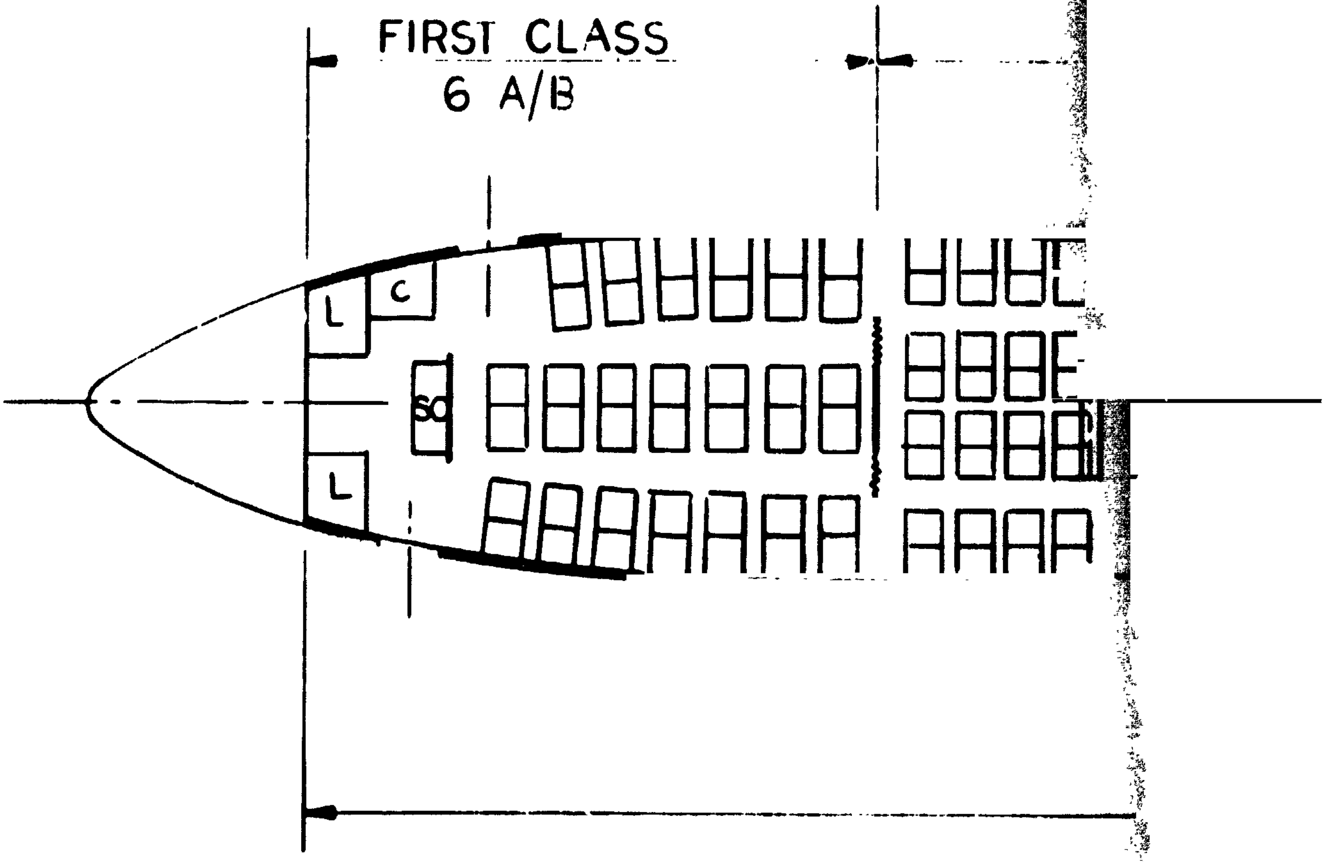


Figure 28. General Arrangement:
Long Range, Jet A
Fuel Transport



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

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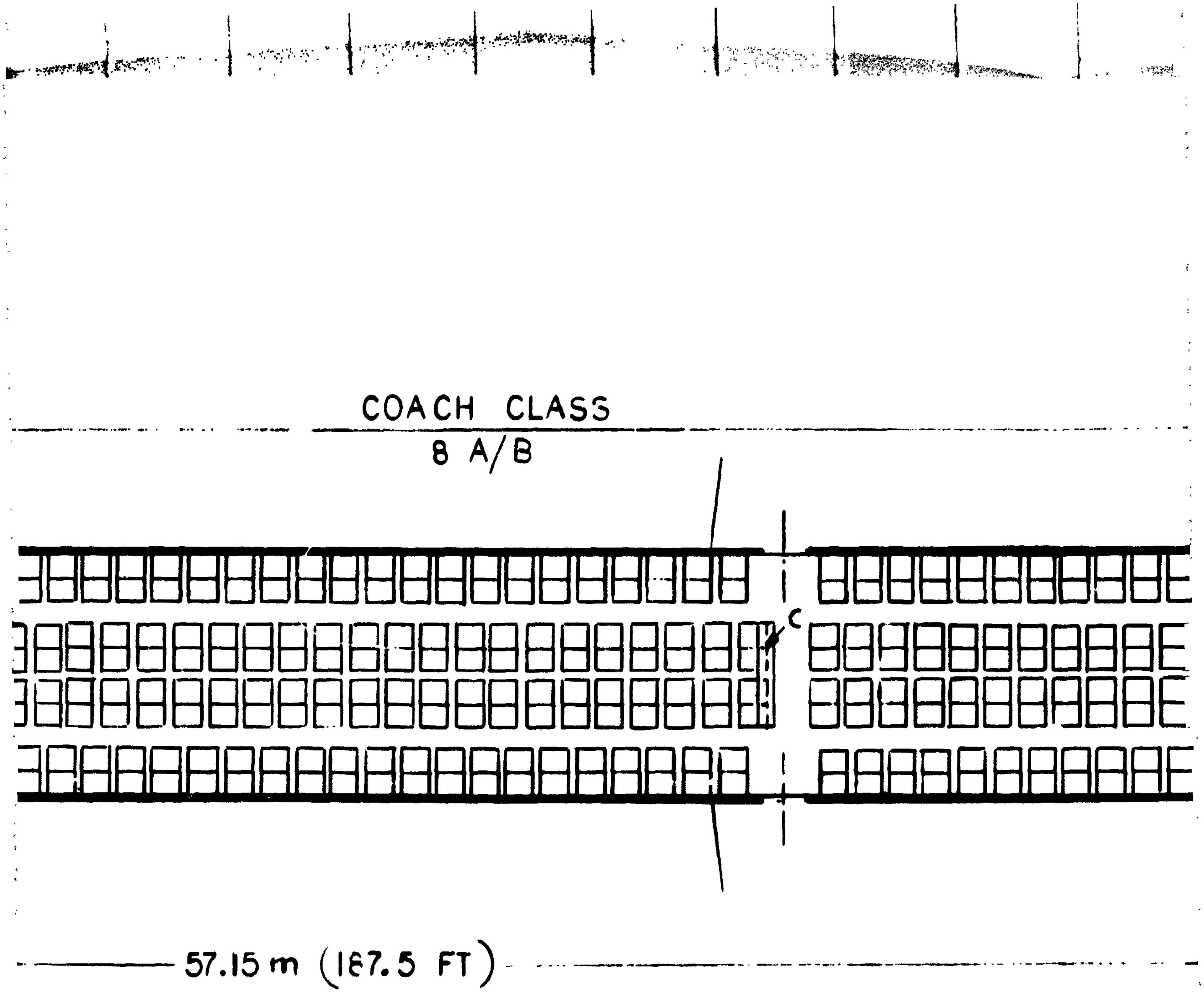
FOLDOUT FRAME



