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Integrated Technology Wing Design Study

A. P. Hays, W. E. Beck,
W. H. Morita, B. J. Penrose,
R. E. Skarshaug, and B. S. Wainfan

CONTRACT NAS1-16273
AUGUST 1982

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Lockheed-California Company
Burbank, California

Prepared for
Langley Research Center
under Contract NAS1-16273

NASA
National Aeronautics
and Space Administration

Scientific and Technical
Information Branch

1982

SUMMARY

This report describes a study to determine the technology development costs and associated benefits in applying advanced technology associated with the design of a new wing for a new or derivative trijet with a capacity for 350 passengers and maximum range of 8519 km (4600 n.mi.). Technology development costs are those costs required to achieve technology readiness by the end of 1986 for an aircraft entering service at the end of 1990. Technology readiness is the point at which a certain level of technology may be committed to an aircraft design.

The areas of technology under consideration in this study are: (1) airfoil technology, (2) planform parameters, (3) high lift, (4) pitch active control system, (5) all-electric systems, (6) E^3 propulsion, (7) airframe/propulsion integration, (8) graphite/epoxy composites, (9) advanced aluminum alloys, (10) titanium alloys, and (11) silicon carbide/aluminum composites. These advanced technologies were applied to the reference aircraft configuration both individually and concurrently; payoffs were determined in terms of block fuel reductions and net value of technology. These technologies were then ranked in terms of the ratio of net value of technology (NVT) to technology development cost. This gives a guideline as to which areas of technology offer the greatest payoff and suggests where future technology development funds may be most profitably spent.

For a fleet of 400 aircraft, the application of all advanced technologies yields an NVT of $72 billion (in 1980 dollars), for a total technology development cost of $643 million. Almost all the benefit is achieved through reduction in block fuel, (40 percent reduction for the all-advanced configuration).

In ranking technology payoffs, technology development in aerodynamics offers the largest benefit in NVT per unit technology development cost, yielding $17 billion increase in NVT (achieved with 11.3 percent reduction in block fuel) for $28 million technology development cost. However, E^3 propulsion technology with airframe/propulsion integration gives the greatest single benefit in NVT of $19 billion, but with a technology development cost of $243 million.

The technology development cost for aerodynamics does not include full scale flight test, and thus remains at a higher risk level than other technologies for which full scale testing is included. Use of the National Transonic Facility, permitting full-scale Reynolds number testing, allows this risk to be held to an acceptable level.

GUIDE TO THIS REPORT

For an overview of this study, the reader should first look at the introduction (Section 1), then Priority Assignment (Section 11) and Conclusions and Recommendations (Section 12). Information on the evaluation of the impact of technology may be found in the Study Ground Rules (Section 2) and Evaluation Methodology (Section 3); the impact of technology on design is in the Definition of the Advanced Configuration (Section 9) and Technology Impact (Section 10) using the Definition of the Reference Aircraft (Section 4) for comparison. Detailed descriptions of the levels of advanced Technology, and plans and costs required to achieve technology readiness, may be found in Sections 5 through 8.

NOTE

The use of trade names and descriptions of these products are for the purposes of definition only. They do not indicate approval or endorsement by NASA.

SYMBOLS AND ABBREVIATIONS

A	area
A/C	aircraft
ACEE	aircraft energy efficiency
ACT	active control technology
ADF	automatic direction finder
adv	advanced
Al	aluminum
AP	autopilot
APU	auxiliary power unit
AR	aspect ratio
ARINC	Aeronautical Radio Incorporated
ASSET	advanced system synthesis and evaluation technique
ATA	advanced transport aircraft
ATC	air traffic control
ATM	air-turbine motor
a/w	crack growth ratio
b	span
C	aerodynamic force or moment coefficient
c	wing chord
$\bar{c}$	mean aerodynamic chord
CAB	Civil Aeronautics Board
CAS	command augmentation system
CAS	curvature airfoil shaping
CB	circuit breaker
CDP	compressor discharge pressure
CER	cost estimating relationship
CFAC	constant frequency - alternating current
cg	center of gravity
CGM	cg management
CRAD	contract research and development
CRYO	cryogenic

CSD	constant-speed drive
D	drag
D	nacelle diameter
dc	direct current
DCBT	dc bus tie
DDGS	direct drive generation system
DLC	direct lift control
DME	distance measuring equipment
DOC	direct operating cost
E^3	energy efficient engine
e	elongation
EACR	emergency ac relay
ECS	environmental control system
EMAS	electro-mechanical actuation system
EMS	elastic mode suppression
EPNdB	effective perceived noise decibels
F	stress (force/unit area)
F	thrust
°F	degrees Fahrenheit
FAA	Federal Aviation Administration
FADEC	full authority digital engine control
FAR	Federal Aviation Regulations
FBW	fly-by-wire
FCC	flight control computer
FCS	flight control system (also flight control surfaces)
FMS	flight management system
FOD	foreign object damage
FPS	flight propulsion system
ft	feet
g	acceleration due to gravity
GA	gust alleviation
gal	gallon (U.S.)

GE	General Electric
gpm	gallons per minute
h	altitude
h	minimum channel width between the wing lower surface and upper fan cowl contour
HMAS	hydromechanical actuation
HP	high pressure
HPC	high pressure compressor
HPT	high pressure turbine
i	incidence referenced to fuselage water-line
ICLS	integrated core low spool
IDG	integrated drive generator
IES/G	integrated engine starter/generator
IGV	inlet guide vane
ILS	instrument landing system
IN	inches
IOC	indurect operating cost
IP	intermediate pressure
IRAD	independent research and development
ISA	international standard atmosphere
K	degrees Kelvin
K	stress intensity
kt	knots
kVA	kilo volt-amperes
L	lift
L	litre
lb	pounds
LCC	life cycle cost
L/D	lift to drag ratio
L.E.	leading edge
LPT	low pressure turbine
M	Mach number

M	million
m	meters
MAC	mean aerodynamic chord
MDM	multiplexed-demultiplexed
MESC	main electric service center
min	minute
MLC	maneuver load control
M(L/D)	specific air range factor
MLG	main landing gear
MPE	mechanical power extraction
MTBF	mean time between failure
MUX	multiplexing
MY	man-year
N	Newton
NADC	Naval Air Development Center
NASA	National Aeronautics and Space Administration
NLG	nose landing gear
n.mi.	nautical miles
NTF	National Transonic Facility
NVT	net value of technology
OEW	operating empty weight
PACS	pitch active control system
PAX	passenger
PBW	power-by-wire
P.D.	preliminary design
PDR	phase delayed rectifier
PERTDRAG	ASSET subprogram for prediction of airplane drag using a perturbation method
pps	pounds per second
psig	pounds per square inch, gage
q	dynamic pressure
Re	Reynolds number

RAT	ram-air turbine
RDT&E	research, development, test and engineering
S	trapezoidal wing area (including fuselage intercept area)
s	seconds
SAS	stability augmentation system
SCR	silicon controlled rectifier
SELCAL	selective calling system
SEP	specific excess power (available rate of climb at start of cruise, assuming aircraft is at max. TOGW)
SFC	specific fuel consumption
SiC	silicon carbide
S.L.	sea level
SSPC	solid state power controllers
TACS	transport aircraft composite structures
TBO	time between overhaul
t/c	average wing thickness/chord ratio, defined by (untwisted wing frontal area)/(planform area)
TOGW	takeoff gross weight
TPS	turbine powered simulator
TR	transformer-rectifier
T/W	(total aircraft static thrust at ISA, S.L.,)/(max takeoff gross weight)
V	speed
$\bar{V}$	tail volume coefficient
VHF	very high frequency
VMOS	very large scale metallic-oxide semiconductor
VOR	VHF omni-range (navigation aid)
VSCF	variable speed constant frequency
WLA	wing load alleviation
W/S	(max. takeoff gross weight)/(reference wing area)
W37	current technology (L-1011) airfoil section
x	distance from leading edge
x/c	position on wing chord to total wing chord ratio
y	distance from aircraft center line
Z	vertical distance between engine centerline and wing reference line

SUBSCRIPTS

Related to area (A)

POD	nacelle maximum cross section

Related to aerodynamic force or moment coefficients (C)

D	drag
D_o	drag at zero lift
D_i	total installed nacelle drag minus friction drag of isolated nacelle/pylon
D_F	skin friction drag
D_{trim}	trimmed drag
$D_{tail\ off}$	tail off drag
L	lift
m	section pitching moment

Related to wing geometry (c or y)

B	batt
E	engine
G	landing gear
p	pylon
R	root (fuselage center-line)
T	tip
W	wing chord at pylon butt line

Related to modulus of elasticity (E)

c	compression
t	tangent

Related to stress (F)

bru	allowable ultimate bearing stress
cy	allowable compressive yield stress
su	allowable ultimate stress in shear
tu	allowable tensile stress
ty	allowable tensile yield stress

Related to angle of incidence (i)

F	fuselage
W	wing

Related to speed (V or M)

2	speed at 10.67m (35 ft) height, one engine inoperative
APP	approach
S	stall
D	design

Related to tail volume coefficient (V)

H	horizontal tail
V	vertical tail

Related to distance from leading edge (x)

2	distance to engine core exhaust plane
cg	distance to engine cg (on pylon butt line) or distance to aircraft cg (on MAC)

Other subscripts

cg	center of gravity
CR	cruise
INT	interference
N	net

GREEK SYMBOLS

α	angle of attack
Δ	difference (used as prefix)
Λ	wing sweep at one-quarter chord

FOREWORD

This study was conducted under contract NAS1-16273 by the staff of Lockheed California Company, a division of the Lockheed Corporation. The contract was performed as part of the Energy Efficient Transport (EET) project of the Aircraft Energy Efficient (ACEE) program.

The NASA Project Manager was R.V. Hood of the EET Project Office at the Langley Research Center. For the first half of this study the Technical Monitor was D.L. Maiden and for the second half was D.W. Bartlett. Their guidance and advice is greatly appreciated.

The following Lockheed personnel were responsible for the direction and supervision of components of this study:

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J.J. Rising - Aircraft Stability and Control
B. Saelman and G.J. Jones - Mass Properties
D.L. Horning - Costs
M.Z. Huang - Propulsion
Dr. R.J. Van Ness - Report Editor

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1. INTRODUCTION

Principal measurements and calculations in this study used customary units (ft, lb, sec). Measurement values used in this report are quoted in the International System of Units (SI) with customary units in parentheses. Values in the Appendix are given in customary units only.

1.1 Background

The NASA/Industry Aircraft Energy Efficiency (ACEE) Program was established in 1975. A major objective of the ACEE Program is to define and demonstrate technological improvements in aerodynamics, systems, propulsion, materials, and structures that can significantly improve the performance of future aircraft with particular emphasis on reducing fuel consumption.

Secondary ACEE goals are to stimulate the aircraft and airline industries to expedite the incorporation of fuel conservative technology and to assist the FAA by providing a database for flight certification of new technology developments.

The ACEE Program is composed of six elements. Three elements are managed by the Lewis Research Center and three elements are managed by the Langley Research Center. The Lewis elements are turboprops, engine component improvement, and energy efficient engine. The Langley elements are composite primary structures technology, energy efficient transport, and laminar flow control.

Generally each element has functioned somewhat independently, pursuing high payback/high risk technology within its own discipline, while maintaining a sensitivity for how its new technology might interface with the aircraft system development. As these technologies mature, it is evident that significant improvements in transport fuel efficiency and operational economics could be achieved by the integration of a majority of these proven concepts. Achievement of the maximum synergistic benefits from this technology integration may require innovations in the airplane design process.

Prior to 1973, it was difficult to justify the introduction of fuel-efficient technology because the potential benefit of the fuel saved versus the cost of technology was minimal, as shown in the example of figure 1. However, 15% improvement in block fuel could only be justified if aircraft price rose by less than 15%; with fuel at $0.8/L($3.00/gal) airlines should be willing to pay up to double the price for an aircraft, for a 15% fuel saving. Thus, one way to soften the impact of increasing fuel prices is through aggressive use of advanced, fuel-efficient technology to a new generation of transport aircraft.

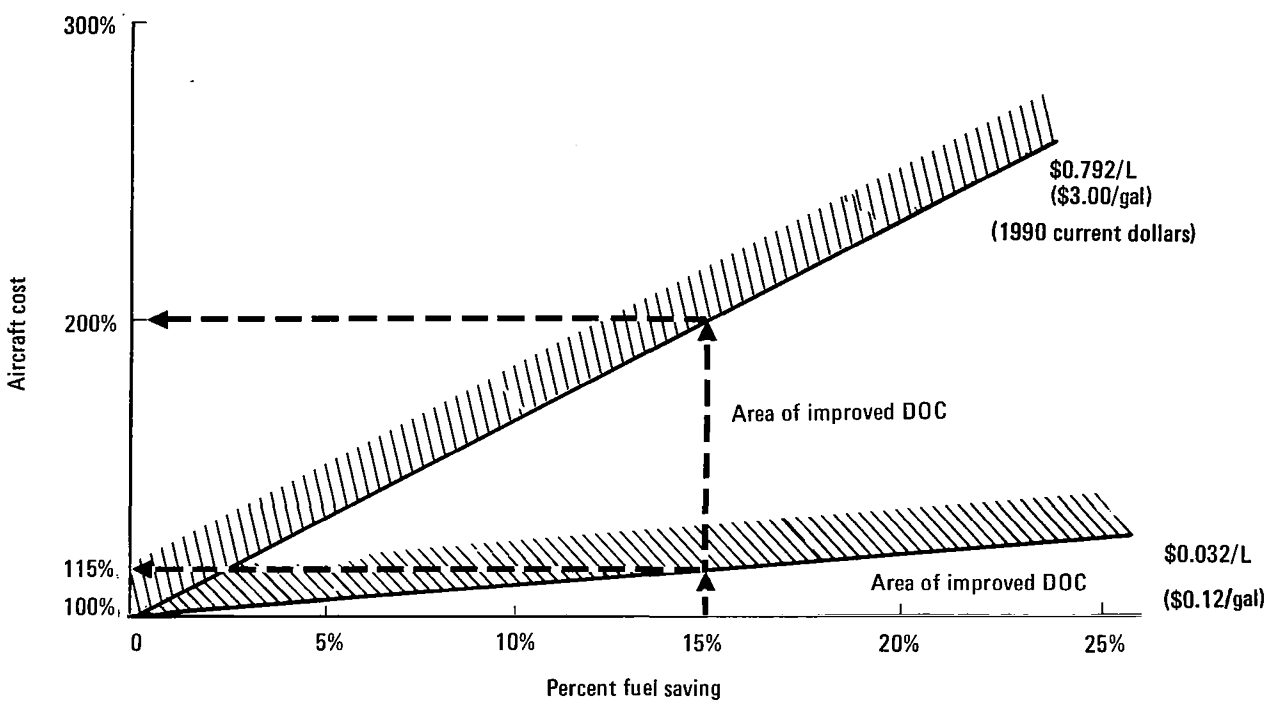

Figure 1. - Example of initial cost vs fuel saving tradeoff.

One of the greatest potential for improvement in transport energy efficiency is in integrated technology wing design. The wing contributes the majority of drag, and almost all the lift; therefore, it is logical to focus efforts on an advanced wing design program with the integration of other technologies to determine the maximum benefit of integrating maturing ACEE developed and other appropriate energy efficient technologies. This focused effort will help guide the proper timing of the development and integration of emerging advanced technologies in the disciplines of aerodynamics, active controls, aircraft systems, propulsion, structures, and materials.

Therefore a program was initiated to study and plan the effort required by commercial transport manufacturers to integrate advanced technology into a new wing for a derivative and/or new aircraft that could enter service in the late 1980s to early 1990s time period. The study also proposed to define the technology, its priority, and timing needed to support these introductory dates.

If one places a new wing on an existing airframe, technology may also be updated for aircraft systems, flight controls, advanced propulsion system, and advanced materials. An integrated technology wing design includes these items.

1.2 Study Objectives

The purpose of the program is to develop a plan of the orderly effort required by a commercial transport manufacturer to integrate advanced technology into a new wing for a derivative and/or new aircraft that could enter service in the late 1980s to early 1990s time period. The specific objectives of the program are:

- To assess the cost/benefits of evolving technological elements and combinations of elements compared to a conventional technology design. The technological elements are divided into the classifications of aerodynamics, advanced systems and controls, propulsion, and materials.

- To assess the risks associated with the development and application of each technological element, in terms of probability of achieving the desired goal and possibility of adverse side-effects.

- To establish the costs of a subsequent integrated wing technology program to develop and validate the individual and combined technological elements.

- To develop plans that will establish the technology base needed for the development of an advanced technology wing.

1.3 Study Approach

The study program is divided into three technical tasks: (1) cost/benefits assessment, (2) technology development and (3) management and documentation. All of the technical disciplines which would be involved in an advanced technology wing development program participate in the study. The resultant technology development plan reflects the continuous interaction of these disciplines both during the study and in the planned development and implementation efforts.

A conventional technology aircraft is defined as a reference configuration for technology integration. This configuration is a derivative of the L-1011-1 incorporating a stretched fuselage and a wing-root plug with additional thrust/ weight and wing loading optimization (figure 2).

The reference configuration represents a long-range, high-density aircraft expected to be operational in the mid 1980s. The configuration provides the basis for the technical and economic trades and evaluations.

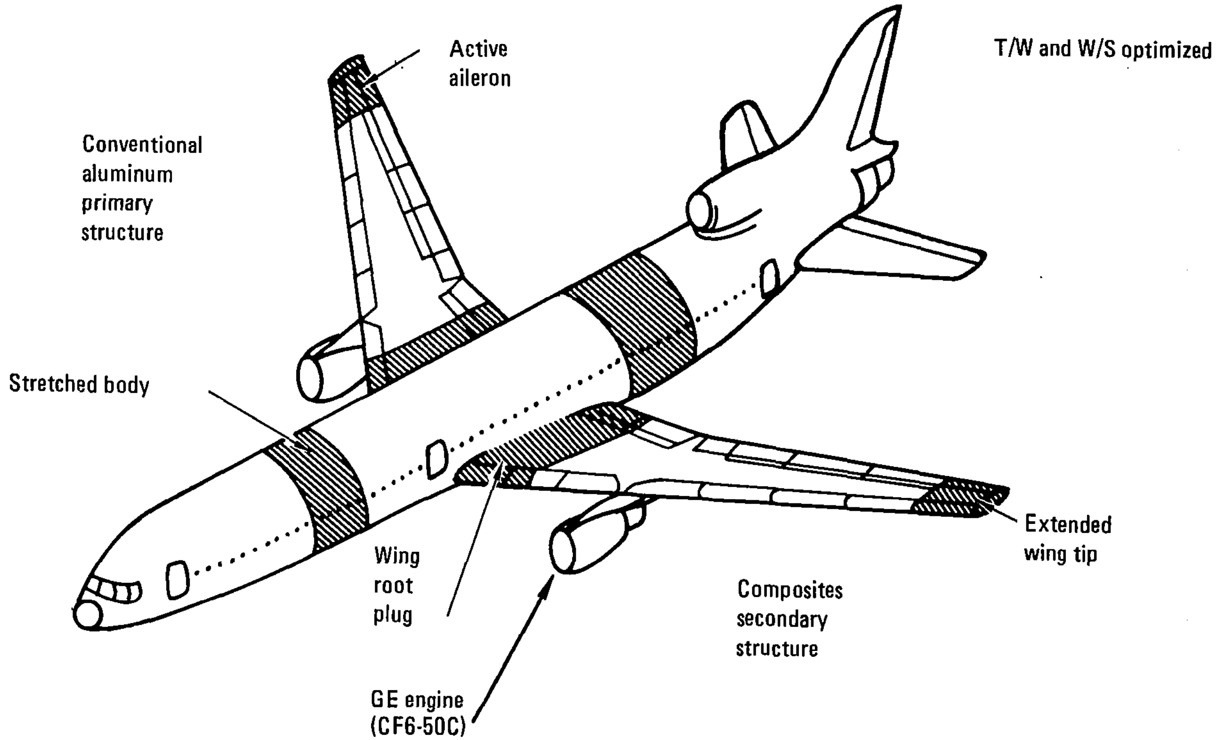

Figure 2. - Reference configuration.

This reference configuration is used as a basis for other reference configurations used in studies under NASA contract occuring concurrently with this study. The derivation of these reference configurations is shown in figure 3.

1.3.1 Cost/benefits assessment. - The study assesses the cost/benefits of evolving technological elements. The aerodynamic elements include airfoil technology, planform parameters, and high-lift technology. Advanced systems and controls elements include all-electric systems, active controls, and advanced flight controls. The propulsion element includes advanced propulsion technology and airframe/propulsion integration. Structures and materials elements include composites, advanced aluminum alloys, titanium alloys, and hybrid structures.

Each technological element is applied individually to the reference configuration. Combinations of technologies are also applied to define the synergistic effect of interrelated technologies. The planned study configuration matrix is presented in figure 4. Aircraft performance is estimated and the impact of incorporating advanced technology into a new wing design is assessed. The figure of merit is block fuel required to perform the specified mission for which the reference configuration is designed.

Economic data are generated for each aircraft incorporating each technological element. The economic data consist of a cost summary which details total RDT&E program costs, aircraft production costs, and procurement cost per aircraft. A summary of aircraft operational costs (both direct and indirect) and rate of return on investment are prepared for each aircraft incorporating each technological element.

Base values are obtained for the reference configuration with comparable values obtained for each aircraft with advanced technological elements. The payoffs are represented as deltas to base values and the net value of technology ($/aircraft) are determined by establishing the development, production, and operational costs to incorporate the technology(s) and subtracting it from the economic returns over the aircraft life.

The cost/benefits assessment in conjunction with the projected technology development costs defines the cost effectiveness of each technological element. By assigning an appropriate priority to each element, the study serves as a guide for determining overall priorities for future technology development programs.

1.3.2 Technology development. - The technology development plan effort identifies the technology needs, formulates an overall plan for effecting the required development, defines program options for accomplishing these objectives, performs comparative evaluations of the program options, and assesses the technical and program risks to the cost and schedule of the program.

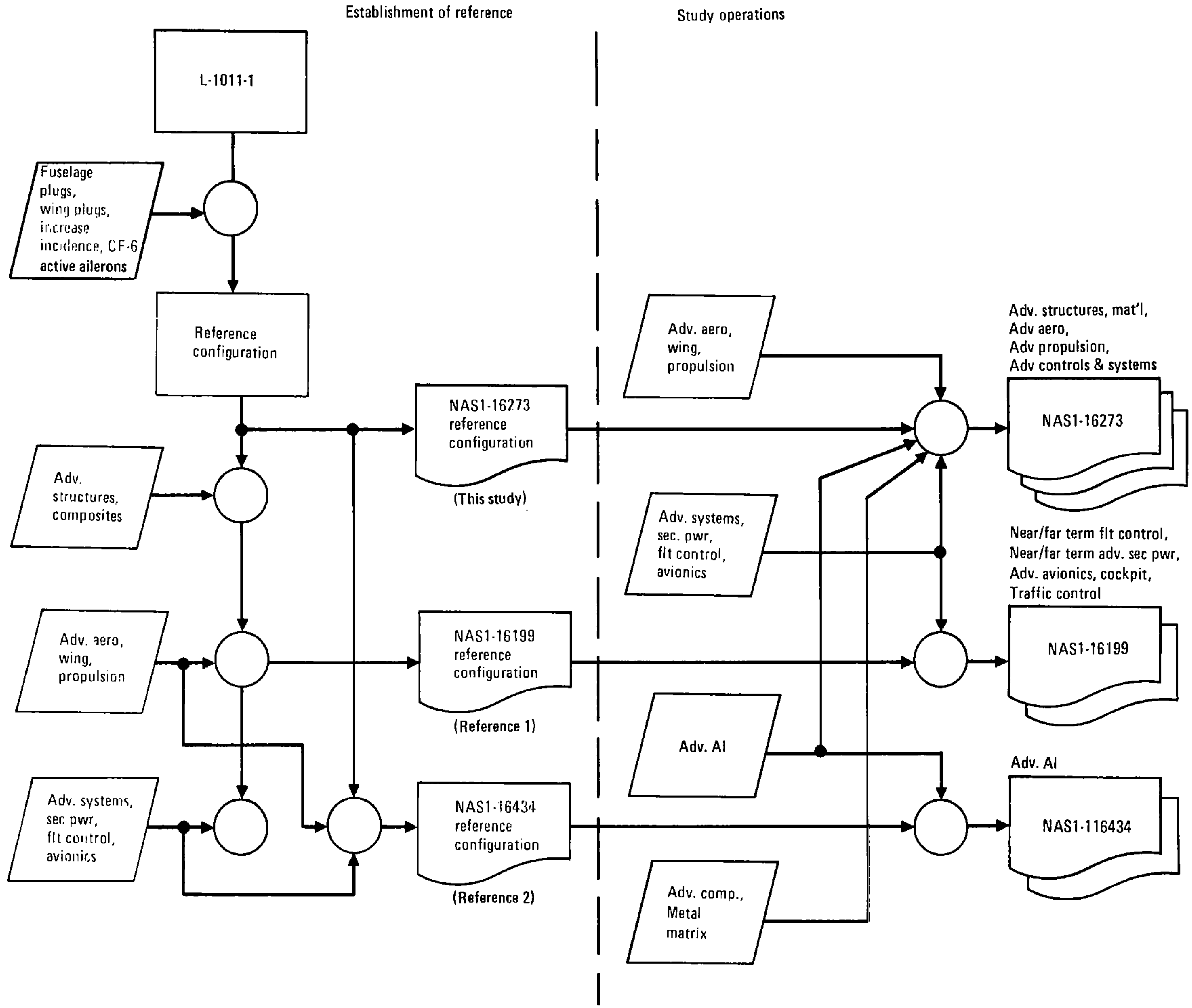

Figure 3. - Establishment of reference configuration.

An important factor in defining a development plan for introducing new technology is the relationship of such a program to a subsequently new aircraft production program. This relationship is illustrated in figure 5.

To introduce a new aircraft into service in the early 1990s, the production program must be initiated in the mid-to-late 1980s. The production program includes the normal design development, design verification, and flight test programs.

For an aircraft entering service at the end of 1990, technology readiness for the major airframe components must be achieved by the end of 1986. This includes structures, materials, and aerodynamics. Other areas of technology, such as propulsion, require earlier technology readiness, whereas later technology readiness may be permitted in avionics and systems.

Plans are described which establish the technology base needed for the development of an advanced technology wing. The plans include all the factors that enter into a decision by an airframe manufacturer to commit to the production of an advanced technology wing. Factors considered include program costs, technical risk, schedule, and timeliness in relation to future aircraft programs expected to benefit from a major wing development program.

An assessment is made of the technological risk associated with each of the technological elements. Where significant risk items are identified, recommendations are made as to the course of action to reduce this risk and estimate the cost associated with the effort.

Advances in technology are specified which are expected to occur and which could significantly affect the future application of an integrated technology wing. A clearly developed rationale or basis for selecting these advances is provided. The earliest date for operational capability of each technological item in the wing is estimated, premised on technological readiness including new FAA certification efforts. Advances in technology that are essential to the cost effective development of a new wing are also identified and a process for effecting those advances is defined.

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Config. No.	Configuration	
1	Reference	
2	Reference	+airfoil technology
3	Reference	+planform parameters
4	Reference	+high lift technology
5	Reference	+active controls
6	Reference	+advanced systems and controls
7	Reference	+advanced propulsion technology
8	Reference	+airframe/propulsion integration
9	Reference	+composites
10	Reference	+advanced aluminum alloys
11	Reference	+titanium alloys
12	Reference	+hybrid structures
13	Config.	1 + 2 + 3 + 4
14	Config.	13 + 5 + 6
15	Config.	14 + 7 + 8
16	Config.	15 + 9 + 10 + 11 + 12 = Advanced technology aircraft

Figure 4. - Study configuration matrix.

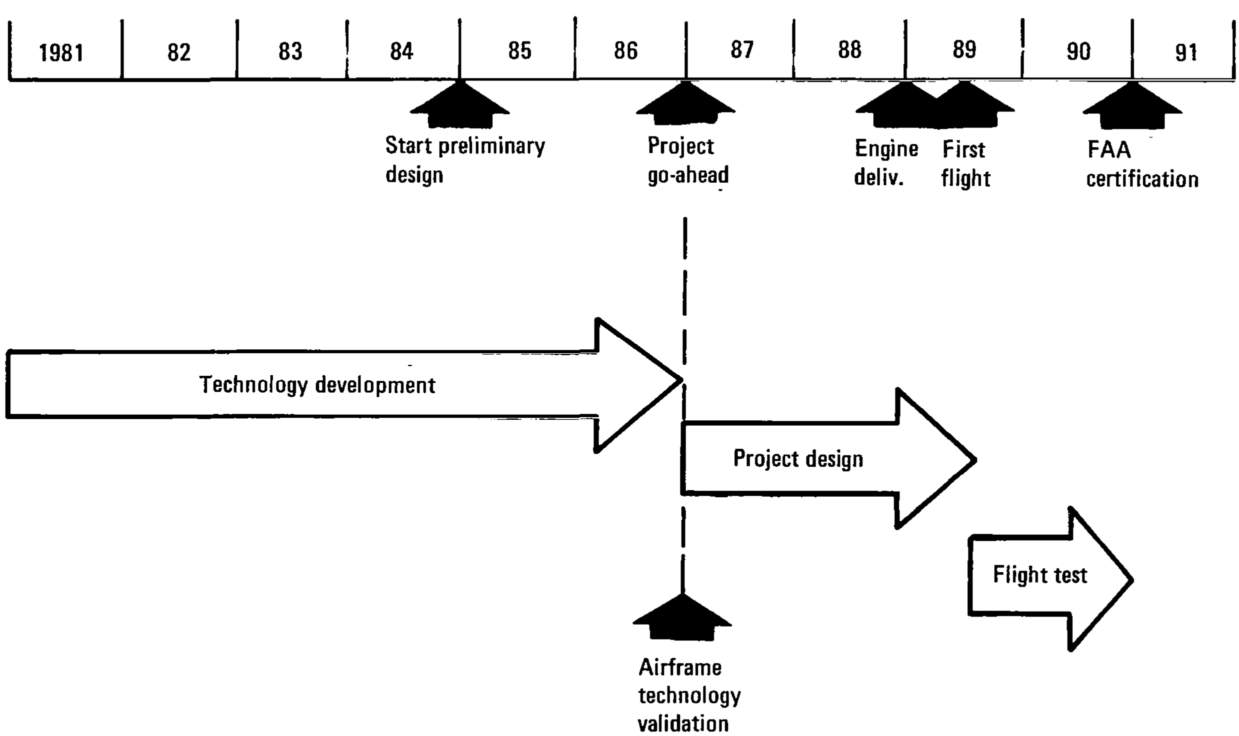

Figure 5. - New aircraft program schedule.

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Costs are established for a subsequent wing technology program to develop and validate the individual technological elements. Technology is validated when the basic unknowns and uncertainties are small enough to allow a decision for the incorporation of such technology into a new or derivative aircraft program. The validation programs include methods development, analytical evaluations, testing, and manufacturing.

The reference configuration represents an aircraft that could be flying in 1981 with no technology development, as shown in figure 6. The propulsion system represents technology that could have been flying before 1981. Technology development costs are therefore based on the amount of work required to get from the level of technology assumed in the reference aircraft to that of the advanced aircraft. It is realized (and will be emphasized in the relevant plans and costs sections of this report) that some of this work has already been performed.

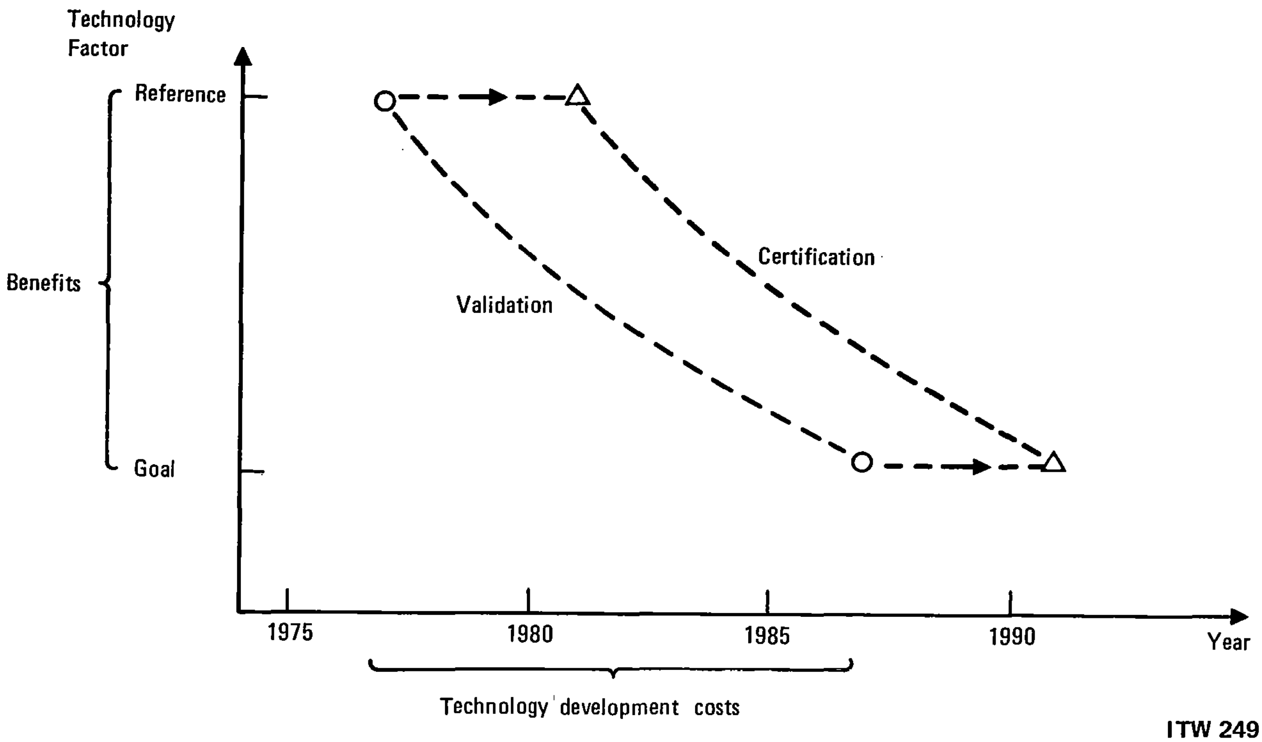


Figure 6. - Cost and benefit timescales.

The sequence of configuration development is shown in figure 7. Configuration 16 is developed from Configuration 1, and intermediate configurations are developed by either adding technology elements to the reference configuration or subtracting elements from the advanced configuration.

1.4 Study Limitations

Some of the most significant limitations of this study are common to any study which attempts to forecast trends. For the most part the levels of technology assumed for advanced configurations are based on extrapolation of trends of technology advancements up to the present time, modified where necessary by judgments of specialists in each technological area. These predictions cannot account for fundamental breakthroughs which may (remotely) occur between now and technology readiness in 1986; however, it is rather unlikely that any major breakthrough could reach technology readiness by 1986. On the pessimistic side, these predictions cannot completely account for roadblocks in technology development. It is the purpose of risk assessment to make judgments about the probability and severity of roadblocks which may occur.