FIRST CLASS: 40 PAX, .96 m (38 IN) SPACING
COACH CLASS: 360 PAX, .86 m (34 IN) SPACING

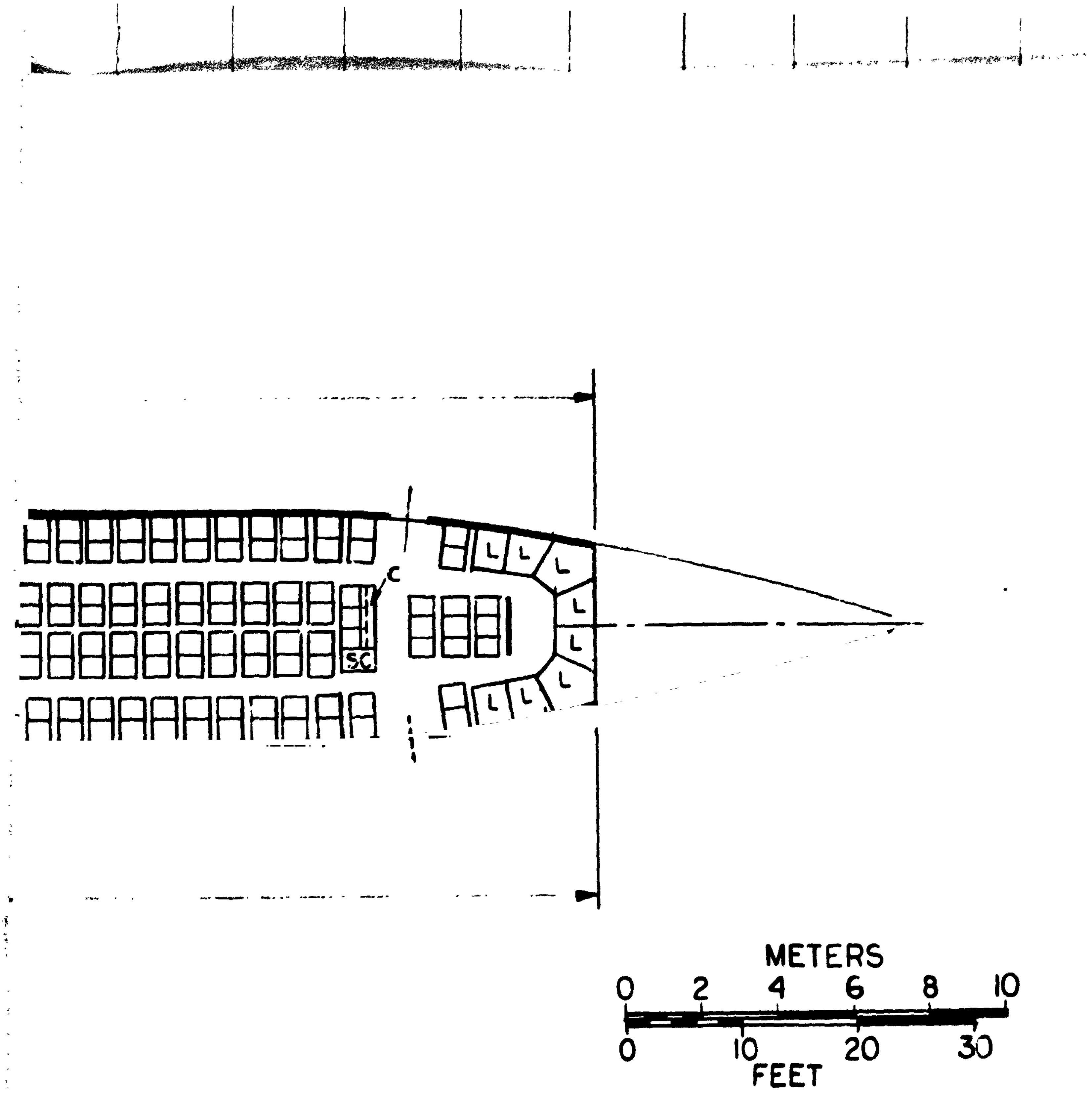


Figure 29. Interior Arrangement:
400 Pax Transport,
Jet A Fuel

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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 $\frac{\text{(Jet A)}}{\text{(Int. } LH_2\text{)}}$
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	$\frac{¢}{\text{seat km}}$	0.738[1]	0.723[2]	0.98
Energy Utilization	$\frac{kJ}{\text{seat km}}$	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.

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 $\frac{\text{(Jet A)}}{(\text{Int } LH_2)}$
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	$\frac{¢}{\text{seat n.mi.}}$	1.366[1]	1.339[2]	0.98
ENERGY UTILIZATION	$\frac{\text{Btu}}{\text{seat n.mi.}}$	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 XV.

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		39.936	
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.

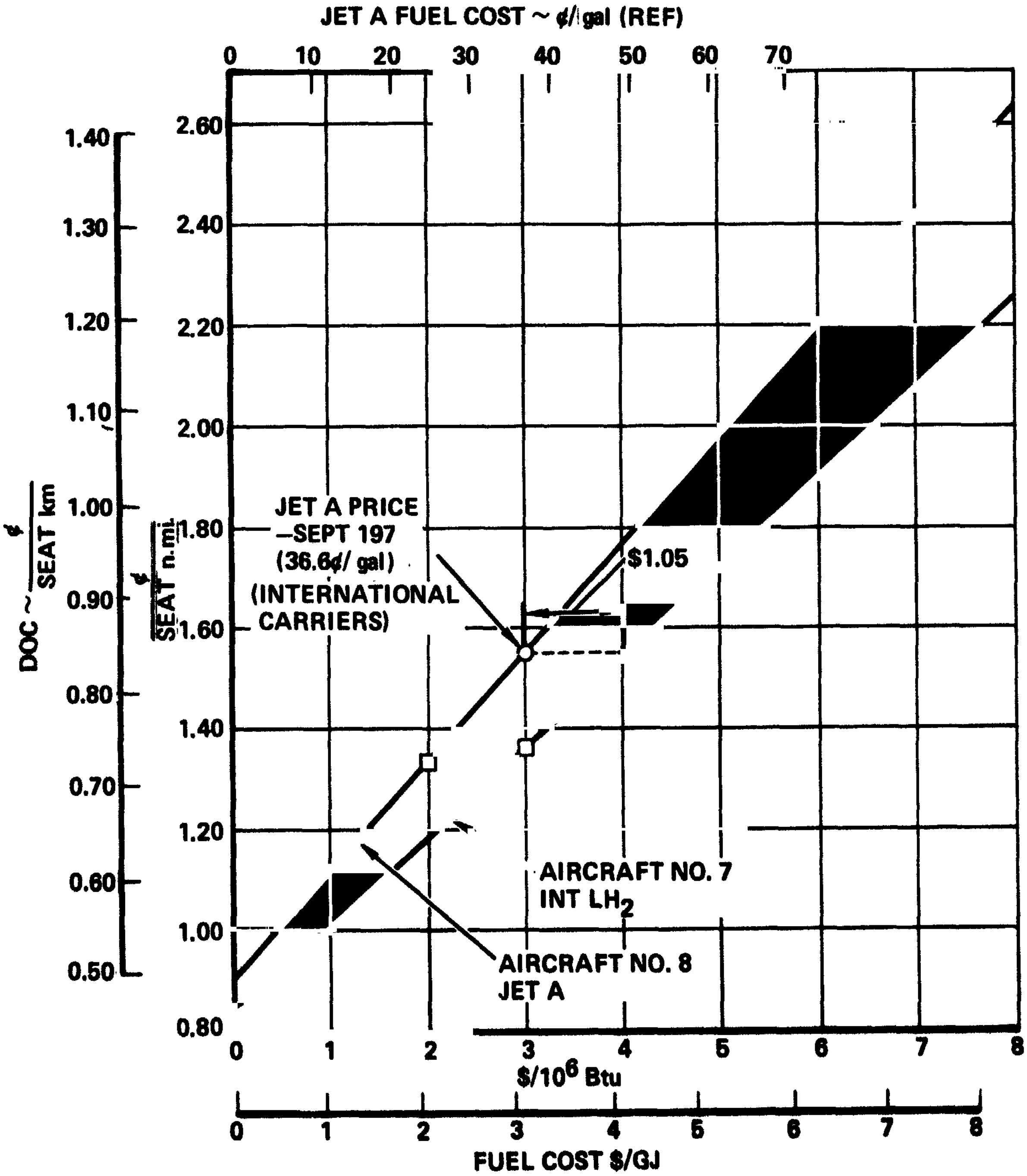

Figure 30. DOC vs Fuel Cost - 5000 n.mi. radius, 400 Pax Aircraft

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	50.38	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