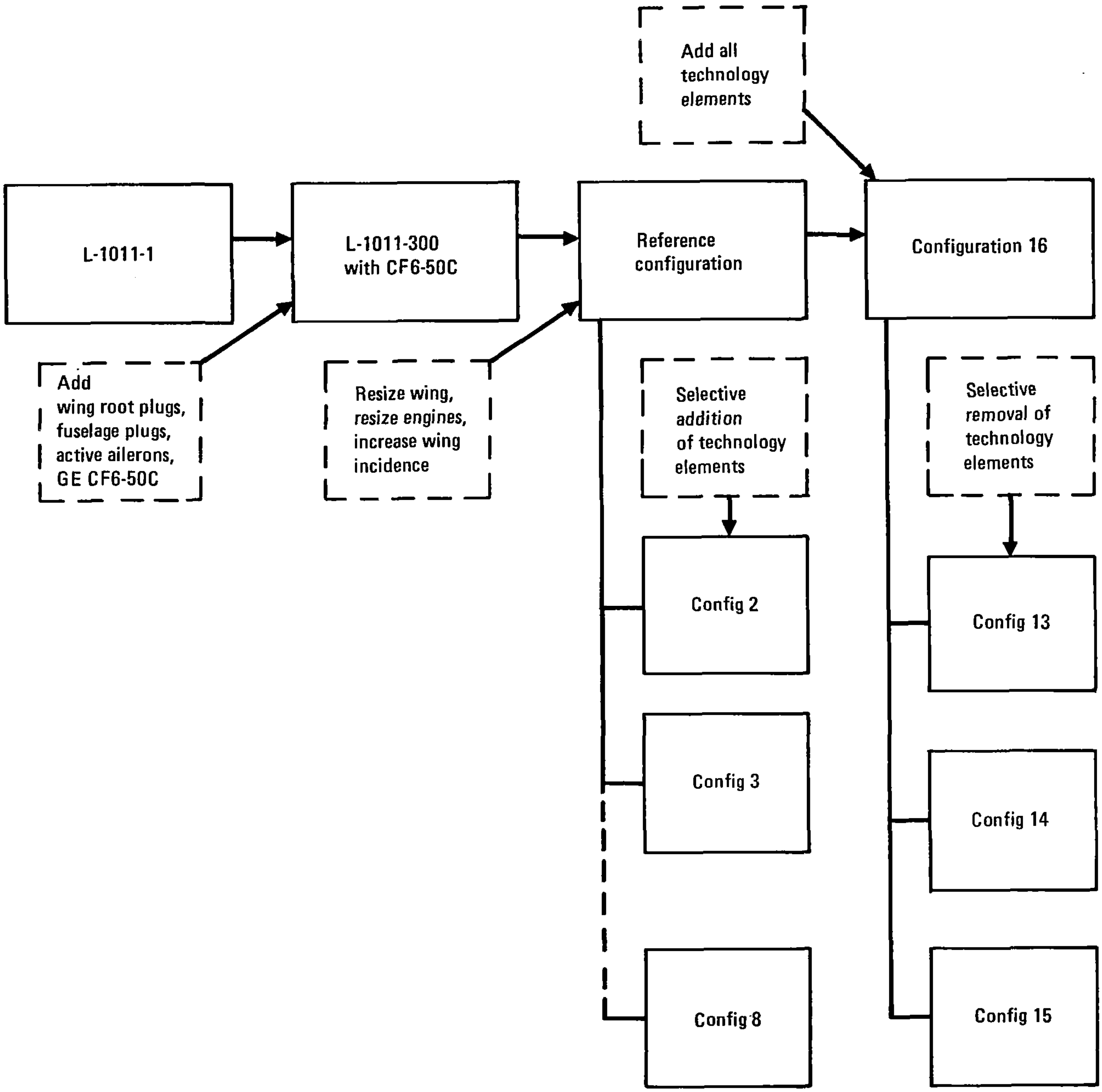


Figure 7. - Sequence of configuration development.

In assessing the benefits of these advances in technology by applying them to the reference aircraft, there are several cases where compromises in aircraft design must be made in order to implement these advances, and these compromises may involve many fundamental aspects of the design. Time and cost limitations preclude detailed tradeoffs to find the best compromise, so that the net result is a configuration which is not completely optimized. The level of optimization reached is probably within about one or two percent of a perfectly optimized design, but we are looking for differences from the reference aircraft of the order of 5-10 percent by applying advanced technology elements, so that the 1 percent lost through failing to optimize the design may be significant.

In addition, aircraft design is a convergent (the designer hopes) iterative process. Preliminary estimates of, for example, tail scrape angle or neutral point, have proven to be slightly in error, so that adjustments should be made in wing incidence and fore-and-aft positioning. Differences between the initial assumptions and the characteristics of the final configuration are made clear in the text.

Another limitation to this study is the method of allocating technology development costs. An aircraft manufacturer usually writes off technology development as an overhead cost, and profits from individual aircraft programs are used to underwrite this overhead. Although a director of research is expected to justify the cost of technology development when this cost is borne directly by a manufacturer, these costs are not actually allocated to a single program. In this study, development costs are assumed to be allocated to this program only, because it would be difficult to quantify with any degree of consistency what the applicability of each advanced technology actually is. If the users of this report wish to use different assumptions, then development costs per aircraft can be adjusted accordingly.

2. PROGRAM GROUND RULES

Many of the ground rules of this study are implicit in the Lockheed vehicle synthesis program. This section covers some of the ground rules which are external to the program, and highlights some of the ground rules within the program. Other ground rules implicit to the program may be found in Section 3.1.

2.1 Aircraft Design

2.1.1 Wing. - Wing characteristics common to all configurations are summarized in table I, with dimensions shown in figure 8. For reference planform configurations, the wing planform is derived from the L-1011-1 wing by the addition of 1.57 m (62 in.) wing root plugs either side, extended wing tips and active ailerons. This results in a taper ratio of 0.246 and average t/c of 10.26 percent.

For advanced wing configurations the taper ratio is maintained at 0.246 and batt geometry is simplified slightly to that of a single batt which intersects the wing trailing edge at 42.7 percent of semi-span. The ratio of trapezoidal root chord to total root chord is 0.695. This implies a constant ratio of batt total area to trapezoidal area. Spanwise t/c distribution is shown in figure 9 for an average t/c of 12.33%. For other average t/c values, the spanwise t/c distributions are ratioed accordingly.

For all configurations the wing-mounted engines are at 11.95 m (39.2 ft) from the aircraft centerline.

Fuel volume for all constrained configurations is designed to be at least 110 percent of that required to achieve the design mission. This ensures that the aircraft design has adequate stretch capability.

Reference 3 gives trends in aircraft design characteristics as a guide to airport operators. Figure 10, taken from this reference, is used as a guideline in limiting the span of high aspect ratio wings. The figure shows that wing spans up to 79 m (260 ft) should be expected by 1990. In practice the largest span of any selected configuration (Configuration 3) is 73.8 m (242 ft).

2.1.2 Fuselage. - The fuselage is a conventional semi-monocoque shell construction of conventional aluminum alloy. It has a constant cross-sectional diameter of 5.97 m (19.6 ft) for the major portion of its length. Skin and stringers are supported by sheet metal frames spaced at 50.8 cm (20 in.) intervals.

TABLE I. - WING CHARACTERISTICS

Dimension	Symbol	Value
Taper ratio	$\frac{c_T}{c_R}$	0.246
$\frac{\text{Trapezoidal root chord}}{\text{Total root chord}}$	$\frac{c_R}{c_R + c_B}$	0.695
$\frac{\text{Centerline to T.E. break}}{\text{Semi-span}}$	$\frac{y_B}{b/2}$	0.427
Centerline to gear butt line	y_G	5.48 m (18 ft)
Centerline to engine mount	y_E	11.95 m (39.2 ft)

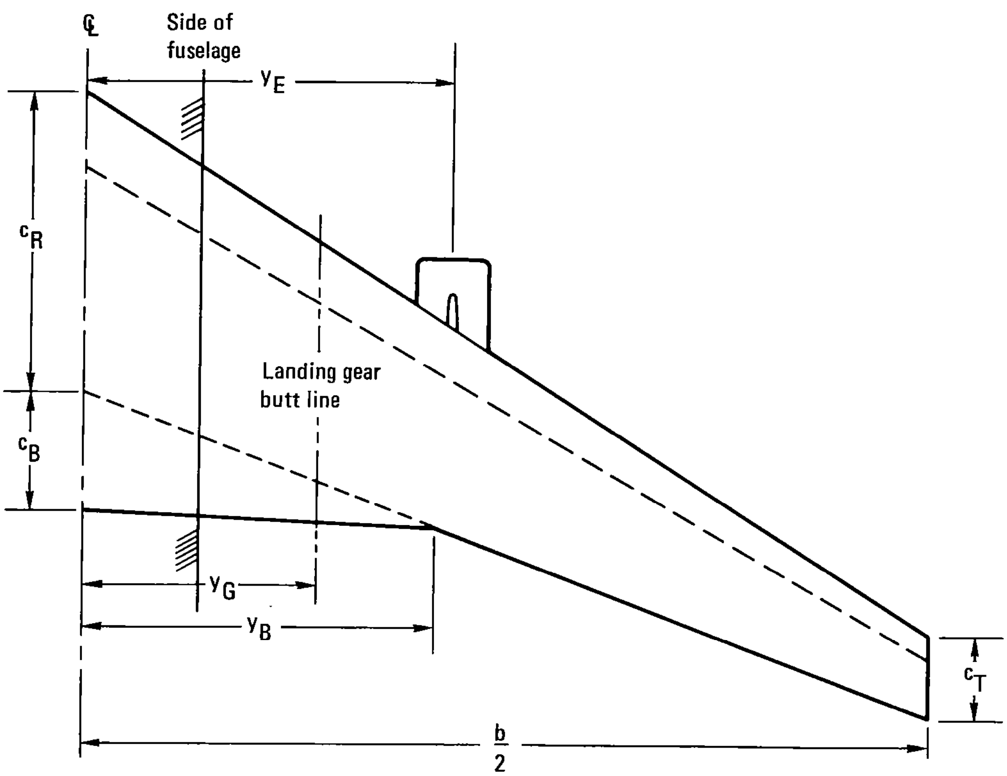


Figure 8. - Wing geometry.

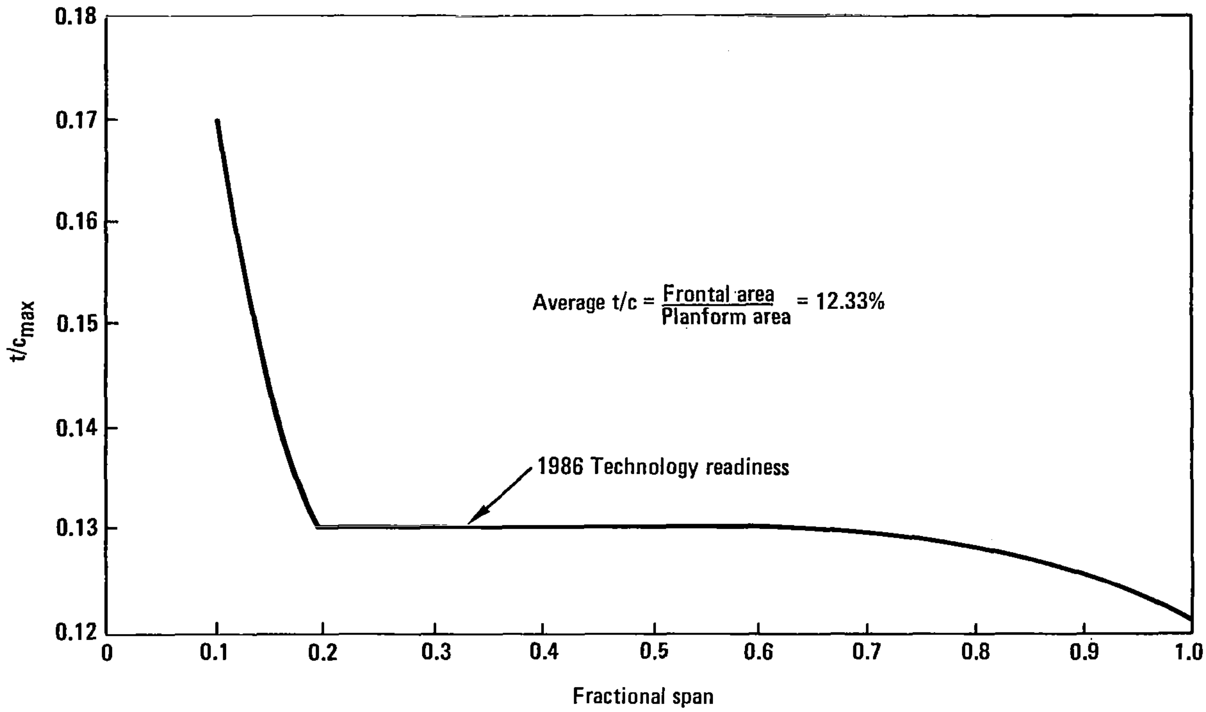


Figure 9. - Spanwise t/c schedule for 1986 wing technology.

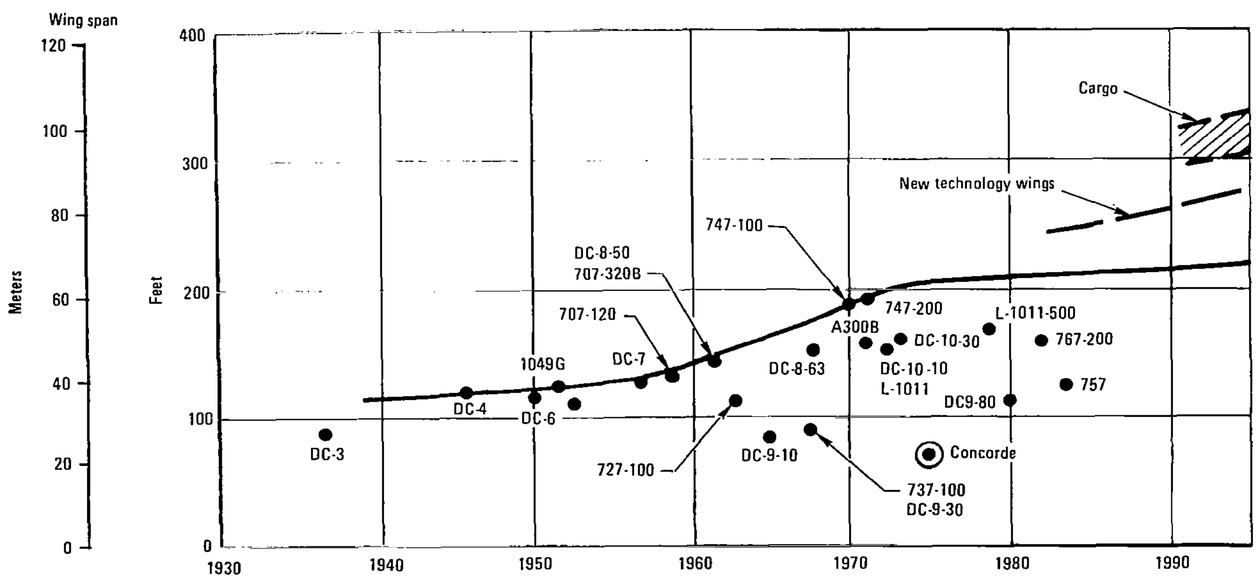


Figure 10. - Wing span growth vs year.

Fuselage length is extended by 7.11 m (280 in.) over the basic L-1011-1 to a total length of 61.26 m (201 ft). Fuselage design, materials, and construction are unchanged for all configurations.

2.1.3 Empennage. - The horizontal tail is designed as a 'flying' tail, with an elevator geared to rotate in the same sense as the stabilizer. Elevator chord is 30 percent of the stabilizer chord.

The vertical tail is fixed, with a single element rudder.

2.1.4 Propulsion system. - The propulsion system is defined in Section 4.4.

2.1.5 Landing gear. - Landing gear design for all configurations is similar to that of the L-1011, with a vertical main strut and side brace. The L-1011 landing gear is shown in Figure 11. The gear is supported on a trunnion between the rear of the wing box and an auxiliary beam forward of the inboard flaps. The landing gear butt line is 5.48 m (18 ft) from the aircraft centerline.

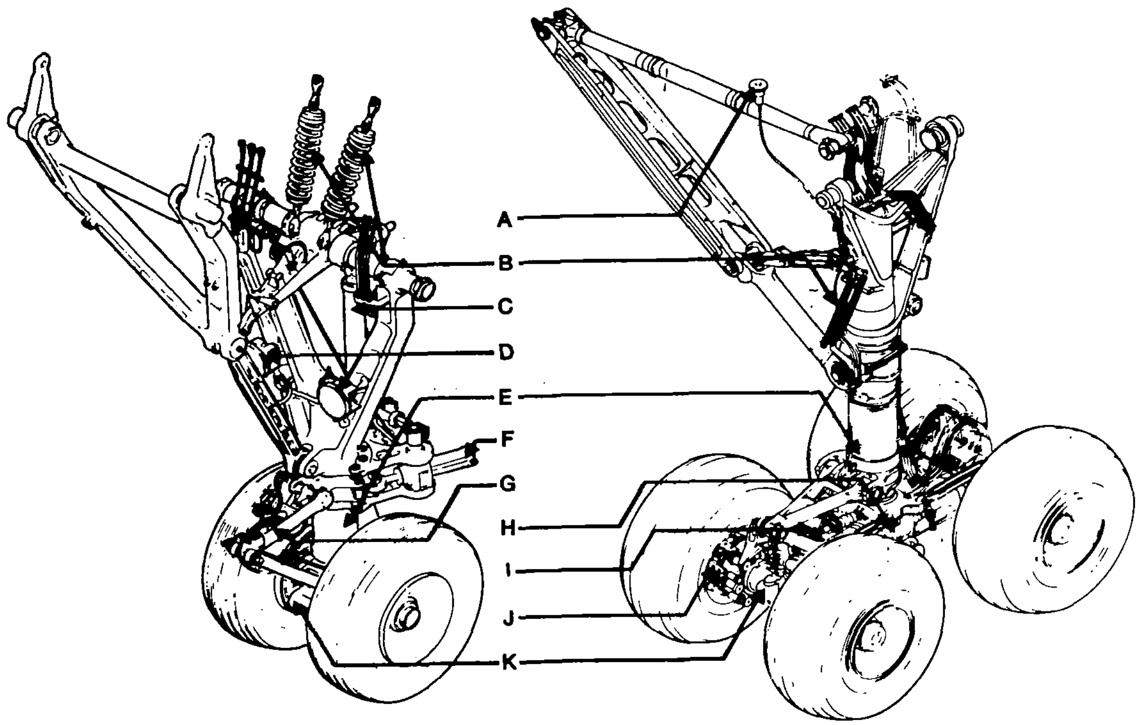
Figure 12, also taken from reference 1, shows the trend in the number of wheels on the main gears, plotted against takeoff gross weight (TOGW). For this study it is assumed that the maximum TOGW with eight wheels on the main gears (four wheels per bogey) is 273 360 kg (510,000 lb); above this weight six wheels per bogey are used. In the preliminary design procedures used in this study, landing gear weight is assumed to be a continuous function of TOGW, i.e., there is no additional weight penalty when transitioning from four to six wheels per bogey.

2.1.6 Cockpit. - Cockpit layout is the same as that for the L-1011-1. Configurations with all-electric secondary power or pitch active control system have modified instrumentation to reflect changes in monitoring and control of these systems. These will not significantly affect pilot workload.

2.1.7 Center of gravity range. - For the L-1011-1 the cg range is 1.65 m (5.4 ft). For the reference configuration the fuselage plugs increase the cg range to 1.83 m (6.0 ft). For advanced configurations, it is assumed that airlines will be willing to accept a more restricted cg range in the interests of performance improvement. The cg range for all advanced configurations is therefore reduced to 1.46 m (4.8 ft).

2.2 Performance

2.2.1 Performance requirements. - Each configuration is sized based on achieving the design range with 100 percent load factor. Minimum block fuel configurations are derived at the average stage length with 65 percent load factor.



LANDING GEAR SUBASSEMBLIES

A Visual downlock indicator

B Downlock springs

C Retract actuator

D Taxi lights

E Shock strut assembly

F Steering actuators

G Torque arms

H Bogie beam

I Bogie positioner

J Brake assembly

K Towing pads

Figure 11. - Landing gear.

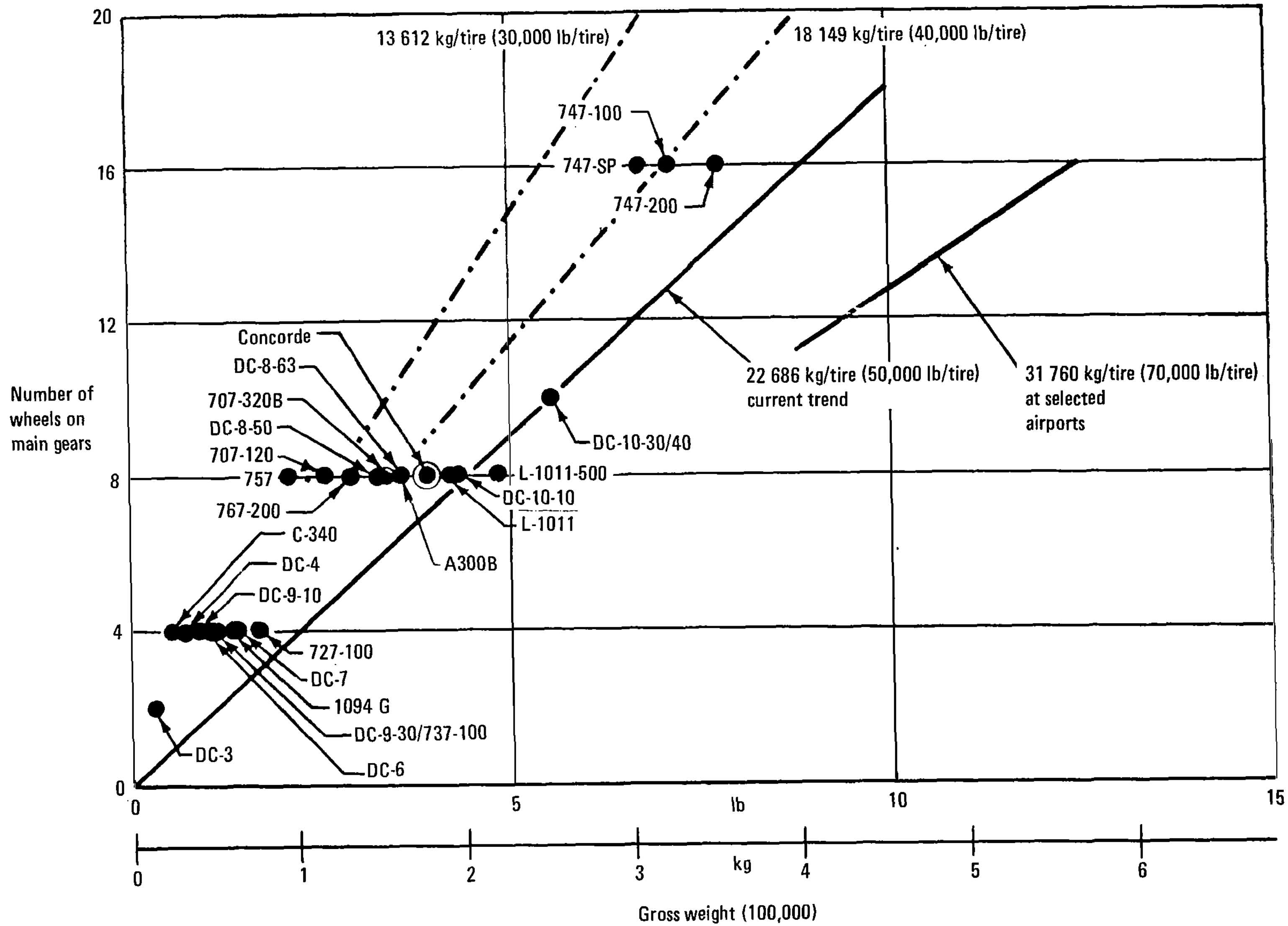


Figure 12. - Main gear tire load.

- Cruise Mach No. = 0.8
- Still air design range on standard day = 8519 km (4600 n.mi.)
- Average stage length = 4630 km (2500 n.mi.)
- Takeoff field length = 3200 m (10,500 ft) @ S.L., 302 K (84°F)
- Engine out second segment gradient = 2.7%
- Initial cruise altitude = 9449 m (31,000 ft) with climb capability of 1.52 m/s (5 ft/sec) and 1.3g buffet
- Landing field length = 2134 m (7000 ft) @ S.L., 302 K (84°F) L.W. = 136 987 kg (302,000 lb)
- Approach Speed = 74.6 m/s (145 kt)

2.2.2 Payload. -

- 350 passengers @ 74.8 kg/passenger (165 lb/passenger) = 26 195 kg (57,750 lb)
- Baggage = 7 144 kg (15,750 lb)
- Total payload = 33 340 kg (73,500 lb)
- Space-limit cargo (not included in performance calculations) = 14 333 kg (31,600 lb)

2.2.3 Mission. - The mission for each configuration is shown in Figures 13 and 14.

2.3 Technology Development Cost

The cost of technology development is defined as those costs required to achieve technology readiness prior to a program go-ahead on a specific aircraft configuration (costs prior to 1987) (figure 15). These costs are for the effort required in each advanced technology to attain a level of confidence appropriate for incorporation in a production aircraft program. Costs include design, manufacture, and test of models; breadboards, prototypes, or

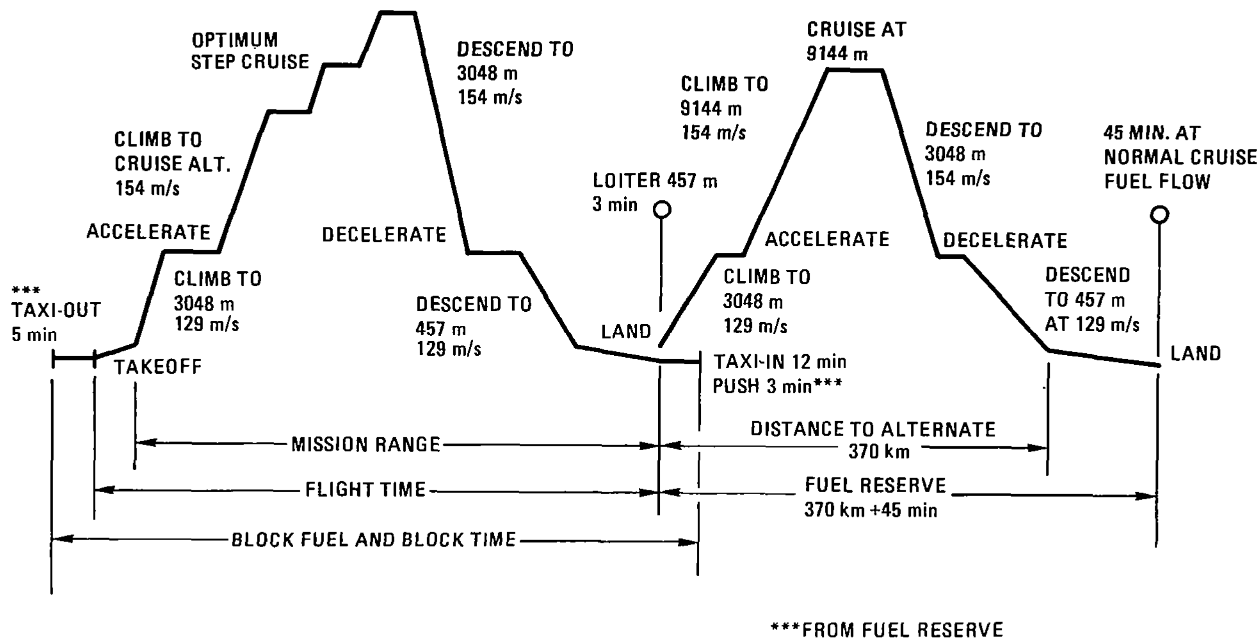


Figure 13. - Mission profile, SI units

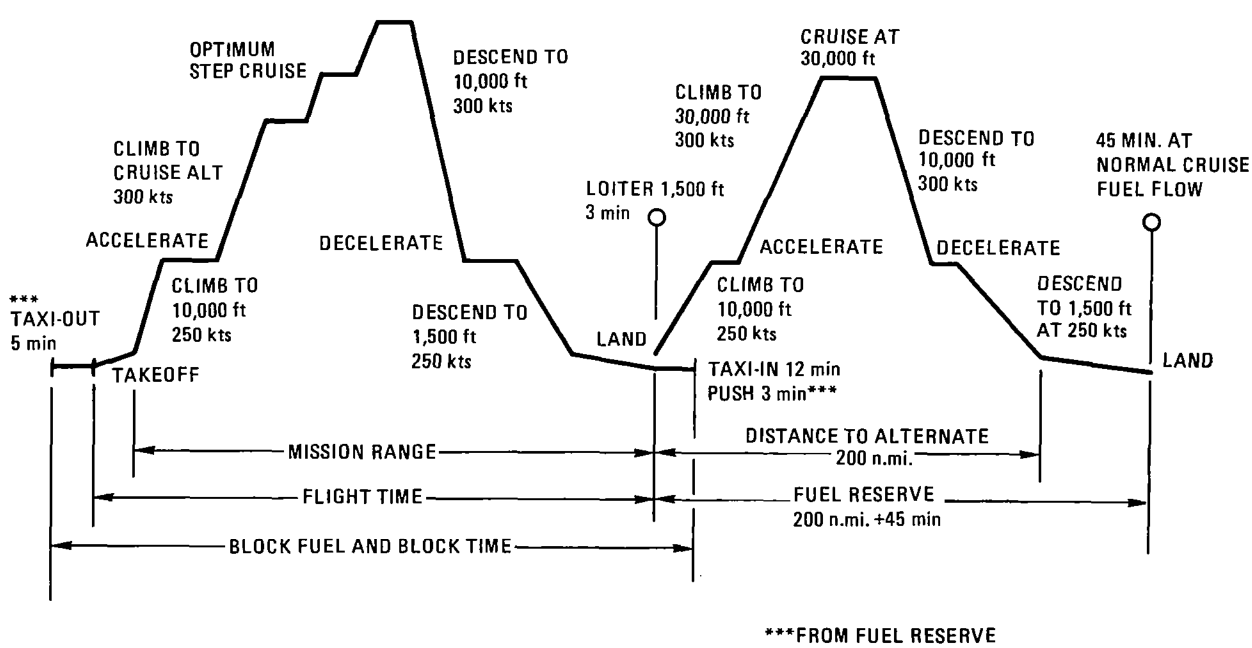


Figure 14. - Mission profile, conventional units

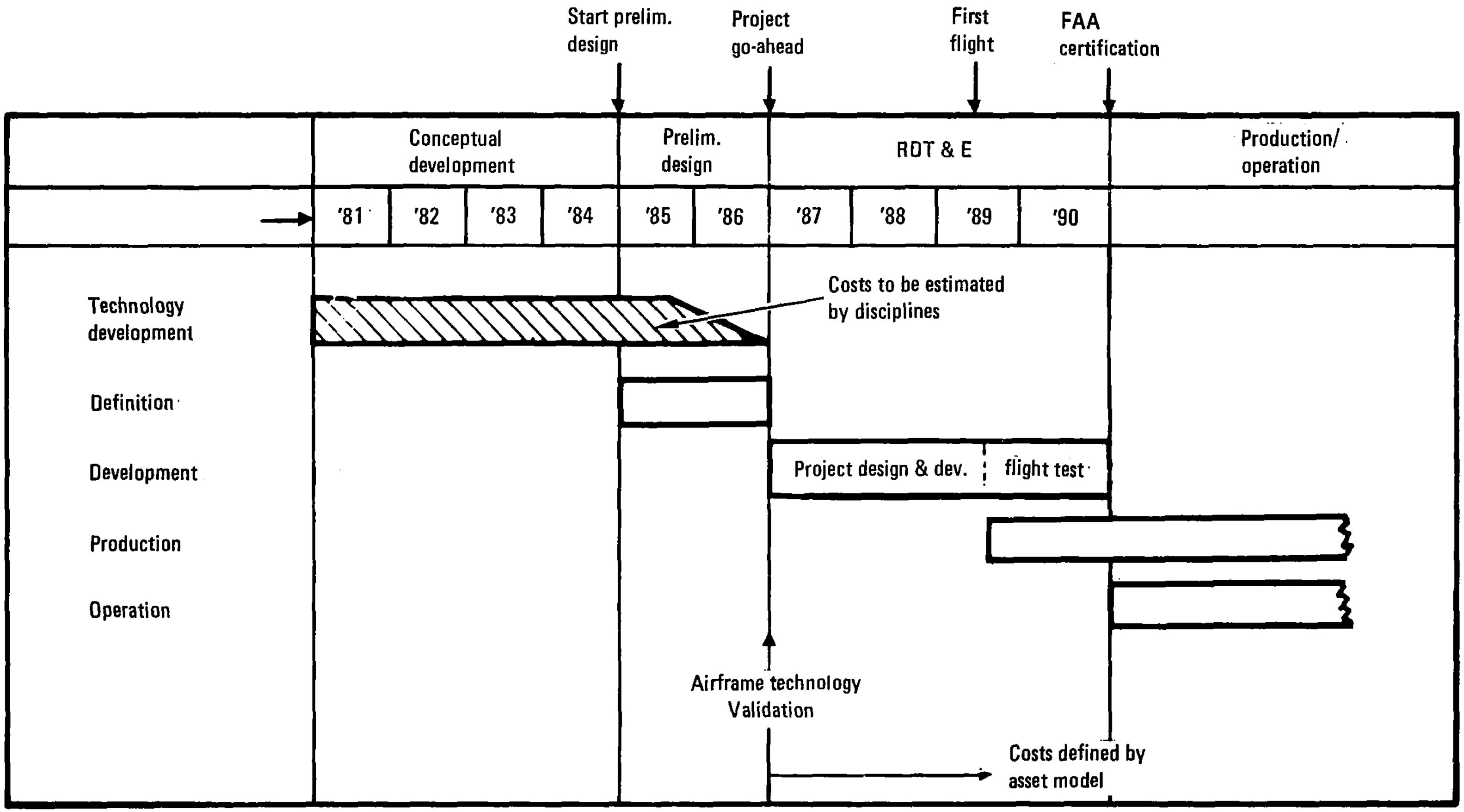


Figure 15. - Program schedule.

pilot applications required for the advanced materials, processes, structures, system equipment and engines. Capital cost for pilot plants and equipment are included but capital cost of production facilities and equipment are excluded. Costs exclude parallel or associated Department of Defense technology costs.

Cost for each advanced technology is determined through identification of each advancement required, preparation of a plan for each, and estimating labor and material costs for each plan. These costs are developed in consultation with raw material suppliers, vendors, the engine manufacturer, and Lockheed technical specialists. All costs are in constant 1980 dollars. Effort appropriate for NASA funding is identified and costs are divided between Independent Research and Development (IRAD) and Contract Research and Development (CRAD) with eight percent profit applied to the CRAD portion. Lockheed actual 1980 direct, overhead, and general and administrative costs applied to Lockheed labor hours.

To establish priorities, each of the technologies is ranked in relative order of its ratio of reduced life cycle cost (LCC) to cost of the technology development.

$$\text{Priority ratio} = \frac{\text{Net Value of Technology}}{\text{Investment in Technology Development}} \qquad (1)$$

where:

$$\text{Net value of technology} = \text{LCC (Reference aircraft)} - \text{LCC (advanced technology aircraft)}$$

$$\text{LCC} = (\text{DOC} + \text{IOC}) \times \frac{\text{block hours}}{\text{trip}} \times \frac{\text{trips}}{\text{year}} \times \text{aircraft life} \times \text{fleet size} \qquad (2)$$

2.4 Economics Analysis

The economic analysis for the Integrated Technology Wing Study is performed to arrive at a realistic life cycle cost (LCC) for the reference configuration and to provide appropriate variations for each of the variant configurations. Appropriate cost input data were developed to accomplish analysis of the benefits of each variant configuration using expected costs developed by vendors and Lockheed.

The costs for the reference and each variant aircraft is based on the following premises.

- All costs are in constant 1980 dollars.

- The development and production costs are estimated in direct labor hours and material dollars with Lockheed's actual 1980 levels for direct, overhead, and general and administrative rates, plus a profit factor applied. Manufacturing costs are based upon a production run of 400 aircraft.

- The direct operating costs are determined from 1967 Air Transport Association (ATA) equations with coefficients updated to 1980 experience (reference 4).

- The indirect operating costs (IOC) are determined using Lockheed's IOC method with 1980 coefficients (references 5 and 6).

- The operational factors and costs are based on international operation of a theoretical U. S. trunk airline with a fleet of 23 aircraft operating at an average stage length of 4630 km (2500 n.mi.), an annual utilization of 4142 hours per year, an aircraft life of 16 years, and a passenger load factor of 65 percent.

- A fuel price of $0.56/L ($2.12/gal) is used, assuming fuel density of 0.80 kg/L (6.70 lb/gal). This reflects a 1980 international price escalated at 3.5 percent over normal inflation through the year 2000.

- Block time at the average stage length is 6 hours.

Three cost components or phases are used in defining advanced technology aircraft costs. These are: development, production, and operation.

For cost development, basic program elements are identified within each of the phases. These basic elements were selected at a level where significant cost variations may occur. This is a level where configuration and program variations can be directly reflected in cost and yet at a level compatible with conceptual design analysis. Cost-significant configuration and program parameters were identified and combined into cost estimating relationships (CER) for each basic element. These CERs are programmed within the cost module of the Lockheed ASSET computer program for calculation of investment cost, operating expenses, and return on investment.

The CERs for the development and production costs are formulated from a comprehensive analysis of Lockheed aircraft. The RAND Corporation CERs are used for tooling. Engine prices are developed from a comprehensive analysis of current engines. The Lockheed database includes 14 prototypes and 16 production programs.

Development, production, and maintenance costs factors for each variant configuration are developed at a detail level using Lockheed, vendor, and engine manufacturer analysis to determine variations for advanced materials and processes, systems and engines.

The output of the development and production CERs are, for the most part, in the form of labor hours and material dollars. Hours are translated to dollars, using Lockheed's actual January 1980 direct, overhead and general and administrative rates plus a profit factor of 15 percent.

Development costs include all the costs necessary to design, develop, and demonstrate that the aircraft meets its requirements culminating in FAA certification.

Operation expense includes both direct operating cost (DOC) and indirect operating cost (IOC). The 1967 Air Transportation Association (ATA) equations with coefficients updated to January 1980 experience are used to calculate all elements of DOC. Indirect operating costs are based on a Lockheed-Boeing method of coefficients and factors. The factors were extracted from U. S. Civil Aeronautics Board (CAB 41) data reflecting inputs for 1980.