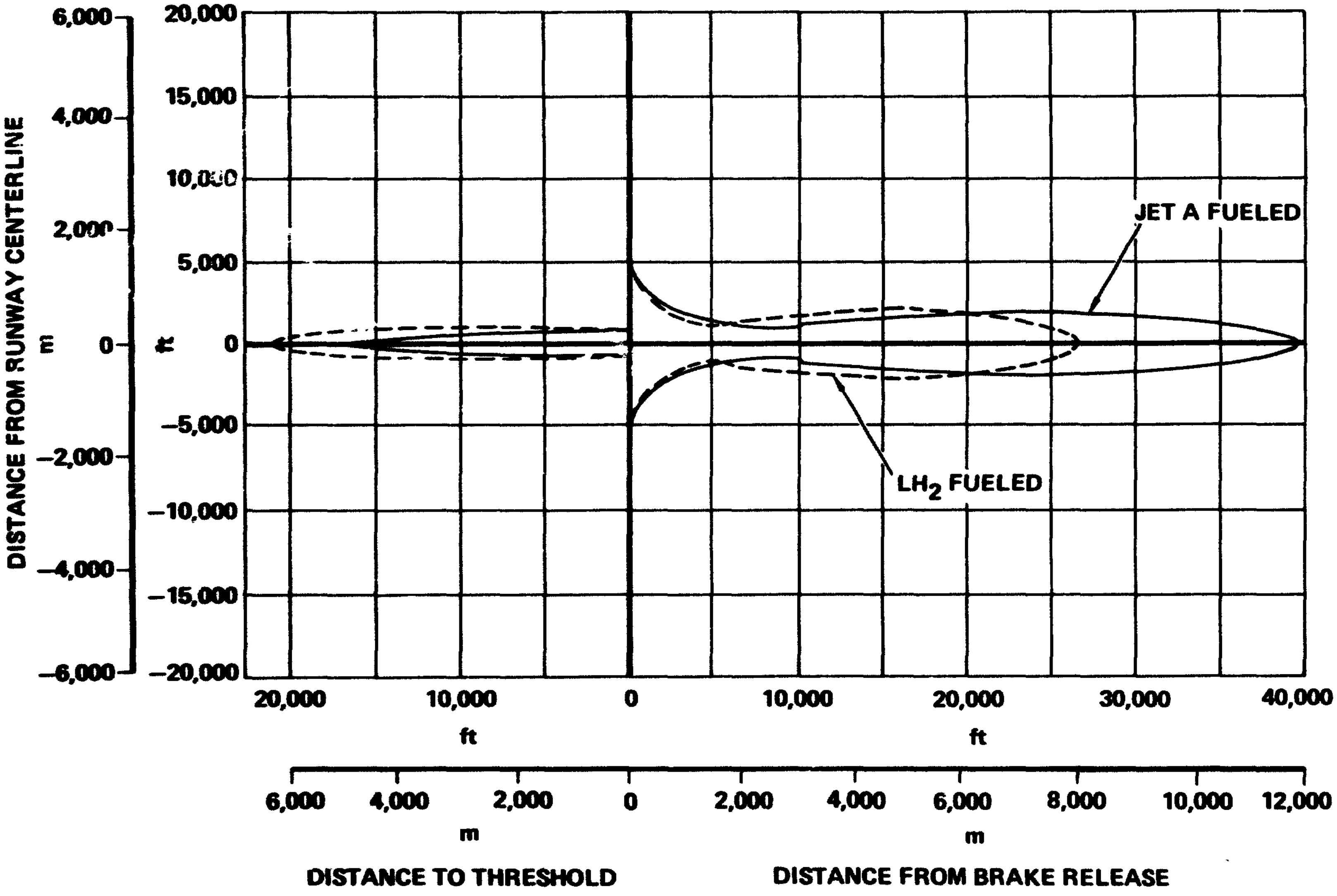

Figure 31. 9 EPNdB Contour Comparison - Long Range Aircraft

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)	70,980	(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	$\$10^6$	39.89		40.27	
DOC	$\frac{¢}{\text{seat km}}\left(\frac{¢}{\text{seat n.mi.}}\right)$	0.738	(1.366)	0.762	(1.412)
Energy Utilization	$\frac{\text{kJ}}{\text{seat km}}\left(\frac{\text{Btu}}{\text{seat n.mi.}}\right)$	964	(1695)	999	(1756)
Growth Factors					
Gross Weight	$\left(\frac{\text{kg}}{\text{kg}}\ \frac{\text{lb}}{\text{lb}}\right)$			1.27	(2.8)
Block Fuel Weight	$\left(\frac{\text{kg}}{\text{kg}}\ \frac{\text{lb}}{\text{lb}}\right)$			0.22	(0.48)
Price	\$/kg \$/lb			304.	(138)
DOC	$\frac{¢}{\text{seat km}/4536\text{ kg}}\left(\frac{¢}{\text{seat n.mi.}/10{,}000\text{ lb}}\right)$			.025	(0.046)
Energy Utilization	$\frac{\text{kJ}}{\text{seat km}/4536\text{ kg}}\left(\frac{\text{Btu}}{\text{seat n.mi.}/10{,}000\text{ lb}}\right)$			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	$\$/\text{kg}\left(\$/\text{lb}\right)$		(0)	434	(197)
DOC	$\frac{¢}{\text{seat km}/4536\text{ kg}}\left(\frac{¢}{\text{seat n.mi.}/10{,}000\text{ lb}}\right)$		(0)	0.032	(0.059)
Energy Utilization	$\frac{\text{kJ}}{\text{seat km}/4536\text{ kg}}\left(\frac{\text{Btu}}{\text{seat n.mi.}/10{,}000\text{ lb}}\right)$		(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

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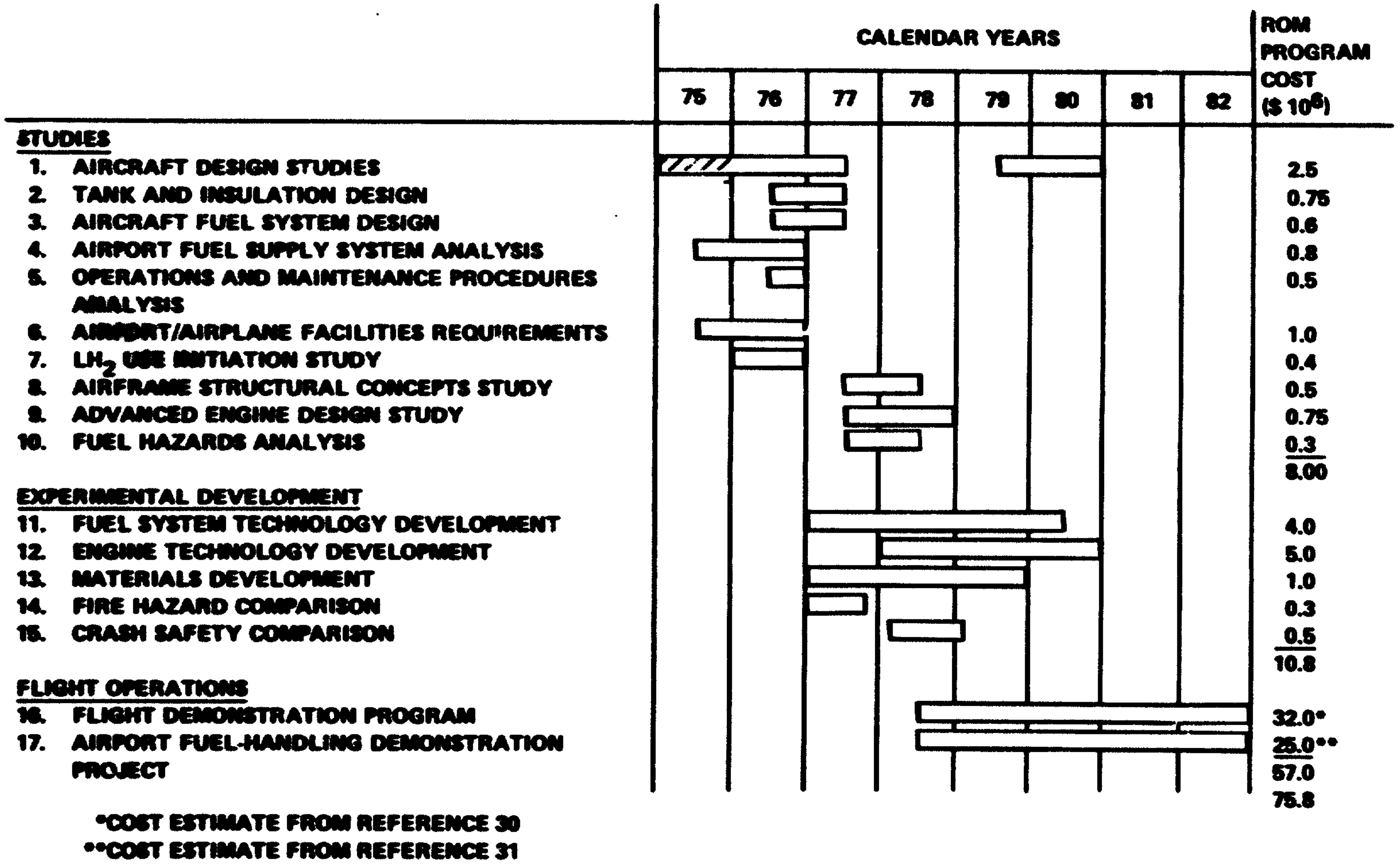
*This study suggested by Stanford Research Institute, September 26, 1975.



	ROM PROGRAM COST ($ 10^6)
STUDIES	
1. AIRCRAFT DESIGN STUDIES	2.5
2. TANK AND INSULATION DESIGN	0.75
3. AIRCRAFT FUEL SYSTEM DESIGN	0.6
4. AIRPORT FUEL SUPPLY SYSTEM ANALYSIS	0.8
5. OPERATIONS AND MAINTENANCE PROCEDURES ANALYSIS	0.5
6. AIRPORT/AIRPLANE FACILITIES REQUIREMENTS	1.0
7. LH_2 USE INITIATION STUDY	0.4
8. AIRFRAME STRUCTURAL CONCEPTS STUDY	0.5
9. ADVANCED ENGINE DESIGN STUDY	0.75
10. FUEL HAZARDS ANALYSIS	0.3
	8.00
EXPERIMENTAL DEVELOPMENT	
11. FUEL SYSTEM TECHNOLOGY DEVELOPMENT	4.0
12. ENGINE TECHNOLOGY DEVELOPMENT	5.0
13. MATERIALS DEVELOPMENT	1.0
14. FIRE HAZARD COMPARISON	0.3
15. CRASH SAFETY COMPARISON	0.5
	10.8
FLIGHT OPERATIONS	
16. FLIGHT DEMONSTRATION PROGRAM	32.0*
17. AIRPORT FUEL-HANDLING DEMONSTRATION PROJECT	25.0**
	57.0
	75.8

*COST ESTIMATE FROM REFERENCE 30

**COST ESTIMATE FROM REFERENCE 31

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.