2.5 Noise

Both the CF6-50C and E^3 engines on the reference or advanced configurations are projected to meet current noise levels, although the CF6 can only just meet these levels, whereas the E^3 program goal is 2 to 4 EPNdB below FAR Part 36 (1978).

This is a real benefit, but it is difficult to make tradeoffs between noise levels and operating economics of the aircraft; noise calculations also require considerable computing time and cost. Because of this combination of factors, it was decided to omit noise calculations from this study.

2.6 Market Requirements

The point in time when technology readiness must be established depends upon:

- The degree of technology advancement required.
- The funding support made available to establish the technology.
- Production of a new aircraft that incorporates the technology.
- Capability of the market place to accept and employ this new advanced technology aircraft.

The ability of airlines to purchase new equipment is related to the airline debt-to-equity ratio. The trends of this economic indicator is cyclic as displayed in figure 16.

The purchase of new equipment (B757, B767) by the airlines to replace their current narrowbody equipment (727-100, 707, DC-8) will drive the debt-to-equity ratio back up again. These trends indicate that the early 1990 time period as the earliest date in which the airlines will have the ability to purchase further new equipment.

An historical look at the commercial air transport development further indicates the cyclic nature of the airline industry (figure 17). Starting with the initial passenger aircraft of the 1920s, there has been an introduction of an advanced technology transport approximately every 12 years.

These trends indicate the potential availability of airline resources for new equipment buys for advanced technology aircraft will be in the early 1990s. Targeting technology readiness for the mid-1980s will provide sufficient time to pursue a systematic technology development program.

The following assumptions were made in assessing the market potential for a 350-passenger aircraft:

- Passenger traffic growth will be slowed down by advancements in telecommunications, etc. after 1990.
- The advanced trijet will obsolete 4-engine aircraft by 1995.
- There will be a minimum of 2 manufacturers of the advanced trijet.
- Advanced twins will dominate the market on routes under 5556 km (3000 n.mi.) by 1995 (as limited by 90-minute rule).
- Wide bodies delivered between 1970 and 1990 will be retired in 16 to 20 years after original delivery although many will spend their last years in the fleets of developing countries.

Using these assumptions, the preliminary forecast is for a market of between 1200 and 1400 aircraft deliveries in the period 1990-2005.

This study assumes a total market of 1200 aircraft with three manufacturers, so that design development and production costs are based on production runs of 400 aircraft per manufacturer.

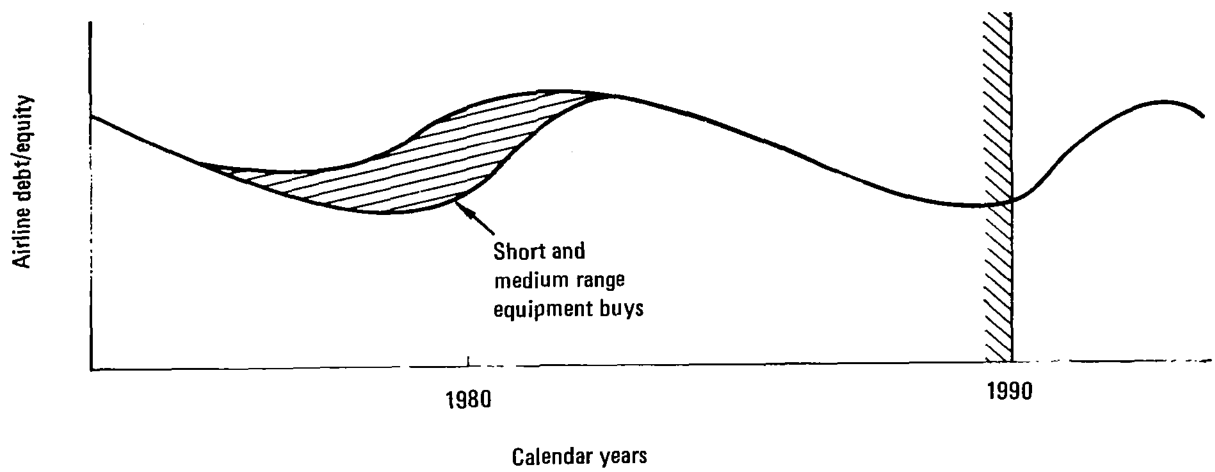


Figure 16. - New aircraft timing.

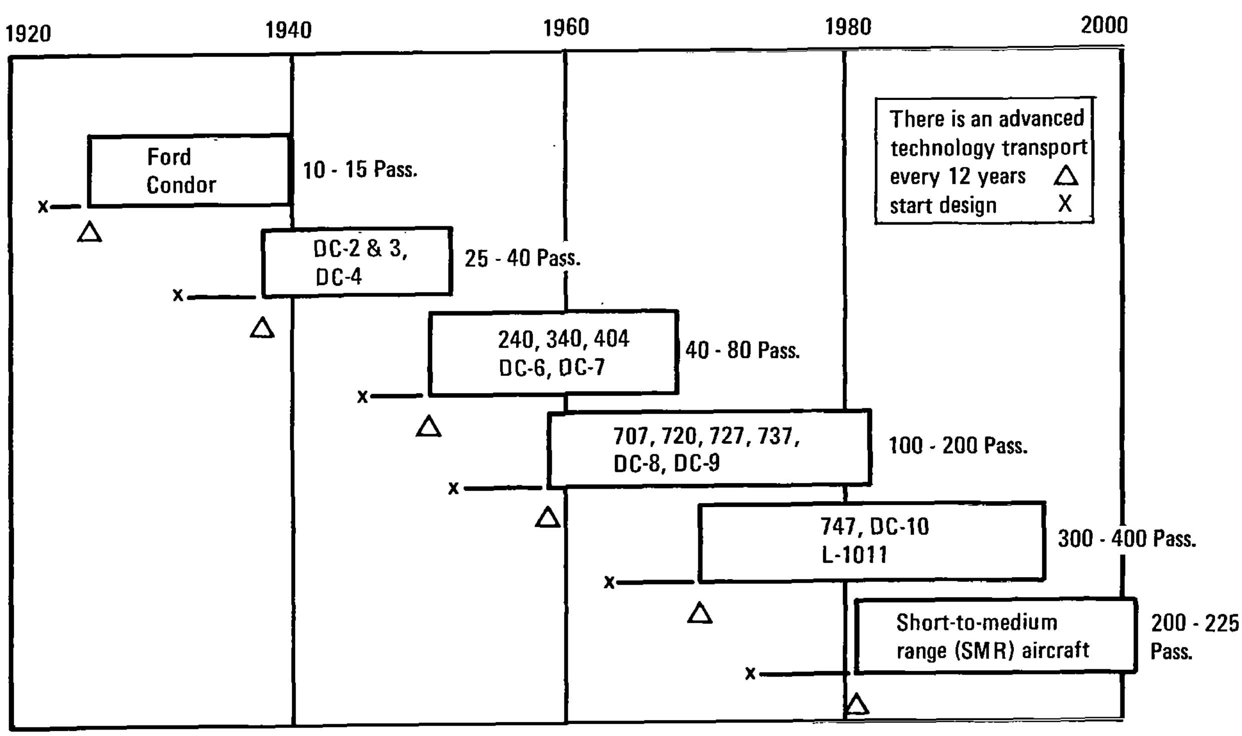


Figure 17. - Commercial air transport development.

3. EVALUATION METHODOLOGY

3.1 The ASSET Vehicle Synthesis Model

Aircraft parametric sizing, configuration tradeoff, and performance evaluation studies are performed through the use of the Lockheed-developed Advanced System Synthesis and Evaluation Technique (ASSET) vehicle synthesis model. A schematic presentation of the primary input and output data involved in the ASSET synthesis cycle, which is programmed on an IBM-3033 computer, is shown on figure 18. The ASSET program integrates input data describing vehicle geometry, aerodynamics, propulsion, weights, and subsystems, and analyses candidate vehicles which satisfy given mission requirements. It provides the means to assess the effects of airframe, propulsion, and systems options (thrust to weight, wing loading, engine cycle, advanced materials usage, etc.) on the vehicle weight, size, and performance.

The main benefits from the employment of this computerized synthesis technique are:

- A defined format exists for relating technical data from the various disciplines. Data requirements for design and performance analysis are well defined and specified.
- Tradeoffs between different technologies are properly related and are evaluated on the basis of their effects on the total system.
- Last-minute changes to the design ground rules can be rapidly incorporated into the vehicle synthesis.
- The output from the computer program provides an automatic bookkeeping and documentation instrument.

A generalized schematic illustrating key elements and the flow of information through the ASSET program is shown in figure 19. The three major subprograms of ASSET are sizing, performance, and costing. The sizing program sizes each parametric aircraft to specified W/S and T/W and computes the fuel weight required for a design mission. The design characteristics and component weights of the sized aircraft are then transferred to (1) the costing program, which computes aircraft cost on the basis of component weights and materials, engine cycle and size, avionics packages, payload, production and operational schedules, and input cost factors; and (2) the performance program which computes maneuverability, airport performance (takeoff and landing distances), and other performance parameters.

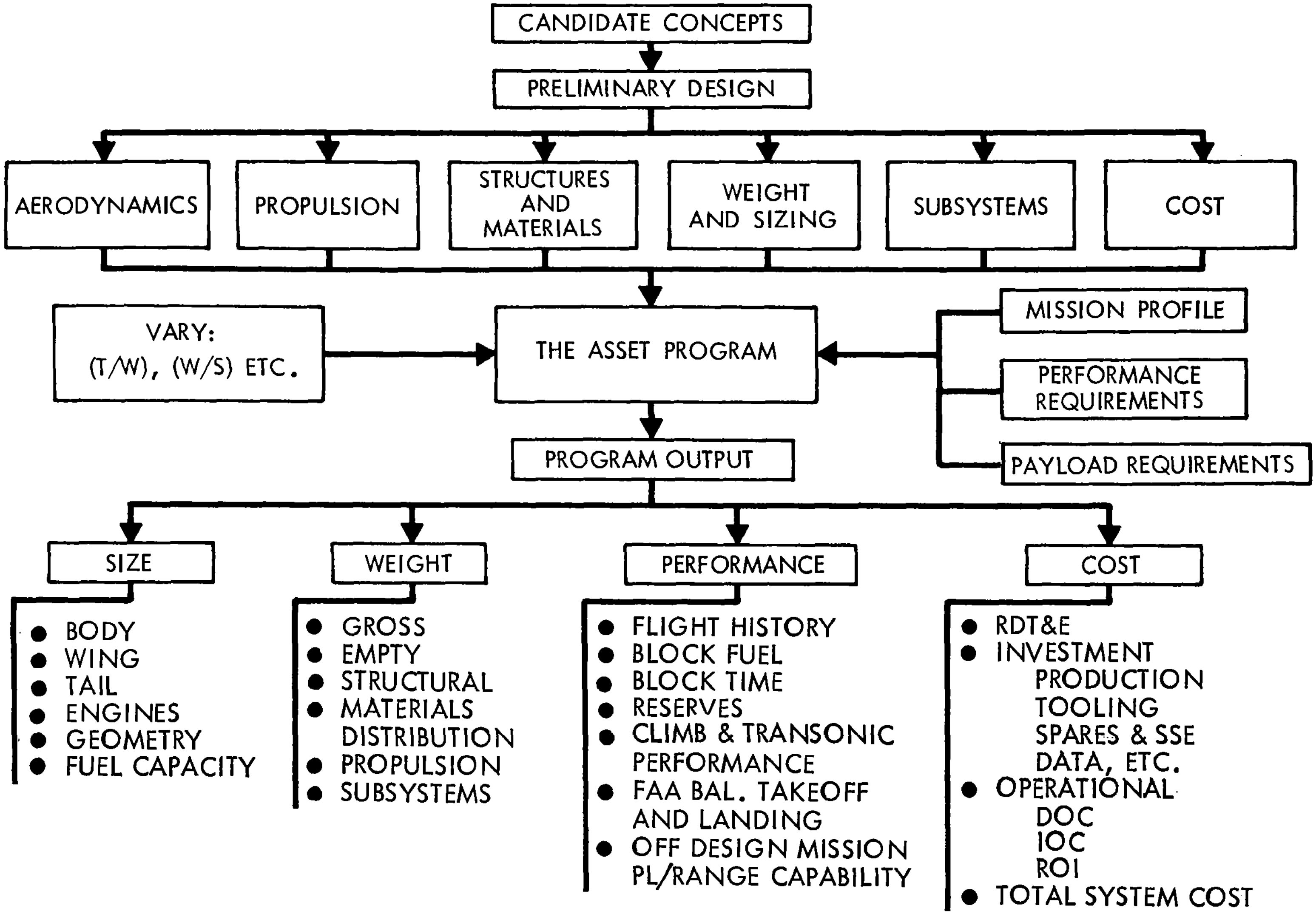


Figure 18. - The ASSET synthesis cycle.

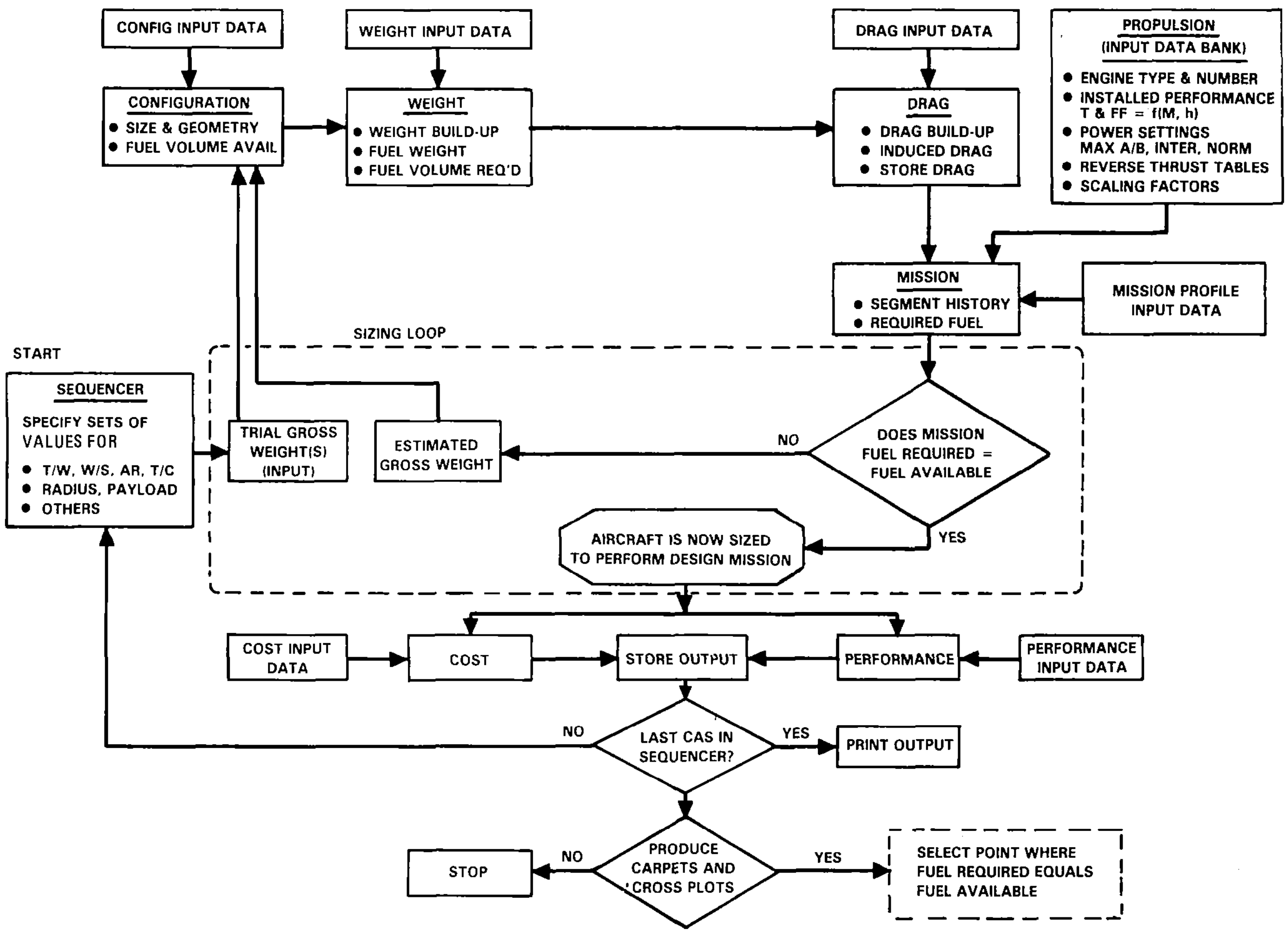


Figure 19. - ASSET program schematic.

ASSET program output consists of a group weight statement, vehicle geometry description, mission profile summary, a summary of the vehicle's performance evaluation, and RDT&E production and operational cost breakdowns.

3.1.1 Vehicle sizing. - The sizing subprogram is composed of five routines: sequencer, configuration, weight, drag, and mission. In addition, the sizing subprogram uses propulsion data input in the form of thrust and fuel-flow tables and an independent atmosphere subroutine.

The sequence routine groups the sets of independent variables (design options and mission requirements) that are to be varied parametrically. Examples of these variables include (but are not limited to) thrust/weight, wing loading, aspect ratio, wing thickness ratio, wing sweep angle, design load factor, payload, equipment, avionics weights, materials usage factors, and design mission requirements, (range, radius, endurance, speed, etc.).

The input parameters from the sequence routine and the configuration and weight inputs are transmitted to the configuration and weight routines. The configuration inputs describe the fuselage geometry (forebody, cockpit, fuel section, engine section, afterbody), the wing geometry, wing fuel-tank volumes, the tail geometry and sizing relationships, engine scaling relationships, and engine nacelle or inlet geometry. The weight input consists of equipment and payload weights, propulsion system weight relationships, loads criteria, component airframe weight coefficients and exponents applicable to conventional constructions, and the materials distribution for each major structural airframe component, and the corresponding weight correction references to conventional construction. The configuration routine computes the geometric data for the vehicle components (planform areas, wetted areas, frontal areas, lengths, diameters, chords, reference lengths, volumes, shapes, etc.) required by the weight and drag routines. The weight routine determines the component weight build-up, materials usage for the major airframe elements, and the fuel available. These data are used in the configuration routine. The configuration and weight routines, operating together, determine the geometric and weight characteristics for an airplane having an assumed trial takeoff gross weight. The trial vehicle is geometrically sized to contain the crew, equipment, payload, and propulsion system. The tail sizing criteria can be either to maintain (1) a specified tail volume, (2) a specified tail area to wing area ratio, or (3) and (4) a constant ratio of each of these to the T/W value.

The geometric data for the trial aircraft are transmitted to the drag routine. Profile and skin friction drags are computed for each component based upon surface wetted area and geometry.