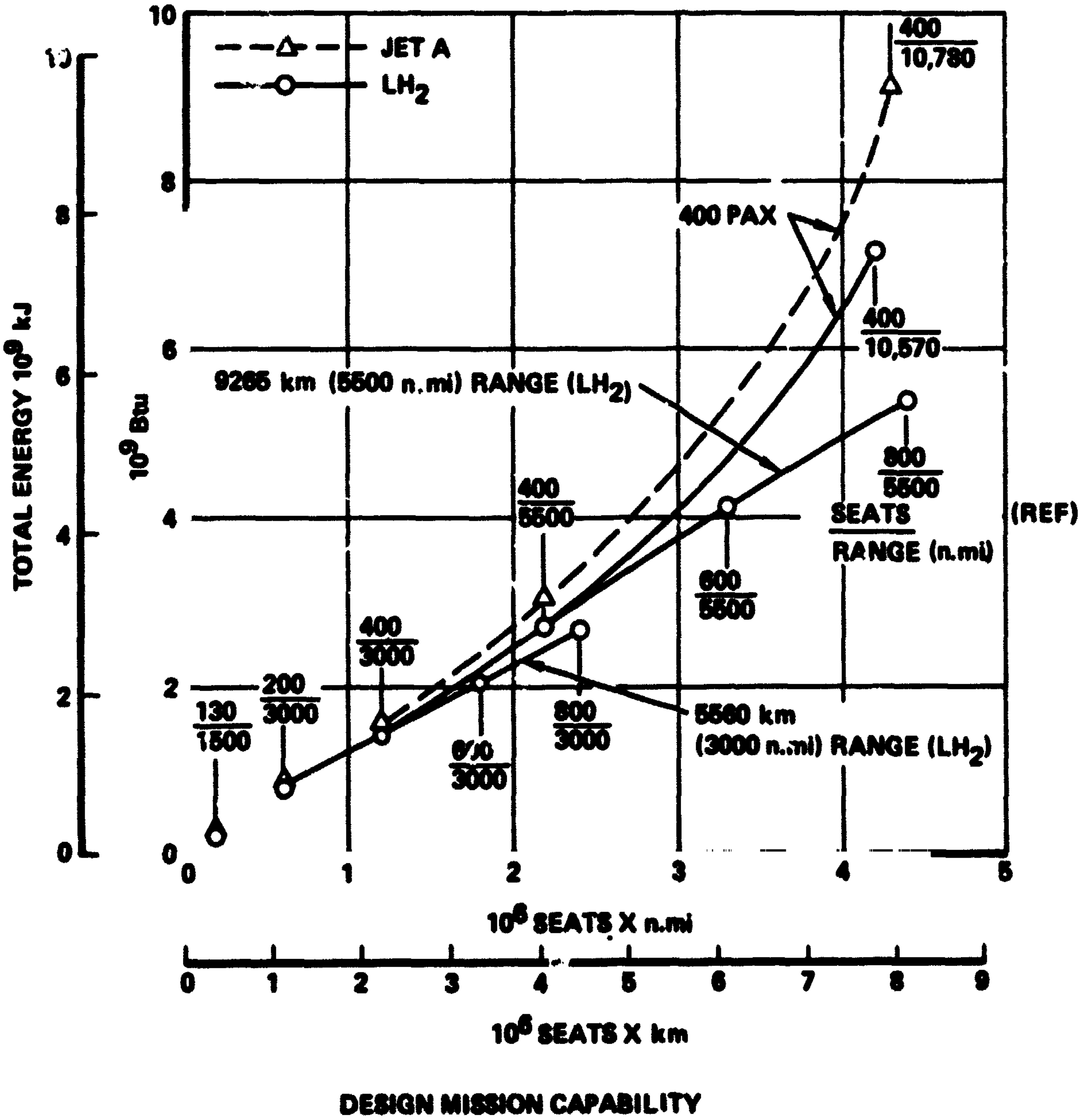


Figure 33. Total Energy vs Design Mission Capability ·

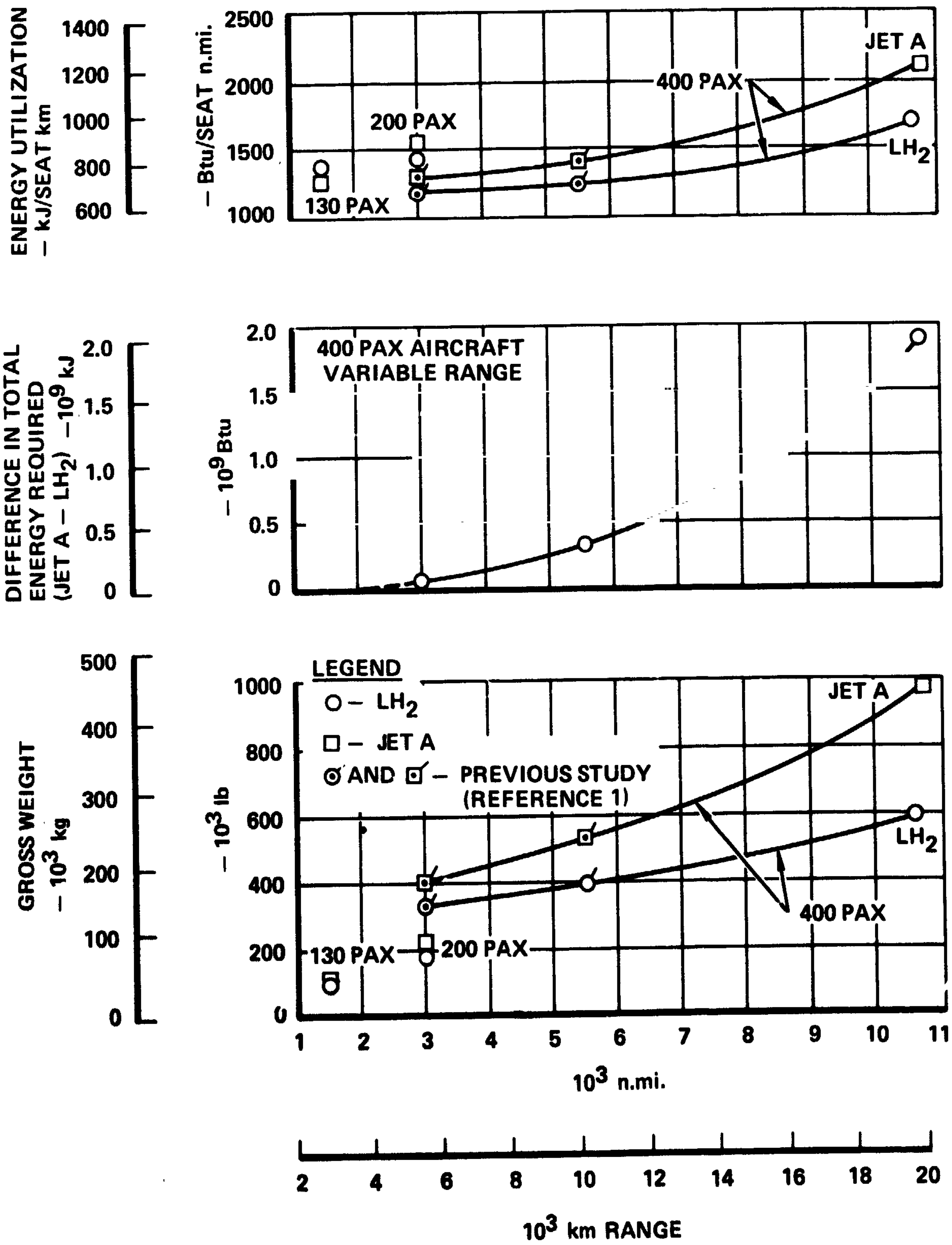


Figure 34. Growth Characteristics

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

```
LIQUID HYDROGEN---BASIC DESIGN MISSION/130 PASS/ 1500 N MI    MISS     INT. LH2

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

           10.00    0.30   10.00   30.00  107.8    0.345


                   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.F.P/CHORD
                                                        (DEG)      (DEG)
                  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)   BWW(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     NO. PODS   INLET L(FT)
                                                                   (SQ. 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

```
                    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
ELFCTRICAL                                          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
```

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

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.	15.29	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

```
                    C O S T   S U M M A R Y

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
PROC. 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

  DIRECT OPERATING COST-DOLLARS/N. MILE     0/0
CREW                                 0.4216   22.95
AIRFRAME LABOR AND BURDEN MAINT.     0.1336    7.27
ENGINE LABOR AND BURDEN MAINT.       0.0531    2.89  RANGE
AIRFRAME MATERIAL MAINT.             0.0689    3.75  N. MI     730.      859.      987.     1115.     1243.     1372.     1500.
ENGINE MATERIAL MAINT.               0.0692    3.77   DOC
FUEL AND OIL                         0.5490   29.89  C/ASM   1.6527    1.5830    1.5314    1.4916    1.4601    1.4344    1.4132
INSURANCE                            0.1114    6.07
DEPRECIATION (INCLUDING SPARES)      0.4303   23.42  TR-HR   1.9360    2.1989    2.4618    2.7247    2.9876    3.2505    3.5134
                                                     $/TRP    1569.     1767.     1965.     2163.     2360.     2558.     2756.

  TOTAL DOC $/N. MILE                1.8371  100.00
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                 R AND D
DEVELOPMENT TECHNICAL DATA      4956555.
DESIGN ENGINEERING            110145660.
DEVELOPMENT TOOLING            53545904.
DEVELOPMENT TEST ARTICLE       17999564.
FLIGHT TEST                    12982084.
SPECIAL SUPPORT EQUIPMENT       1321747.
DEVELOPMENT SPARES             15257614.
ENGINE DEVLEOPMENT                   0.
AVIONICS DEVLEOPMENT                 0.
       TOTAL R AND D                     216209120.
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                              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                 ENGINE I.D. --  83000               WING QUARTER CHORD SWEEP = 30.00 DEG
I.O.C. DATE     --1996                      SLS SCALE 1.0 = 35000               WING TAPER RATIO = 0.300
DESIGN SPEED    --SUBSONIC                  NUMBER OF ENGINES = 2.

  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 SVM(1) 36000   35000   35000   35000   36000   35000   35000   35000 | 36000 |   0      0      0      0      0      0      0
 25 MISSION SVM(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
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LIQUID HYDROGEN---BASIC DESIGN MISSION/130 PASS/ 1500 N MI    MISS    EXT LH2

           T/C     T/F      AR     LAM    W/S      T/W

          16.00    0.40    9.50   30.00  100.0    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  L.E. SWEEP  L.E.R/CHORD
                                                        (DEG)       (DEG)
                  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        10.99       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)   BWW(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)
                   13.60         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      NO. PODS   INLET L(FT)
                                                                      (SQ. FT)
                    9.55         5.93        14.16         6.48        780.37          2.          0.0

FUEL PODS--     VOL(CU FT)    LENGTH(FT)   SPI(SQ FT) S WET(SQ FT)     NO PODS
                 2356.21        45.68        107.33      2290.5           2.
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A-2
Aircraft No. 2
LH_2 External 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    0.40    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-MFG.                                                     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                           10209.
      AIR INTAKE                        1179.
      EXHAUST                            925.
      COOLING                              6.
      OIL SYSTEM (LESS OIL)               11.
      ENGINE CONTROLS                     57.
      ENGINE STARTING                    176.
      TANKS                             2655.
      INSULATION                        3382.
      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                                         146.    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
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                                    M I S S I O N   S U M M A R Y

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

SEGMENT        INIT     INIT     INIT      SEGMT   TOTAL    SEGMT   TOTAL    SEGMT   TOTAL      EXTERN     ENGINE   EXTERN     AVG        AVG
             ALTITUDE   MACH    WEIGHT     FUEL    FUEL     DIST     DIST    TIME    TIME       STORE      THRUST   F TANK     L/D        SFC
               (FT)      NO      (LB)      (LB)    (LB)    (N MI)  (N MI)   (MIN)   (MIN)      TAB ID     TAB ID   TAB ID    RATIO     (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.     93301.       0.      8.82    -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       39000.    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       39000.    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.       9.      9.      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.     11.09     0.175

 CLIMB        10000.    0.547  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.     93301.       0.     11.10     1.701

 DESCENT      10000.    0.456  100617.      67.   9351.      20.    160.      4.4    86.9         0.     93301.       0.     12.24     0.889

 CRUISE       30000.    0.605  100550.     152.   9504.      40.    200.      6.7    93.5         0.    -83101.       0.     13.47     0.184

 LOITER        1500.    0.260  100398.     107.   9611.       0.    200.      6.0    99.5         0.    -83101.       0.     14.28     0.153

TOGRWT=  109901.9     FUEL A=   9615.8     FUEL R=   9610.9
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                    C O S T   S U M M A R Y

WING                                        676719.88
TAIL                                        121069.04
BODY                                        950616.62
LANDING GEAR                                 95033.29
FLIGHT CONTROLS                             115182.63
NACELLES                                    342859.56
  PROPULSION
ENGINE                       14091.92
AIR INDUCTION               100526.69
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                                   71185.56
ELECTRICAL                                  219102.69
ELECTRONIC RACKS                             57967.46
FURNISHING                                  211164.13
AIR CONDITIONING                            153862.19
ANTI ICING                                   11814.62
APU                                          96258.88
SYS. INTEGRATION                             93763.31

  TOTAL EMPTY MFG. COST                                 6620345.00

SUSTAINING ENGINEERI        279089.00
TECHNICAL DATA                   0.0
PROD. TOOLING MAINT.        367671.13
MISC.                       132089.31
ENG. CHANGE ORDER                0.0
QUALITY ASSURANCE           383418.69
AIRFRAME WARRANTY                           257619.06
AIRFRAME FEE                                811500.00
AIRFRAME COST                                           6221501.00
ENGINE WARRANTY                              40858.38
ENGINE FEE                                  226447.06
ENGINE COST                                             2113469.00
AVIONICS COST                                            220000.00
RESEARCH AND DEVELOPMENT                                 784744.56
                TOTAL FLY AWAY COST                                 9339714.00

  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  RANGE
AIRFRAME MATERIAL MAINT.            0.0785    3.62  N. MI      657.       797.       939.      1079.      1219.      1359.      1500.
ENGINE MATERIAL MAINT.              0.0952    4.39   DOC
FUEL AND OIL                        0.7209   33.23  C/ASM    2.0051     1.8997     1.8259     1.7713     1.7293     1.6960     1.6689
INSURANCE                           0.1320    6.09
DEPRECIATION (INCLUDING SPARES)     0.5140   23.69  TP-HP    1.7696     2.0579     2.3461     2.6343     2.9226     3.2108     3.4991
                                                    $/TRP     1712.      1969.      2226.      2483.      2740.      2997.      3254.
  TOTAL DOC $/N. MILE               2.1696  100.00
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             R AND D
DEVELOPMENT TECHNICAL DATA         6910823.
DESIGN ENGINEERING               153573672.
DEVELOPMENT TOOLING               58828632.
DEVELOPMENT TEST ARTICLE          20597352.
FLIGHT TEST                       14199478.
SPECIAL SUPPORT EQUIPMENT          1842886.
DEVELOPMENT SPARES                18708608.
ENGINE DEVLEOPMENT                       0.
AVIONICS DEVLEOPMENT                     0.
       TOTAL R AND D                       274660352.
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                      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-II                  ENGINE I.D. --  83000            WING QUARTER CHORD SWEEP = 30.00 DEG
I.O.C. DATE     --1990                       SLS SCALE 1.0   35000            WING TAPER RATIO = 0.400
DESIGN SPEED    --SUBSONIC                   NUMBER OF ENGINES = 2.

  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    0.42    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  109620  109255  109221  109901     0     0     0     0     0     0     0     0     0     0     0
  7 FUEL WEIGHT        9579    9705    9901   10108    9615     0     0     0     0     0     0     0     0     0     0     0
  8 OP. WT. EMPTY     71385   71016   70753   70512   71686     0     0     0     0     0     0     0     0     0     0     0
  9 ZERO FUEL WT.     99985   99916   99352   99112  100286     0     0     0     0     0     0     0     0     0     0     0
 10 THRUST/ENGINE     24652   24050   23479   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.    996.    993.    993.   1018.    0.    0.    0.    0.    0.    0.    0.    0.    0.    0.    0.
 13 WING SPAN          97.3    97.2    97.1    97.1    98.3   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   6.940   6.930   7.006   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    6706    6874    7030    6447     0     0     0     0     0     0     0     0     0     0     0
CONSTRAINT OUTPUT
 26 CEILING MAP(1)    38665   39152   37716   37133   38700     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)    169.6   169.6   169.3   169.2   168.6   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)     6584    6579    6569    6560    6499     0     0     0     0     0     0     0     0     0     0     0
 35 AP SPEED-KT(3)    137.5   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
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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)
                  14.16          4.24        10.08        12.86      1602.8      10.08

WING TANK--     CCAR1(FT)    CCAR2(FT)     FTL(FT)  FVWINC(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)  SPI(SQ FT)
                  113.00       4077.0       13.00       13.32       139.30

                   HW(FT)       BH(FT)      SRW(SQ FT)   FVF(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)
                  132.66        96.25         9.60      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
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A-3
Aircraft No. 3
JET A Fueled
130 PAX, 1500 n mi range
Mach 0.85

ORIGINAL PAGE IS
OF POOR QUALITY

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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                           865.
      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
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                                    M I S S I O N    S U M M A R Y

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

SEGMENT        INIT     INIT     INIT      SEGMT   TOTAL   SEGMT    TOTAL   SEGMT   TOTAL     EXTERN   ENGINE   EXTERN    AVG       AVG
             ALTITUDE   MACH    WEIGHT     FUEL    FUEL    DIST     DIST    TIME     TIME     STORE    THRUST   F TANK    L/D       SFC
               (FT)      NO      (LB)      (LB)    (LB)   (N MI)  (N MI)   (MIN)    (MIN)    TAB ID   TAB ID   TAB ID   RATIO    (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.   0.628  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.   0.628   96637.       43.  12064.       9.   1326.     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.    17.59    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.   0.376   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   90998.      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.      163.  19055.      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   89580.      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