Induced drag is computed by a perturbation method that corrects flight test based data for changes in aircraft geometry.

Propulsion data for the engine under study are input to the program. Applicable power setting, (takeoff, maximum, intermediate, continuous, etc.) thrust and fuel-flow data are provided as functions of Mach number and altitude. Partial power tables are used to simulate operation at thrust levels required during cruise or loiter. The partial power tables describe fuel flow as a function, Mach number, and altitude. Engine scaling factors, determined from the configuration routine, are applied to the propulsion data to determine thrust and fuel flow for the engine size of the aircraft under study for any flight condition.

The atmosphere subroutine, used by the mission routine and the performance subprogram, allows computation of pressure, density, temperature, and the speed of sound at any given geometric or pressure altitude. Standard or nonstandard days may be considered. Standard or arbitrary atmosphere models can be used.

The mission routine uses the propulsion thrust and fuel-flow tables, the aerodynamic-drag tables, and the atmosphere subroutine to determine the fuel required to perform the design mission profile. The mission profile is assembled from specified flight segments, such as takeoff, climb, acceleration, cruise, loiter, combat, etc. Simplified two-dimensional point mass flight equations are used in determining the time history of the mission. Simplifying assumptions common to classical aircraft performance analysis, which ignore rotational and normal accelerations, are incorporated into the flight equations.

An iterative convergence technique completes the sizing subprograms. Using this technique, the fuel available from the weight routine and the fuel required determined by the mission routine are compared. If the difference between the available and required fuel is greater than acceptable tolerances, a new trial takeoff gross weight is computed. This iteration continues, passing trial aircraft through the sizing cycle until acceptable agreement is reached between the available and required fuel. The configuration, weight, and aerodynamic data generated for the final aircraft satisfying the mission requirements are saved for use in running alternate (nonsizing) missions and as input to the performance subprogram.

3.1.2 Performance evaluation. - The performance uses the aerodynamic, weight, and propulsion data generated for the synthesized aircraft by the size subprogram, and additional aerodynamic, weight, and propulsion input data required to evaluate any or all of the following performance characteristics:

- Climb characteristics (sea level rate of climb, ceiling)
- Speed (maximum speed at sea level, maximum speed at optimum altitude)
- Maneuverability (steady state maneuvering load factor, specific excess power, time to accelerate, time to decelerate)
- Airport performance (takeoff distance over an obstacle, landing distance over an obstacle, wave-off rate of climb)
- Alternate mission capability (range, radius, endurance, etc., for off-design missions)

The climb characteristics of the synthesized aircraft are assessed at specific vehicle weights for given thrust settings. Ceiling altitudes are determined for specified rate of climb requirements for a series of aircraft weights ranging from the takeoff weight to the zero fuel weight. Cruise ceilings may be determined by specification of the appropriate thrust settings, and rate-of-climb requirement.

Maneuverability capabilities are evaluated for specified aircraft weights, thrust settings, speeds, and altitudes. Steady state load factors are determined for buffet boundary lift coefficient flight conditions. Acceleration and deceleration time histories are determined between given speeds. Drag brakes and/or thrust reversal may be employed during deceleration.

Airport performance can be evaluated for any altitude and for both standard and nonstandard days. Low-speed aerodynamic characteristics are computed based upon a specified zero-lift angle of attack, maximum lift coefficient, and flight-test-based drag data that takes into account the high-lift system position. Other factors that are input-defined to determine takeoff and landing performance are scrape angle, brake effectiveness, and pilot reaction times.

Takeoff flight path options can be selected that meet FAR requirements for speed ratios and optimize rotation speed between minimum and maximum values. V_2 can be either fixed at a percentage of stall speed or increased to meet gradient requirements. Both all-engine and engine out performance is calculated.

The landing approach is defined by a specified V_{APP} to V_S ratio with maximum allowable limits on the sink rate and load factors during segment transition and flare.

3.1.3 Costing. - The costing program computes RDT&E, investment, and operational costs. Both the RDT&E and production (flyaway) aircraft costs are broken down by airframe, engines, avionics, and armament. Airframe costs are further broken down into engineering, tooling, manufacturing, quality control, and material costs. The various cost elements are computed on the basis of cost estimating relationships (CER) which are established by analysis of historical data of applicable aircraft programs, Lockheed's R&D and production experience, and subcontractor/supplier quotations. Cost input consists of dollars-per-hour (labor cost) and dollars-per-pound (material cost) factors by aircraft structural element and material, labor rates, production rates and schedule, learning curves, subsystem, engine and avionics cost factors, and operational (fuel, maintenance, etc.) considerations. The model permits parametric costing as function of thrust, inert weight elements/and advanced material usage.

3.2 Wing Weight Estimation

When a configuration is resized within ASSET, all component weights are correspondingly adjusted. A significant weights relationship, which affects the choice of optimum wing geometry is that between wing weight and aspect ratio.

The ASSET wing weight equation used for parametric studies used to estimate the wing weight is:

$$WW = [QT * (BENDMO * QN)^{EWNTGW} * GEOM + CLE * S] * (1+AMRFW) \qquad (3)$$

where

WW = total wing weight, lb

QT = constant

BENDMO = UPLOAD - WR = net wing root bending moment, lb x fraction of semispan

UPLOAD = wing upload root bending moment, lb x fraction of semispan

WR = wing relief root bending moment, lb x fraction of semispan

QN = ultimate load factor

GEOM = $AR^{EWAR} * S^{EWS}/TCW^{EWTCW} * (COS(CLMR))^{EWCLMR}$, in.

AR = basic wing aspect ratio

S = basic wing area, ft^2

TCW = basic wing structural thickness ratio, percent

CLMR = sweep angle of structural axis, degree

EWAR = aspect ratio exponent

EWS = area exponent

EWTCW = thickness ratio exponent

EWCLMR = sweep angle exponent

CLE = secondary structure constant, lb/ft^2 (applied to basic wing area)

EWNTGW = root bending moment exponent

AMRFWI = wing advanced materials reduction factor

In equation (3) the term QT contains the material density (lb/in^3) divided by the effective stress (lb/in^2), so that the dimensionality of both terms contained within the brackets have the dimensionality of weight.

The wing weight-parameter relationship has evolved from substantial analytical development and shows a good correlation to a variety of subsonic swept wing transports with aspect ratios from 6.9 to 8.9. The wing weight accounts for a strength critical wing (including effects of gust and maneuver loads) and includes the effect of aeroelastic relief at high aspect ratios. For aspect ratios greater than nine, an additional weight increment is added for flutter considerations ranging from zero at AR = 9 to $\pm$ 4% at AR = 12. Improved confidence levels at high aspect ratios would require a detailed flutter analysis.

The wing advanced materials reduction factor, AMRFWI, accounts for the time-frame-technology availability. These factors account for the material technology employed, such as current aluminum alloys, advanced aluminum alloys, advanced composites, and metal matrix composite configurations. The technology factors also account for the usage of active controls, advanced airfoils and other advanced concepts; the technology factor AMRFWI is set to a negative value. Weight effects of active controls are included.

Figure 20 shows the variation of wing weight with aspect ratio, obtained by Equation (3) and the baseline wing with an aspect ratio of 7.79 and a weight of 29 433 kg (64,899 lb).

3.3 Selection of the Point Design

If the basic planform characteristics, i.e., (AR, t/c, Λ) are fixed, the ASSET program may be used to find the values of T/W and W/S of an aircraft which can perform the required average stage length of 4630 km (2500 n.mi.) with the minimum block fuel. A matrix of aircraft with selected values of T/W and W/S are sized to perform the design range of 8519 km (4600 n.mi.).

Each defined configuration is then reflown at the average stage length and the block fuel is determined. Carpet plots are automatically generated with contraints superimposed.

These constraints are:

1.	All engine takeoff distance	3200 m (10,500 ft)
2.	Engine out takeoff distance	3200 m (10,500 ft)
3.	Engine out 2nd segment gradient	2.7%
4.	Approach speed	74.6 m/s (145 kt)
5.	Conventional landing distance	2134 m (7000 ft)
6.	Fuel volume available to volume required ratio	1.1
7.	Specific excess power (SEP)	1.52 m/s (5.0 ft/sec)

If the planform parameters are undefined, this process is repeated for selected values of AR, t/c and Λ . Carpet plots are then generated of AR vs t/c (a separate plot is generated for each sweep). Each point on the AR vs t/c carpet plots represents an optimized value of T/W and W/S.

3.4 Landing Gear Fit

When Λ and AR are varied parametrically, the batt shape is varied in order to keep

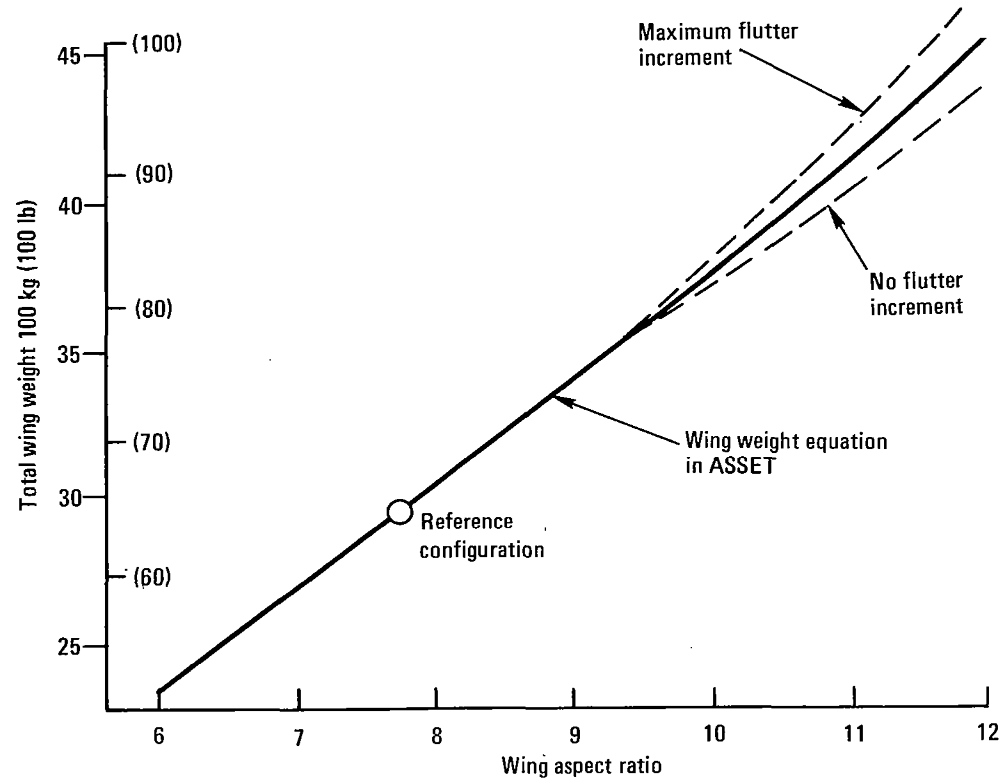


Figure 20. - Effect of aspect ratio on wing weight.

$$\frac{y_B}{b/2} = 0.427 \tag{4}$$

and

$$\frac{c_R}{c_R + c_B} = 0.695 \tag{5}$$

(see figure 8).

The flap chord is sized so that the ratio

$$\frac{\text{Flap chord}}{\text{Wing chord at flap mid-span}} = 0.261 \tag{6}$$

The ASSET program does not check whether the landing gear will fit between the wing box and the rear auxiliary beam. When an optimized configuration is found, the wing must be laid out to check whether the landing gear fits. If it does not, the batt shape is revised and the revised planform rerun on ASSET.

4. DEFINITION OF REFERENCE AIRCRAFT

4.1 Derivation of Reference Configuration

The derivation of the reference aircraft from the L-1011-1 is shown in figure 7. The reference aircraft represents the level of technology of aircraft currently in service. It should be pointed out that the aircraft does not necessarily represent current technology readiness, because significant gains have been made in some technology areas, such as aerodynamics and propulsion, so that the benefits of advanced technology, as compared with the reference aircraft, represent advances in technology readiness from the late 1970s time period.

4.1.1 Reference aircraft. - A reference configuration is derived from the L-1011-1, figure 21, by the addition of wing root plugs, fuselage plugs, sixwheel main gear, extended wing tips, active ailerons, and General Electric CF6-50C engines. This aircraft represents a long-range, high density aircraft of conventional design. The initial gross weight estimate was 272 000 kg (600,000 lb), requiring a six-wheel main gear. The fuselage length is extended by 7.11 m (280 in.) over the basic L-1011-1, as shown in figure 2. A 3.05 m (120 in.) fuselage plug is located forward of the wing, plus a 406 m (160 in.) plug aft of the wing. The aircraft has a cargo capacity for 20 LD3 containers with an underfloor galley. Space limit cargo is 14 300 kg (31,600 lb). The latter is not included in the payload-range calculations. The aircraft requires a wing area increase over the L-1011-1. The concept incorporates the L-1011-1 wing plus active ailerons and extended wing tips (the same as for the L-1011-500). In addition, it provides for a 1.57 m (62.0 in.) wing root plug (per side). The cg for performance calculations is at 25 percent MAC (figure 22). The General Electric CF6-50C engine is used as the reference propulsion system. The CF6-50C engine is a high-bypass ratio turbofan with SFC levels representative of early 1970s technology. The engine would be resized to meet the reference aircraft thrust requirements.

4.1.2 Optimization of reference aircraft. - The optimized reference configuration is derived by resizing the wing, increasing wing incidence, and resizing the engines.

The addition of the wing root plug as described in Section 4.1.1 does not produce an optimum wing loading for the design range defined in this study. The wing loading has therefore been optimized, but keeping the same planform shape. This results in a wing span of 58.86 m (193.1 ft) for the optimized reference configuration. Derivation of optimum thrust/weight and wing loading for minimum block fuel at the average stage length is shown in figure 23. The reference configuration is presented in figure 24.

The 4 m (160 in.) aft fuselage extension results in a reduction in tail scrape angle from 15° (on the L-1011-1) to 9.9°. This limits the achievable C_L at liftoff resulting in an excessive takeoff field length.

A two-part solution to the problem has been adopted. The first part is to increase the wing incidence relative to the fuselage reference plane from 3° to 5°. This results in an increase in interference drag of 4 counts at cruise. The second part is to improve the flap effectiveness and to deflect the inboard ailerons at takeoff. This results in a 1.5° shift in the C_L vs line. The net result is a 3.5° shift of the C_L vs α_F line, where α_F is fuselage incidence relative to free stream (figure 25).

A carpet plot showing the constrained point design is shown in figure 23. A three-view is shown in figure 24. This configuration has the following characteristics:

- TOGW = 280 302 kg (617 950 lb)
- T/W = 0.265
- W/S = 6.18 kN/m^2 (129 lb/ft^2)
- Block fuel at average stage length = 43 827 kg (96,620 lb)

A complete definition of this and other configurations may be found in Appendix 1.

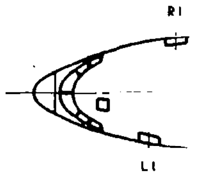
4.1.3 Configuration comparisons. - A comparison between existing Lockheed designs (L-1011-1 and L-1011-500), and the reference configuration is shown in table II.

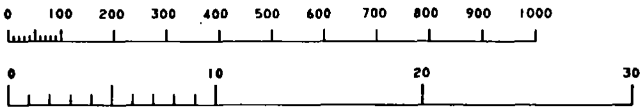
- Because of the 4.06 m (160 in.) increase in aft fuselage length, the tail volume coefficient is slightly larger than that of the L-1011-1.
- Vertical tail size: The vertical tail is sized so that $\overline{V}_V/(T/W)$ is maintained constant.

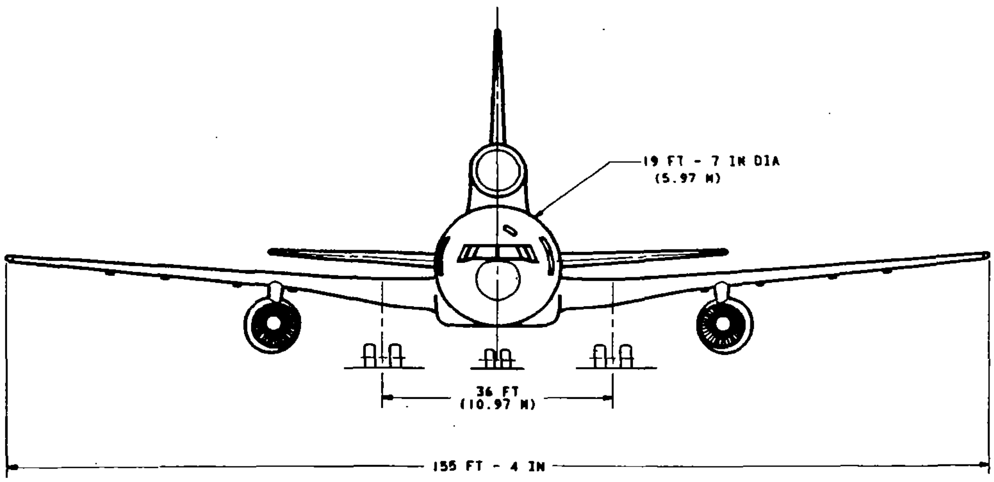
4.2 Reference Aerodynamics

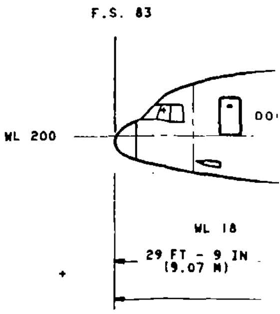
The aerodynamic database used for the reference aircraft is the L-1011, developed in the late 1960s. A multitude of FAA approved flight test data and wind tunnel data for the various L-1011 models is available and correlates well with the drag levels obtained by Lockheed's ASSET sizing subprogram for the reference aircraft. The profile and skin friction drag of the additional surface areas, at the appropriate Reynolds number and form factor, are accounted for through the ASSET sizing subprogram. The wave drag is computed

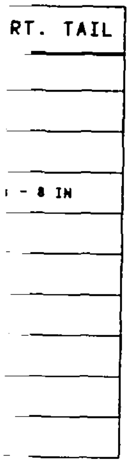
CHARACTERISTIC	WING	HORIZ. TAIL	VERT. TAIL
AREA (SQ FT)	3456	1282	550
ASPECT RATIO	6.95	4.0	1.6
TAPER RATIO	0.30	.33	.30
SPAN (THEO)	155 FT - 0 IN	71 FT - 7 IN	29 FT - 8 IN
ROOT CHORD (IN)	412	323	342
TIP CHORD (IN)	123	107	102.6
M.A.C. (IN)	293.50	233	243.8
DIHEDRAL AT T.E.	INBD 7 31'11.12" OUTBD 5 30'	3.0	--
SWEEP AT 25% CHORD (DEG)	35	35	35
L.E. M.A.C. (STA)	1143	1885	1924