TOGRWT=  108657.7      FUEL A=  19704.4      FUEL B=  19672.9
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                    C O S T   S U M M A R Y

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                                                      R AND D
ENG. CHANGE ORDER            0.0                                       DEVELOPMENT TECHNICAL DATA      5278414.
QUALITY ASSURANCE       313187.81                                      DESIGN ENGINEERING            117298096.
AIRFRAME WARRANTY                    215754.00                         DEVELOPMENT TOOLING            65516176.
AIRFRAME FEE                         674625.13                         DEVELOPMENT TEST ARTICLE       16988560.
AIRFRAME COST                                    5210460.00            FLIGHT TEST                    16059858.
ENGINE WARRANTY                       59509.50                         SPECIAL SUPPORT EQUIPMENT       1407576.
ENGINE FEE                           149963.75                         DEVELOPMENT SPARES             14251270.
ENGINE COST                                      1399663.00            ENGINE DEVLEOPMENT                    0.
AVIONICS COST                                     220600.00            AVIONICS DEVLEOPMENT                  0.
RESEARCH AND DEVELOPMENT                          676571.19                 TOTAL R AND D               236799904.
              TOTAL FLY AWAY COST                          7506694.00

  DIRECT OPERATING COST-DOLLARS/N. MILE        O/O
CREW                                 0.4231   25.50
AIRFRAME LABOR AND BURDEN MAINT.     0.1286    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
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                                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                  ENGINE I.D. --   81000              WING QUARTER CHORD SWEEP = 30.00 DEG
I.O.C. DATE     --1990                       SLS SCALE 1.0 = 35000              WING TAPER RATIO = 0.300
DESIGN SPEED    --SUBSONIC                   NUMBER OF ENGINES = 2.

  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   108889  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   60563   60353     0     0     0     0     0     0     0     0     0     0     0     0     0     0
  9 ZERO FUEL WT.   89167   88953     0     0     0     0     0     0     0     0     0     0     0     0     0     0
 10 THRUST/ENGINE   19163   18906     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   5.867   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    5140     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. LH2

                  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   L.E. SWEEP   L.E.R/CHORD
                                                            (DEG)        (DEG)
                    1602.3        123.38       0.300       30.000      3.[illegible]76       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     NO. PODS   INLET L(FT)
                                                                         (SQ. FT)
                    6.84           4.62        16.12         5.07        1027.51         4.          0.0
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A-4
Aircraft No. 4
LH_2 Internal Tank
200 PAX, 3000 n mi range
Mach 0.85

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          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   0/0               POUNDS   0/0

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
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                                        M I S S I O N    S U M M A R Y
          LIQUID HYDROGEN---BASIC DESIGN MISSION/200 PASS/ 3000 N MI    MISS

SEGMENT      INIT     INIT    INIT      SEGMT   TOTAL   SEGMT    TOTAL   SEGMT   TOTAL    EXTERN    ENGINE   EXTERN    AVG      AVG
           ALTITUDE   MACH   WEIGHT     FUEL    FUEL    DIST     DIST    TIME    TIME     STORE     THRUST   F TANK    L/D      SFC
             (FT)      NO     (LB)      (LB)    (LB)   (N MI)  (N MI)   (MIN)   (MIN)    TAB ID    TAB ID   TAB ID   RATIO    (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    55.9        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
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                    C O S T   S U M M A R Y

WING                                   976538.75
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                                                    R AND D
ENG. CHANGE ORDER            0.0                                      DEVELOPMENT TECHNICAL DATA     8206321.
QUALITY ASSURANCE       609190.19                                     DESIGN ENGINEERING           182362704.
AIRFRAME WARRANTY                      409115.56                      DEVELOPMENT TOOLING           88812128.
AIRFRAME FEE                          1288713.00                      DEVELOPMENT TEST ARTICLE      32720032.
AIRFRAME COST                                      9880140.00         FLIGHT TEST                   21019664.
ENGINE WARRANTY                        107985.88                      SPECIAL SUPPORT EQUIPMENT      2188352.
ENGINE FEE                             272124.19                      DEVELOPMENT SPARES            26927328.
ENGINE COST                                        2539828.00         ENGINE DEVLEOPMENT                   0.
AVIONICS COST                                       500000.00         AVIONICS DEVLEOPMENT                 0.
RESEARCH AND DEVELOPMENT                           1034958.94              TOTAL R AND D                   362235392.
           TOTAL FLY AWAY COST -                               13954926.00

  DIRECT OPERATING COST-DOLLARS/N. MILE    0/0
CREW                                  0.3948  14.76
AIRFRAME LABOR AND BURDEN MAINT.      0.1702   6.36
ENGINE LABOR AND BURDEN MAINT.        0.0886   3.31  RANGE
AIRFRAME MATERIAL MAINT.              0.0981   3.67  N. MI      884.     1236.     1589.     1942.     2295.     2647.     3000.
ENGINE MATERIAL MAINT.                0.1006   3.76   DOC
FUEL AND OIL                          0.9237  34.53  C/ASM    1.6195    1.5055    1.4421    1.4018    1.3738    1.3533    1.3376
INSURANCE                             0.1855   6.93
DEPRECIATION (INCLUDING SPARES)       0.7139  26.68  TB-HR    2.2501    2.9716    3.6932    4.4147    5.1363    5.8578    6.5794
                                                     $/TRP    2862.     3723.     4583.     5444.     6305.     7165.     8026.
  TOTAL DOC $/N. MILE                 2.6753 100.00
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                              T A K E O F F   P E R F O R M A N C E

POWER     ENGOP     OVERSPD    WEIGHT      FLAP
 CLRN     CORNI      DCDSTA     CDRN       CLRT      CDRT1      DCDSTA      CDRT     DCLSPO      CLST      CLST1     DCDSPO     CDST
 CLTO      TWTO      LDTO      CLCLMB     TWCLMB     LDCLMB      CL2        TW2       LD2
VSTALL      V1       VROT       VTD         V2         XG        XG1       XRDT       XOB        XTO       FIELDL     GRAD

 83401.     4.00       1.00    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   0.19729
 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   0.19729
 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


                    B R A K I N G   R U N   C O E F F I E N T S---L A N D I N G
                    CLRN    DCLSPO   CLGRD    CDGRD1   DCDSPO   DCDSPA   CDGRD

                   0.75479 -0.76500 -0.01021  0.19626  0.06850  0.01960  0.28436


                         L A N D I N G   P E R F O R M A N C E

                 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
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                              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                   ENGINE I.D. --  83000                WING QUARTER CHORD SWEEP = 30.00 DEG
I.O.C. DATE    --1990                        SLS SCALE 1.0 = 35000                WING TAPER RATIO = 0.300
DESIGN SPEED   --SUBSONIC                    NUMBER OF ENGINES = 4.

  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  20882  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  2.537  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  16938  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
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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  L.E. SWEEP  L.E.R/CHORD
                                                         (DEG)      (DEG)
                   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       318.20

                   BW(FT)       BH(FT)     SBW(SQ FT)   FVF(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       264.64       264.64       14.10

PROPULSION--       ENG L(FT)    ENG D(FT)    POD L(FT)    POD D(FT)   POD S WET      NO. PODS  INLET L(FT)
                                                                      (SQ. 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.
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A-5
Aircraft No. 5
LH_2 External Tank
200 PAX, 3000 n mi range

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                  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   0/0                POUNDS   0/0

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                       49.
      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
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ORIGINAL PAGE IS
OF POOR QUALITY

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

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	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	36000.	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

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TOGWT=  207346.1      UEL A=  27229.1      FUEL W=  27233.0


                  C O S T   S U M M A R Y

WING                                    1274539.00
TAIL                                     254304.88
BODY                                    2062172.00
LANDING GEAR                             195907.88
FLIGHT CONTROLS                          195557.56
NACELLES                                 577160.38
   PROPULSION
ENGINE                     23516.38
AIR INDUCTION             169304.09
FUEL SYSTEM              1199342.00
START SYSTEM                4735.46
ENGINE CONTROLS             1001.19
EXH/THRUST REV.             2095.65
LUBE SYSTEM                 2121.73
   TOTAL PROPULSION                     1402995.00

INSTRUMENTS                              156409.69
HYDRAULICS                               134608.19
ELECTRICAL                               342249.56
ELECTRONIC RACKS                          95511.06
FURNISHING                               314515.38
AIR CONDITIONING                         250876.50
ANTI ICING                                16457.63
APU                                       69171.75
SYS. INTEGRATION                         169037.13

   TOTAL EMPTY MFG. COST                              7514463.00

SUSTAINING ENGINEERI    530796.81
TECHNICAL DATA                0.0
PROD. TOOLING MAINT.  6980[illegible]6.96
MISC.                   194183.56                                                   R AND D
ENG. CHANGE ORDER             0.0                                       DEVELOPMENT TECHNICAL DATA     11608136.
QUALITY ASSURANCE       729298.63                                       DESIGN ENGINEERING            257958600.
AIRFRAME WARRANTY                        483382.13                      DEVELOPMENT TOOLING           100268576.
AIRFRAME FEE                            1522653.00                      DEVELOPMENT TEST ARTICLE       38974304.
AIRFRAME COST                                        11673679.00        FLIGHT TEST                    23994432.
ENGINE WARRANTY                          151312.13                      SPECIAL SUPPORT EQUIPMENT       5095502.
ENGINE FEE                               381306.38                      DEVELOPMENT SPARES             33897280.
ENGINE COST                                           3558861.00        ENGINE DEVLEOPMENT                    0.
AVIONICS COST                                          500000.00        AVIONICS DEVLEOPMENT                  0.
RESEARCH AND DEVELOPMENT                              1341131.00               TOTAL R AND D             460395712.
              TOTAL FLY AWAY COST                                 17073664.00

   DIRECT OPERATING COST-DOLLARS/N. MILE      0/0
CREW                                  0.3947  12.14
AIRFRAME LABOR AND BURDEN MAINT.      0.1913   5.88
ENGINE LABOR AND BURDEN MAINT.        0.1067   3.28  RANGE
AIRFRAME MATERIAL MAINT.              0.1162   3.57  N. MI     835.     1195.     1556.     1917.     2278.     2639.     3000.
ENGINE MATERIAL MAINT.                0.1409   4.33   DOC
FUEL AND OIL                          1.1952  36.76  C/ASM   1.9925    1.8390    1.7567    1.7054    1.6703    1.6449    1.6255
INSURANCE                             0.2269   6.98
DEPRECIATION (INCLUDING SPARES)       0.8793  27.05  TB-HR   2.1366    2.8768    3.6170    4.3572    5.0974    5.8377    6.5779
                                                     $/TRP    3325.     4397.     5466.     6539.     7610.     8681.     9752.
   TOTAL DOC $/N. MILE                3.2510 100.00
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                                    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. 104
                                               NOVEMBER 05 1975

AIRCRAFT MODEL  --CL1317-14                   ENGINE I.D. --  E3000                    WING QUARTER CHORD SWEEP = 30.00 DEG
I.O.C. DATE     --1990                        SLS SCALE 1.0 = 35000                    WING TAPER RATIO = 0.400
DESIGN SPEED    --SUBSONIC                    NUMBER OF ENGINES = 4.

  1 W/S             111.2   111.2   111.2   111.2   111.0   111.0   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
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JP FUEL REFERENCE BASELINE DESIGN / 200 PASS / 3000 N MI       .85       JET A

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

                10.00    0.30    9.75   30.00  130.4     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  L.E. SWEEP  L.E.X/CHORD
                                                          (DEG)      (DEG)
                     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      797.88       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)   FVP(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      NO. PODS  INLET L(FT)
                                                                       (SQ. FT)
                      6.89         4.65        16.25         5.07      1034.05          4.         0.0
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A-6
Aircraft No. 6
JET A Fueled
200 PAX, 3000 n mi range
Mach 0.85

ORIGINAL PAGE IS
OF POOR QUALITY

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JP FUEL REFERENCE BASELINE DESIGN / 200 PASS / 3000 N MI        PISE

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

                  10.00     0.30     9.75   30.00  140.4    0.282


                                                  POUNDS   O/O                  POUNDS   O/O

DESIGN GROSS WEIGHT                              216924.  100.00
FUEL                                              61137.   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                                       6542.    3.02
FLIGHT CONTROLS                                    3012.    1.39
NACELLES                                           3520.    1.62
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
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Appendix /

MISSION SUMMARY

JP FUEL REFERENCE FACILITY DESIGN / 200 PASS / 5000 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 THROTT TAB ID	EXTERN F TANK TAB ID	AVG L/D RATIO	AVG SFC (FF/T)
TAKEOFF														
POWER 1	0.	0.0	216923.	332.	332.	0.	0.	14.0	14.0	0.	-91201.	0.	0.0	0.465
POWER 2	0.	0.0	216591.	304.	636.	0.	0.	1.0	15.0	0.	91401.	0.	0.0	0.298
CLIMB	0.	0.378	216287.	1066.	1701.	17.	17.	3.8	18.8	0.	81101.	0.	17.65	0.483
ACCEL	10000.	0.456	215221.	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	166847.	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.	0.547	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	0.463

TOGWT= 216923.9 FUEL A= 61136.6 FUEL R= 61106.3

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                       C O S T   S U M M A R Y

WING                                         1215552.66
TAIL                                          222145.11
BODY                                          111421.00
LANDING GEAR                                  205794.00
FLIGHT CONTROLS                               264161.00
NACELLES                                      349562.75
  PROPULSION
ENGINE                    155000.00
AIR INDUCTION             214799.36
FUEL SYSTEM               171079.31
START SYSTEM                9180.76
ENGINE CONTROLS             1273.57
EXH/THRUST REV.             1417.60
LUBE SYSTEM                 2134.09
  TOTAL PROPULSION                            316199.69

INSTRUMENTS                                   158551.19
HYDRAULICS                                    119482.31
ELECTRICAL                                    320281.31
ELECTRONIC RACKS                               95635.19
FURNISHING                                    316684.63
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                                                         R AND D
ENG. CHANGE ORDER          0.0                                      DEVELOPMENT TECHNICAL DATA      8060272.
QUALITY ASSURANCE     582815.13                                     DESIGN ENGINEERING            179117184.
AIRFRAME WARRANTY                             395965.50             DEVELOPMENT TOOLING           117099824.
AIRFRAME FEE                                 1247102.00             DEVELOPMENT TEST ARTICLE       31442000.
AIRFRAME COST                                            9561118.00 FLIGHT TEST                    27921504.
ENGINE WARRANTY                                91336.38             SPECIAL SUPPORT EQUIPMENT       2149405.
ENGINE FEE                                    230167.56             DEVELOPMENT SPARES             24860352.
ENGINE COST                                              2148231.00 ENGINE DEVLEOPMENT                   0.
AVIONICS COST                                             500000.00 AVIONICS DEVLEOPMENT                 0.
RESEARCH AND DEVELOPMENT                                 1116165.00      TOTAL R AND D                390657536.
             TOTAL FLY AWAY COST                                     13325514.00

  DIRECT OPERATING COST-DOLLARS/N. MILE          O/O
CREW                                     0.3956  16.45
AIRFRAME LABOR AND BURDEN MAINT.         0.1666   6.92
ENGINE LABOR AND BURDEN MAINT.           0.1344   5.59  RANGE
AIRFRAME MATERIAL MAINT.                 0.0962   4.00  N. MI      924.     1270.     1616.     1962.     2308.     2654.     3000.
ENGINE MATERIAL MAINT.                   0.1282   5.33   DOC
FUEL AND OIL                             0.6277  26.09  C/ASM    1.4635    1.3609    1.3022    1.2642    1.2376    1.2178    1.[illegible]
INSURANCE                                0.1775   7.38
DEPRECIATION (INCLUDING SPARES)          0.6794  28.24  TB-HR    2.3458    3.0537    3.7616    4.4696    5.1775    5.8855    6.[illegible]
                                                        $/TRP    2705.     3457.     4209.     4961.     5713.     6465.     7217.
  TOTAL DOC $/N. MILE                    2.4056 100.00
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                              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 OF 1975

AIRCRAFT MODEL --CL1217-15                     ENGINE I.D. -- 81000               WING QUARTER CHORD SWEEP = 30.00 DEG
I.O.C. DATE    --1990                          FLS SCALE I.D = 45000              WING TAPER RATIO = 0.300
DESIGN SPEED   --SUBSONIC                      NUMBER OF ENGINES = 4.

  1 W/S             131.0   131.0   131.0   131.0   130.8   130.8   130.8   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    0.28    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 AP               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  217068  216925  216809  216800  217145  216984  216871  216862 217209 [illegible] 216932|216923
  7 FUEL WEIGHT     60887 [illegible] 60949  61076   60904   60910   60968   61096   60923   60937   60988   61116  60942   60960   61007  | 61136
  8 OP. WT. EMPTY  112144  111965  111800  111663  112164  112006  111841  111704  112225  112047  111865  111745 112266  112096  111924  |111787
  9 ZERO FUEL WT.  156144  155905  155800  155663  156164  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
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LIQUID HYDROGEN---BASIC DESIGN MISSION/400 PASS/10000 N MI    MISS          WT. LH2

           T/C     T/W      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  L.E. SWEEP  L.E.R/CHORD
                                                          (DEG)      (DEG)
                  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         28.75      18124.55    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     NO. PODS  INLET L(FT)
                                                                    (SQ. FT)
                  10.54         7.45        24.86         8.13      2538.08          4.        0.0
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A-7
Aircraft No. 7
LH_2 Internal Tank
400 PAX, 5000 n mi radius
Mach 0.85