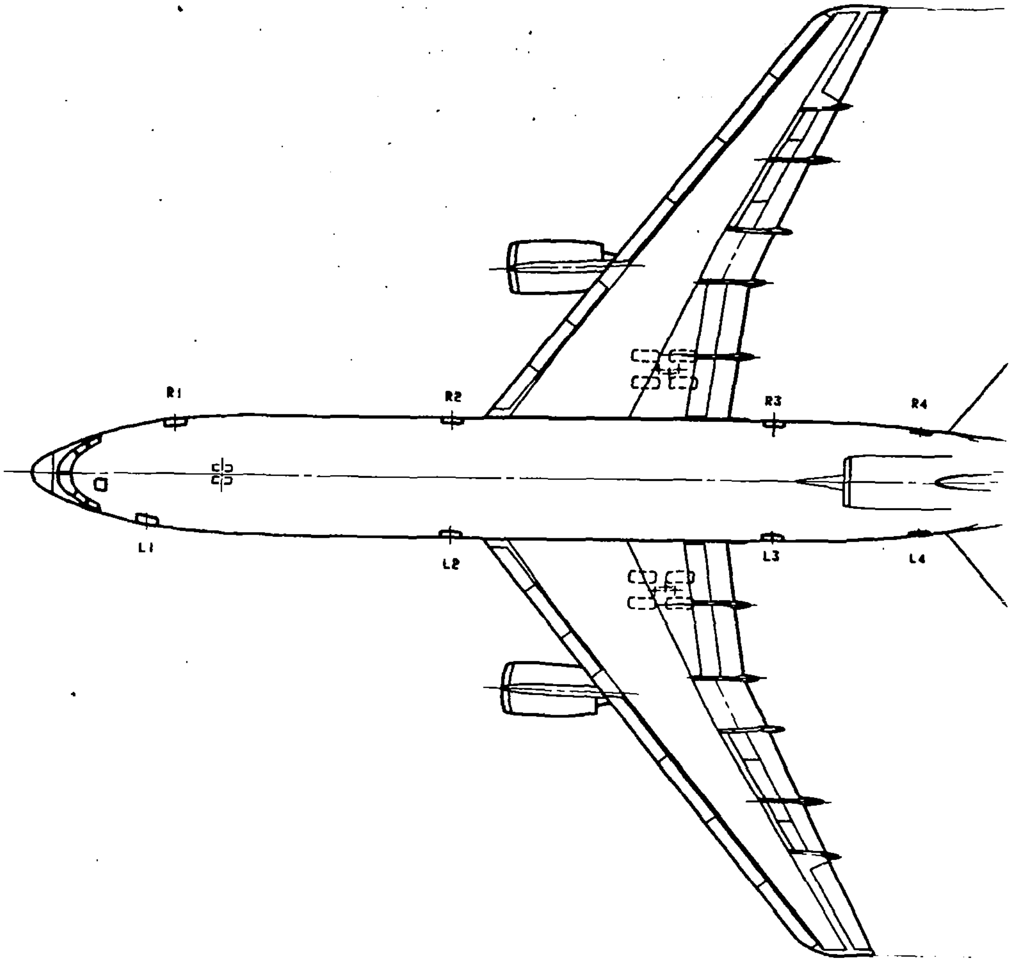


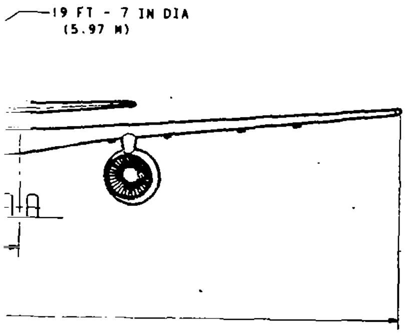


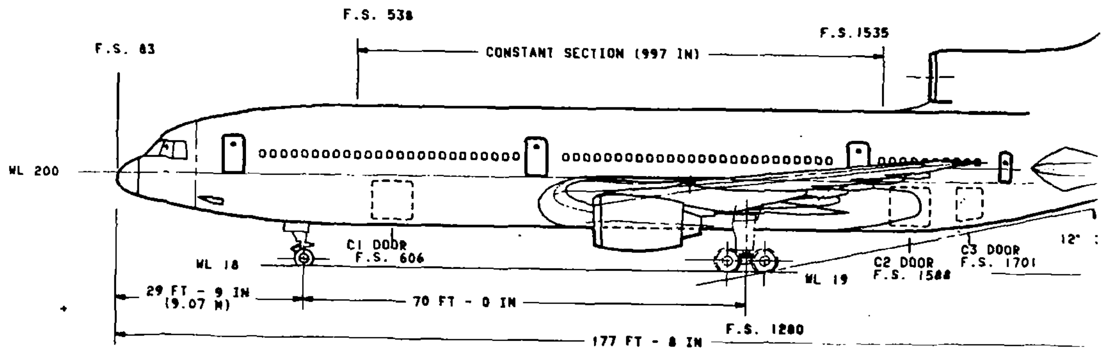





RT. TAIL
- 8 IN


R1
R2
R3
R4
L1
L2
L3
L4


19 FT - 7 IN DIA
(5.97 M)


F.S. 538
F.S. 83
CONSTANT SECTION (997 IN)
F.S. 1535
WL 200
C1 DOOR
F.S. 606
WL 18
C2 DOOR
F.S. 1588
C3 DOOR
F.S. 1701
WL 19
12°
29 FT - 9 IN
(9.07 M)
70 FT - 0 IN
F.S. 1280
177 FT - 8 IN

Figu

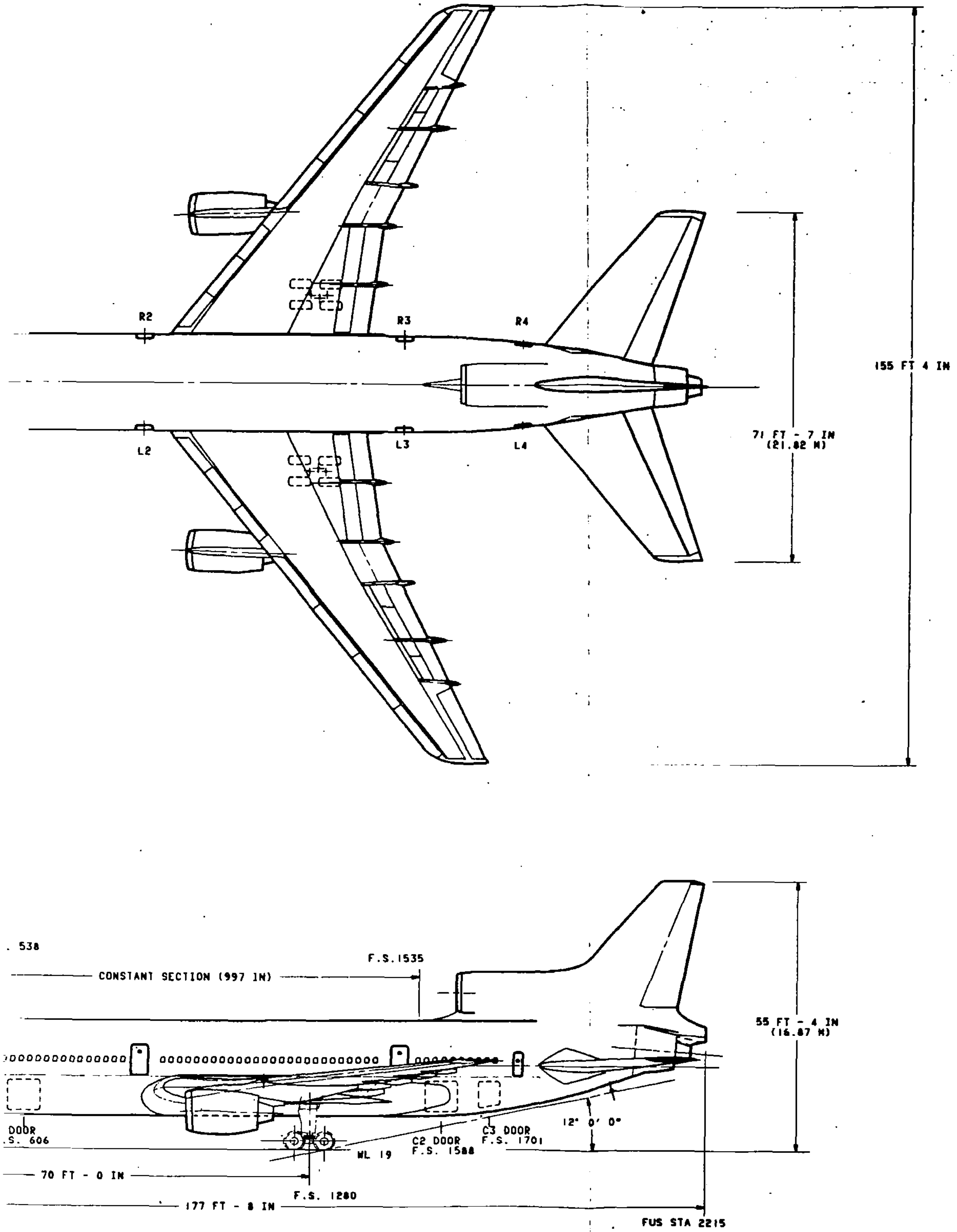


Figure 21. - L-1011-1 aircraft.

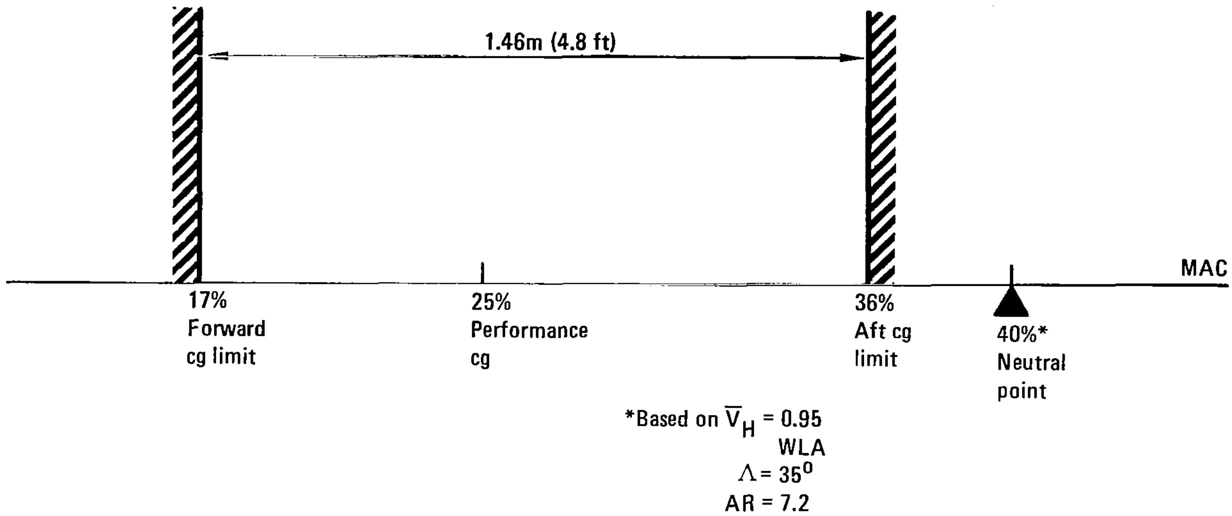


Figure 22. - Center-of gravity range for configuration 1.

using the PERTDRAG database, "L-1011 technology", as shown on figures 45 and 46 as a function of Mach number, sweep and t/c. The 2^o wing incidence increase required to enhance the takeoff performance resulted in a cruise drag increase of 4 counts.

The wing incorporates inboard and outboard ailerons, with a travel of plus or minus 20^o, to provide lateral control. In addition the wing incorporates six spoilers used in various combinations for speed brakes, lateral control augmentation with flaps extended, ground speed brakes and direct lift control.

The reference aircraft's high lift system is of a conventional design, including leading edge slats and trailing edge double slotted flaps with deflected inboard ailerons. The effectiveness of this system is shown in figure 25, as a 1.5^o shift in α_{LO}. The leading edge slat system consists of eight slat panels on each wing, four inboard of the pylon and four outboard. As on the L-1011-500 the wing tip extension does not require a leading edge slat. Fully extended, the four inboard slats deflect 28 degrees and the four outboard panels deflect 30 degrees.

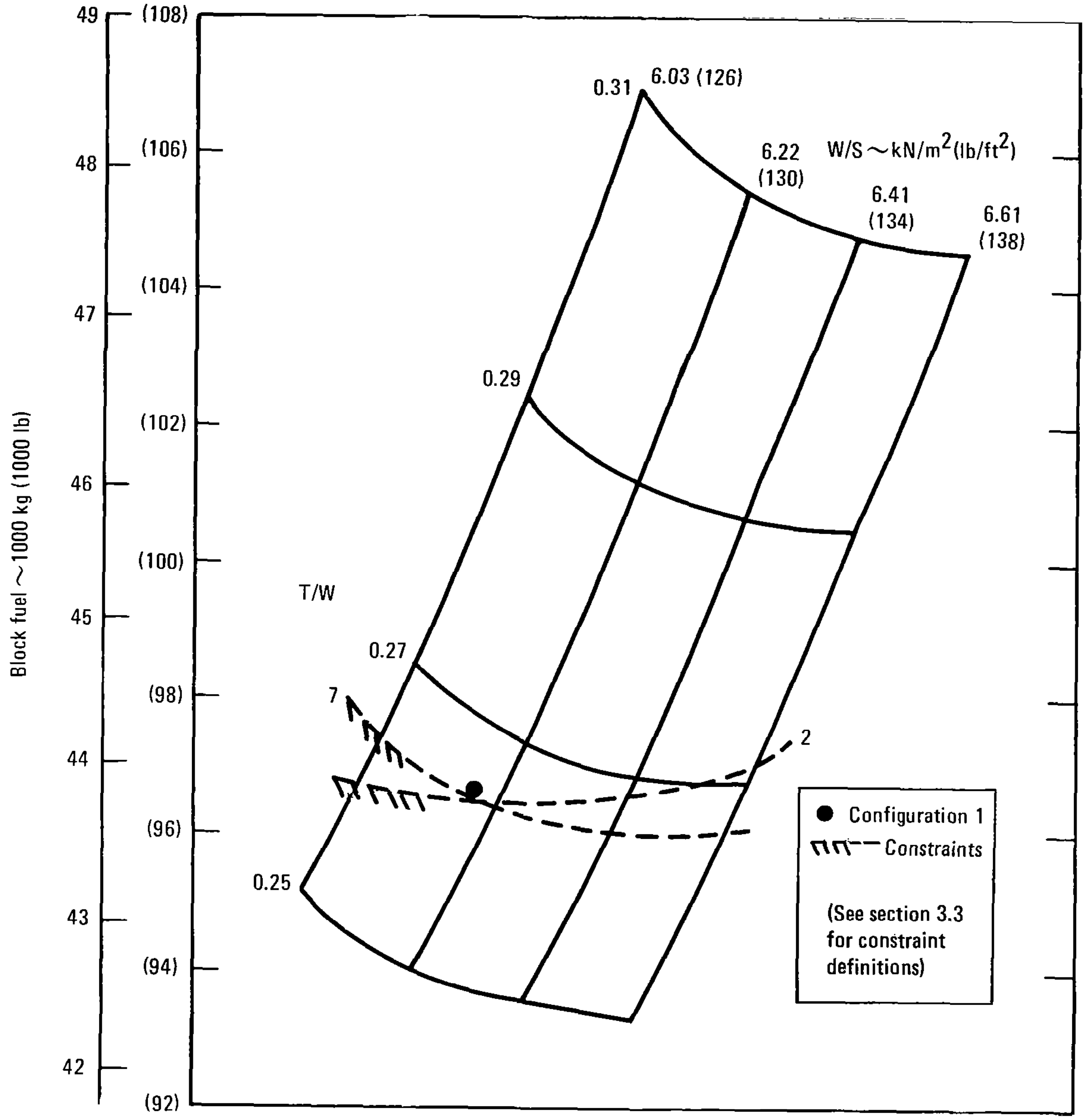
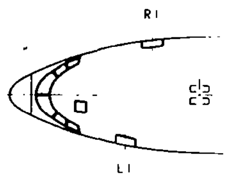


Figure 23. - Reference configuration (configuration 1) block fuel at 4630 km (2500 n.mi.) stage length.