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

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

              10.60    0.30   10.00   30.00 117.0    0.265



                                                 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
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                                            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    INIT    INIT       SEGMT  TOTAL    SEGMT    TOTAL   SEGMT  TOTAL     EXTERN   ENGINE   EXTERN    AVG       AVG
           ALTITUDE    MACH    WEIGHT     FUEL   FUEL     DIST     DIST    TIME   TIME      STORE    THRUST   F TANK    L/D       SFC
              (FT)     NO      (LB)       (LB)   (LB)     (N MI)  (N MI)   (MIN)  (MIN)     TAB ID   TAB ID   TAB ID    RATIO     (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.    390.    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
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                      C O S T   S U M M A R Y

WING                                    4426756.00
TAIL                                     464994.38
BODY                                    4285586.00
LANDING GEAR                             765335.69
FLIGHT CONTROLS                          446608.63
NACELLES                                 904164.38
  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. 1793666.60
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

  DIRECT OPERATING COST-DOLLARS/N. MILE     0/0
CREW                              0.3854   7.05
AIRFRAME LABOR AND BURDEN MAINT.  0.3592   6.57
ENGINE LABOR AND BURDEN MAINT.    0.1352   2.47  RANGE
AIRFRAME MATERIAL MAINT.          0.2342   4.28  N. MI    6264.     6887.     7510.     8132.     8755.     9377.    10000.
ENGINE MATERIAL MAINT.            0.2093   3.83   DOC
FUEL AND OIL                      2.1372  39.11  C/ASM   1.3913    1.3853    1.3802    1.3759    1.3723    1.3691    1.3663
INSURANCE                         0.4163   7.62
DEPRECIATION (INCLUDING SPARES)   1.5885  29.07  TB-HR  13.7755   15.0478   16.3200   17.5922   18.8645   20.1367   21.4089
                                                 $/TRP   34864.    38162.    41460.    44758.    48056.    51354.    54652.
  TOTAL DOC $/N. MILE             5.4652 100.00
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              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.
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                                        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                          ENGINE I.D. --  65000                   WING QUARTER CHORD SWEEP = 30.60 DEG
I.O.C. DATE     --1990                              SLS SCALE 1.0 = 35000                   WING TAPER RATIO = 0.300
DESIGN SPEED    --SUBSONIC                          NUMBER OF ENGINES = 4.

  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    0.27    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  588466  589077  588242  588109  587615  588230  587369  587365       0       0       0       0       0       0
  7 FUEL WEIGHT     151356  151315  150792  150810  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   1.126   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  39.056  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       5.762   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 SYM(1)   34000   34000   34000   35000   34000   34000   34000   35000   34000   34000       0       0       0       0       0       0
 25 MISSION SYM(2)  131978  131861  131376  131282  131861  131623  131099  131062  131627  131417       0       0       0       0       0       0
CONSTRAINT OUTPUT
 26 CEILING PWR(1)   33774   33983   34126   34276   33763   33970   34115   34265   33751   33956       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)0.0640 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
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JP FUEL REFERENCE BASELINE DESIGN / 400 PASS /10000 N MI      MTCS          JET A

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

         10.00    0.30   11.00  30.00  129.3    0.300


                    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)
                  7125.0        279.96      0.300      30.000     32.059      0.0

                  CR(FT)        CT(FT)      MAC(FT)     CRE(FT)  S WET(SQ.FT)  REF L(FT)
                  39.16         11.75       27.91       37.24     13482.9       27.91

WING TANK--      CFAR1(FT)     CFAR2(FT)    FTL(FT)  FVWING(CU FT)  FVBOY(CU FT)
                  37.24         13.73       120.04      8178.20       1194.63

FUSELAGE--      LENGTH(FT)   S WET(SQ FT)   RWW(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        611.94      13.01       762.62       762.62        23.92

PROPULSION--     ENG L(FT)    ENG D(FT)    POD L(FT)    POD D(FT)    POD S WET     NO. PODS  INLET L(FT)
                                                                      (SQ. FT)
                  11.70         8.37        27.59         9.12       3163.69         4.         0.0
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A-8
Aircraft No. 8
JET A Fueled
400 PAX, 5000 n mi radius
Mach 0.85

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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   30.00 139.5    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                             53007.    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
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                                         M I S S I O N     S U M M A R Y

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

SEGMENT       INIT     INIT     INIT       SEGMT    TOTAL    SEGMT    TOTAL   SEGMT   TOTAL     EXTERN    ENGINE   EXTERN     AVG       AVG
            ALTITUDE   MACH     WEIGHT     FUEL     FUEL     DIST     DIST    TIME    TIME      STORE     THRUST   F TANK     L/D       SFC
              (FT)      NO      (LB)       (LB)     (LB)    (N MI)  (N MI)   (MIN)   (MIN)     TAB ID    TAB ID   TAB ID    RATIO    (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.     1661.    3891.       0.      0.     2.0    30.0        0.    81401.       0.     0.0      0.201


 CLIMB           0.   0.378   988626.     4798.    8689.      25.     25.     5.6    35.6        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     0.458
 ACCEL       10000.   0.456   727309.     1071.  266278.       8.   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     0.580
 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     0.583
 LOITER       1500.   0.260   533533.     1164.  460147.       0.  10000.     6.0   *****        0.   -81101.       0.    21.43     0.448
 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     0.584
 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     0.510
 CRUISE      30000.   0.590   489591.     4919.  507845.     142.    200.    24.2   173.8        0.   -81101.       0.    20.87     0.522
 DESCENT     30000.   0.700   484671.     2273.  510117.      93.    293.    16.8   190.6        0.    81301.       0.    16.70    -5.605
 CRUISE      30000.   0.585   482399.     3668.  513785.     107.    400.    18.4   209.0        0.   -81101.       0.    20.89     0.520
 LOITER       1500.   0.227   478730.    10573.  524358.       0.    400.    60.0   269.0        0.   -81101.       0.    21.34     0.436
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                                 C O S T   S U M M A R Y

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                                 541269.06
ANTI ICING                                        53978.34
APU                                              117556.63
SYS. INTEGRATION                                 444030.31

  TOTAL EMPTY MFG. COST                                     19516400.00

SUSTAINING ENGINEERI 1336214.00
TECHNICAL DATA              0.0
PROD. TOOLING MAINT. 1759556.00
MISC.                 486833.00                                                     R AND D
ENG. CHANGE ORDER           0.0                                           DEVELOPMENT TECHNICAL DATA    22709904.
QUALITY ASSURANCE    1835917.00                                           DESIGN ENGINEERING           504664832.
AIRFRAME WARRANTY                               1246844.00                DEVELOPMENT TOOLING          420066048.
AIRFRAME FEE                                    3927558.00                DEVELOPMENT TEST ARTICLE      99036192.
AIRFRAME COST                                               30111280.00   FLIGHT TEST                   94250336.
ENGINE WARRANTY                                  250173.36                SPECIAL SUPPORT EQUIPMENT      6055977.
ENGINE FEE                                       630436.67                DEVELOPMENT SPARES            75007344.
ENGINE COST                                                  5884078.00   ENGINE DEVLEOPMENT                   0.
AVIONICS COST                                                 500000.00   AVIONICS DEVLEOPMENT                 0.
RESEARCH ANC DEVELOPMENT                                     3490829.00        TOTAL R AND D             1221789952.
             TOTAL FLY AWAY COST                                        39986160.00

  DIRECT OPERATING COST-DOLLARS/N. MILE         0/0
CREW                                0.3860     7.21
AIRFRAME LABOR AND BURDEN MAINT.    0.3766     7.03
ENGINE LABOR AND BURDEN MAINT.      0.2379     4.44  RANGE
AIRFRAME MATERIAL MAINT.            0.2416     4.51  N. MI    6240.      6867.      7493.      8120.      8747.      9373.     10000.
ENGINE MATERIAL MAINT.              0.3204     5.98   DOC
FUEL AND OIL                        1.7283    32.28  C/ASM    1.3521     1.3488     1.3461     1.3438     1.3419     1.3402    1.3387
INSURANCE                           0.4288     8.01
DEPRECIATION (INCLUDING SPARES)     1.6353    30.54  TB-HR   13.7740    15.0527    16.3313    17.6100    18.8886    20.1673   21.4459
                                                     $/TRP   33748.     37048.     40349.     43649.     46949.     50249.    53549.
  TOTAL DOC $/N. MILE               5.3549   100.00
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                         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                   ENGINE I.D. --  F1000                WING QUARTER CHORD SWEEP = 30.00 DEG
I.O.C. DATE    --1990                      SLS SCALE 1.0 = 35000                WING TAPER RATIO = 0.300
DESIGN SPEED   --SUBSONIC                  NUMBER OF ENGINES = 4.

  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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REFERENCES

1. Brewer, G. D., Morris, R. E., Lange, R. H., and Moore, J. W. Final Report: Study of the Application of Hydrogen Fuel to Long Range Subsonic Transport Aircraft, Lockheed Aircraft Corporation, NASA CR-132559, January 1975.

2. Anon., Standard Method of Estimating Comparative Direct Operating Costs of Turbine Powered Transport Airplanes, Air Transport Association of America, December 1967.

3. Anon., Subsonic Transport Category Large Airplanes and Subsonic Turbojet Powered Airplanes - Proposed Noise Reduction Stages and Acoustical Change Requirements, Notice No. 75-37, Federal Register, Vol. 40, No. 214, Nov. 5, 1975.