CHARACTERISTIC	WING	HORIZ. TAIL	VERT. TAIL
AREA (SQ FT)	4790.3	1786	855.71
ASPECT RATIO	7.79	4.0	1.54
TAPER RATIO	0.246	.33	.30
SPAN (THEO)	193 FT - 1 IN	83 FT - 1 IN	36 FT - 3 IN
ROOT CHORD (IN)	477.72	374.72	436.76
TIP CHORD (IN)	117.42	123.78	129.75
M.A.C. (IN)	334.0	270.32	310.99
DIHEDRAL AT T.E.	INBD 7 31'11.12" OUTBD 5 30'	-3.0	--
SWEEP AT 25% CHORD (DEG)	35	35	34.7
L.E. M.A.C. (ARR STA)	1142.5	2047	2034.53

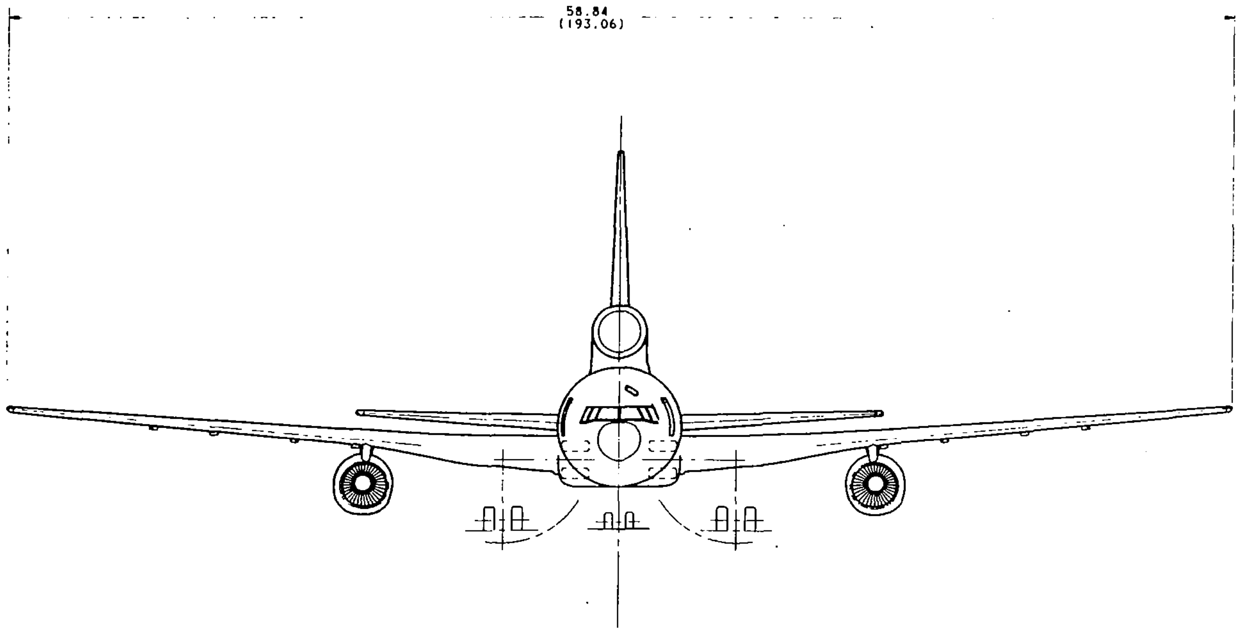


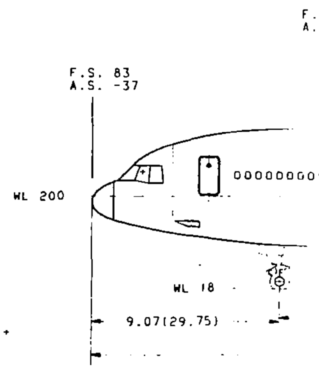
DESIGN GROSS WEIGHT - 1 362 354 KG(617,950 LBS)

POWERPLANT (3)-G.E. CF6-50C TURBOFAN

INSTLD T.O. THRUST-181 041 NEWTONS(40,700 LBS) M 0.2 SL 30 DEG C(85 DEG)

UNINSTLD SLS FLAT RATED-242 808 NEWTONS(54,586 LBS)





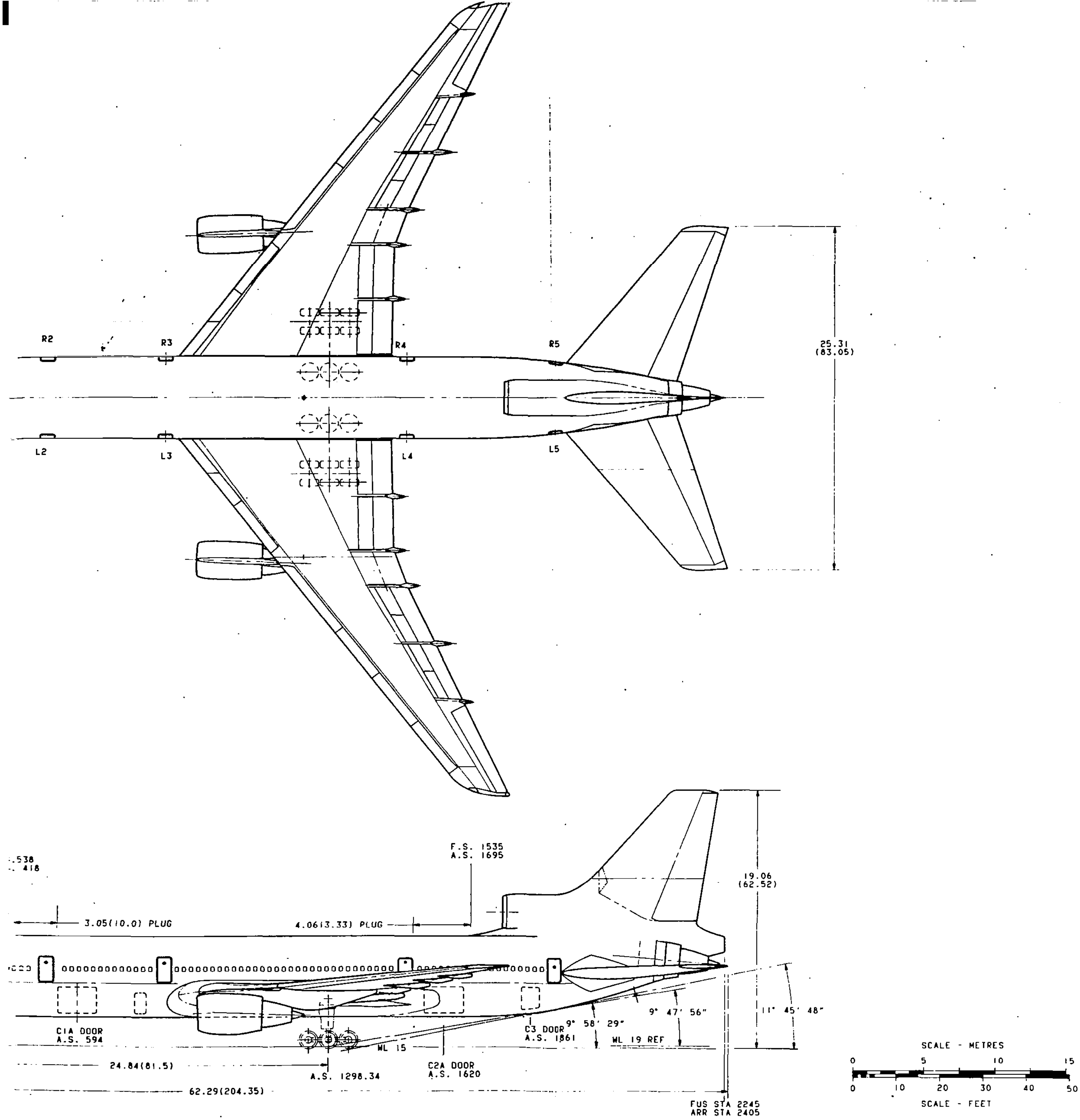


Figure 24. - Optimized reference configuration.

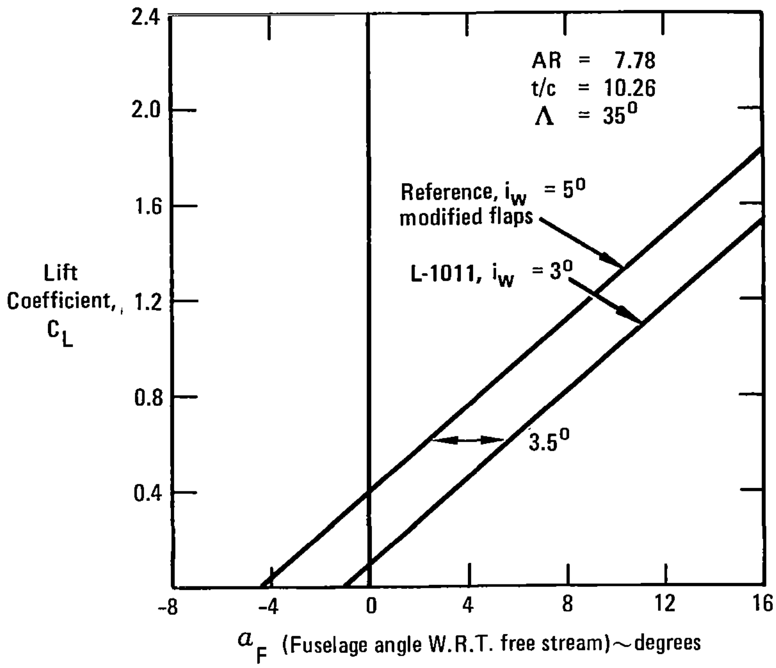


Figure 25. - C_L vs α_F in ground effect.

The trailing edge flaps consists of four surfaces on each wing, two inboard surfaces and two outboard surfaces. Each flap surface is divided into two equal segment panels which are mechanically positioned by flap movement to provide the double aerodynamic slots. The maximum deflection of the aft flap panel segment is 45°.

The configuration, table II, includes resized General Electric CF6-50C engines, 242.8 kN (54,600 lb) of SLS rated takeoff thrust, to meet the following performance criteria:

Takeoff field length	3200 m (10,500 ft) @ SL, 302 K (84°F)
Landing field length	2134 m (7000 ft) @ SL, 302 K (84°F)
Initial cruise altitude	9449 m (31,000 ft) with 1.52 m/s (5 ft/sec) and 1.3 g buffet
Approach speed	74.6 m/s (145 kt) @ SL, 302 K (84°F)
Design range	8519 km (4600 n.mi.) with full payload on Standard Day

Average stage length 4630 km (2500 n.mi.)

Second segment gradient 2.7%

A carpet plot showing the contrained point design is shown in figure 23.

4.2.1 Special aerodynamic features

4.2.1.1 Flying stabilizer: The flying stabilizer concept for pitch control and longitudinal trim on the reference aircraft is identical to the system on the L-1011 and provides excellent control effectiveness and eliminates runaway trim problems. The flying stabilizer entails direct coupling of the pilot's control column to the stabilizer. The elevators are not controlled directly but are geared to the stabilizer in a manner which provides increasing stabilizer camber with increasing stabilizer deflection.

Trim is introduced by adjusting the zero force reference position of the control column itself. The advantage is that, at any time, a pilot can immediately place the control column and the stabilizer in any position required for trimming or maneuvering the airplane. In the event of a mistrim, the longitudinal control capability is unaffected, and the only change is a small increase in control force.

In the high-speed flight regime, the stabilizer is a significantly more efficient control surface than an elevator whose effectiveness is reduced by shock-induced separation and structural flexibility effects.

4.2.1.2 Direct lift control: A direct lift control system (DLC) is incorporated on the reference aircraft, similar to the L-1011, to improve low-speed handling qualities. Direct control of lift at constant air speed and pitch angle is accomplished by modulation of the inboard four flight spoilers symmetrically about a DLC null deflection angle of 8 degrees.

Closing the spoilers from the null angle will increase the lift on the order of 0.10 g, and opening them from the null to the full-open DLC limit

TABLE II. - CONFIGURATION COMPARISON

	L-1011-1		L-1011-500		Reference	
TOGW ~ 1000 kg (1000 lb)	195.0	(430)	225.0	(496)	280.3	(618)
T/W		0.293		0.30)		0.27
W/S ~ kN/m^2 (lb/ft^2)	5956.2	(124.4)	6708.0	(140.1)	6176.5	(129)
AR		6.95		7.63		7.78
t/c ~ %		10.1		10.02		10.26
Λ^o		35.0		35.0		35.0
S_{WING} ~ m^2 (ft^2)	321.0	(3456)	328.9	(3541)	4451	(4790)
S_{HT} ~ m^2 (ft^2)	119.1	(1282)	119.1	(1282)	165.9	(1786)
S_{VT} ~ m^2 (ft^2)	51.1	(550)	51.1	(550)	79.5	(856)
$\overline{V}_{HT}$		0.9135		0.8119		0.954
$\overline{V}_{VT}$		0.066		0.0547		0.695
L_{FUSE} ~ m (ft)	54.2	(177.7)	50.05	(164.2)	61.3	(201.0)

will decrease the lift by approximately the same amount. This results in a speed-stable system in that an increase in lift simultaneously results in a decrease in drag, and vice versa.

DLC enhances the low-speed handling qualities of the reference aircraft by quickening its response in vertical motion to pilot or autopilot inputs. DLC is most effective in tracking the glideslope close in and during the landing flare maneuver because of the tight control DLC provides.

Spoiler roll inputs may be applied simultaneously and will result in spoiler deflections that are the algebraic sum of the roll and DLC inputs.

4.2.1.3 Maneuver load control: The maneuver load control (MLC) system of the L-1011-500 has been carried forward to the reference aircraft. On the L-1011-500 the MLC allowed the wing span to increase 2.74 m (9.0 ft) with a three percent improvement in aerodynamic efficiency without any structural beef-up. The system is described in Section 4.3.4.5.

4.3 Reference Aircraft Systems

This section describes the systems configuration and systems requirements to be used as a reference during the course of this study effort. The reference systems are conventional; state-of-the-art systems as are being applied to the latest commercial aircraft (L-1011-500, B757, DC9-80, etc.). Digital autopilot, flight management system, and active ailerons are included. The active controls technologies of gust alleviation (GA), maneuver load control (MLC), and elastic mode suppression (EMS) are also included within the reference systems as they are presently incorporated within production line models of the L-1011-500. Bleed air, central hydraulics, and constantspeed drive generators are included. Ring-laser-gyro is not included.

The weight statement for the L-1011-500 Pan American model is used to define the systems with the following exceptions and notes:

- The ECS and electrical systems on the -500 are the same as for the L-1011-1, and the L-1011-1 seats up to 345 passengers. Therefore, these systems are adequately sized, as is, for the reference.
- The reference is stretched; so weight (and cost) must be added due to the increased length of wiring, plumbing, and cableing.
- There are 350 seats for the reference vs the 240 seats of the -500, therefore the seat electronics are increased by this ratio.

4.3.1 Reference electric system. - The design of the reference electric system follows the design of the L-1011-500 airplane in that it is a part of a conventional secondary power system in which the engine bleed system and the hydraulic systems are major contributors to the power demands of functions and services in the aircraft. The electric system furnishes power to the following:

- External/internal lighting
- Galley loads
- Passenger service/entertainment
- Windshield defogging/anti-ice
- Instrumentation

- Avionics
- Miscellaneous motor loads, vis-a-vis:
  fuel transfer, fuel-boost, recirculation fans, etc.
- Linear and rotary electric actuators
- Transformer rectifier (T/R) units
- Control power for solenoids, valves, instruments/indicators, etc.

The power-generating system consists of three 75/90 kVA engine-driven integrated drive generators (IDGs). Each IDG operates over a 2:1 input speed range and uses pressurized oil-cooling and a separate (dedicated) heat exchanger. The generator is a conventional 4-pole, 3-phase, 200/115V, 400 Hz ac machine generating 90 kVA power, at 12,000 rpm synchronous-speed. This combination constant-speed drive (CSD) and generator are installed and removed from the airplane as a complete assembly.

Figure 26 is a schematic of the power generator system configuration. It is a three-generator paralleled system which relies on supervisory panels (in each channel) to permit paralleling of the three generators via a synchronizing tie-bus. Such bus ties occur when the voltage, phase-sequence, frequency, and phase angle of the generators are correct. Incorporated in each IDG channel is a supervisory panel, to control the complete power system, during normal and abnormal operating conditions. These supervisory panels provide the following features:

- Automatic/manual ON/OFF control of system
- Automatic paralleling
- Kilowatt load sharing (when paralleled)
- Kilovar load sharing (when paralleled)
- Overexcitation/underexcitation control
- Overvoltage/undervoltage control
- Overfrequency/underfrequency control
- Phase sequence detection
- Differential feeder fault protection

In addition to the above features, the supervisory panels monitor the CSDs for operational anomalies, such as overtemperature, loss of hydraulic pressure, etc. Also integral with the IDG are metal chip detection, clogged filter detection, and oil-level indication.

Power distribution in the reference is accomplished using a conventional radial distribution system in which power from each of the three IDGs is taken directly into the main electric center, MESC (See figure 27). From the MESC, power distribution feeders establish load-busses at the flight station and the empennage area (See figure 28). At each of these load centers, power is fed to the individual loads via conventional trip-free thermal circuit breakers (CBs). These CBs have manual trip/reset buttons and they are located in the right, rear section of the flight station and on overhead panels.

4.3.2 Hydraulic system. - In the reference the hydraulic system powers the following:

- Primary flight surface controls
- Secondary flight surface controls
- Main and nose landing gears
- Main and nose gear doors
- Truck leveling (leveling of the MLG bogie)
- Nose wheel steering
- Brakes
- Miscellaneous jacks/door locks, etc.

The L-1011-500 hydraulic system is used for the reference. A major difference between the L-1011-500 hydraulic system and the reference aircraft hydraulic system is the respective size/weight difference of the two landing gear systems. The reference aircraft has a six-wheel bogie landing gear compared to the four-wheel bogie of the L-1011-500. Since the installed rating of the hydraulic pumps for a transport aircraft is predicated upon the peak load demand which occurs during landing gear retraction and extension, and also since the landing gear are significantly larger for our reference aircraft, the pumps will be sized up accordingly. The L-1011-500 main (engine driven) hydraulic pumps are rated at 2.5×10^{-3} m^3/s (38.8 gpm), installed. Based on this and the increased weight of the landing gear for the reference about 2268 kg (5000 lbs) more, the pumps have been sized up to 2.9×10^{-3} m^3/s (46 gpm), installed, to meet the peak hydraulic load demand for the reference load profile. Figure 29 is a schematic of the system. The hydraulics are arranged into four separate, parallel, continuously operating systems; A, B,C, and D systems.

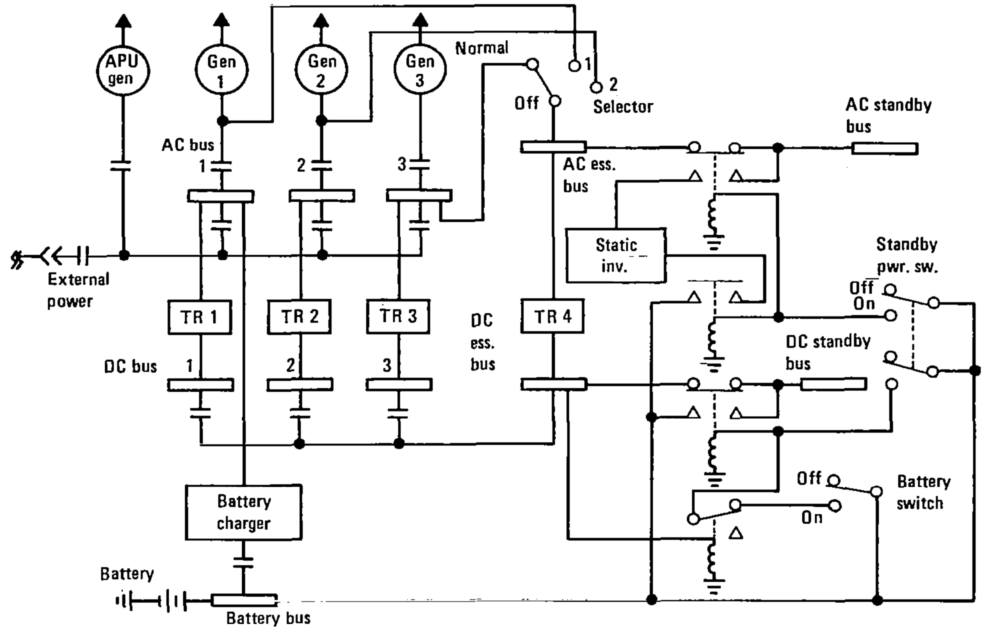


Figure 26. - Reference electrical power system.

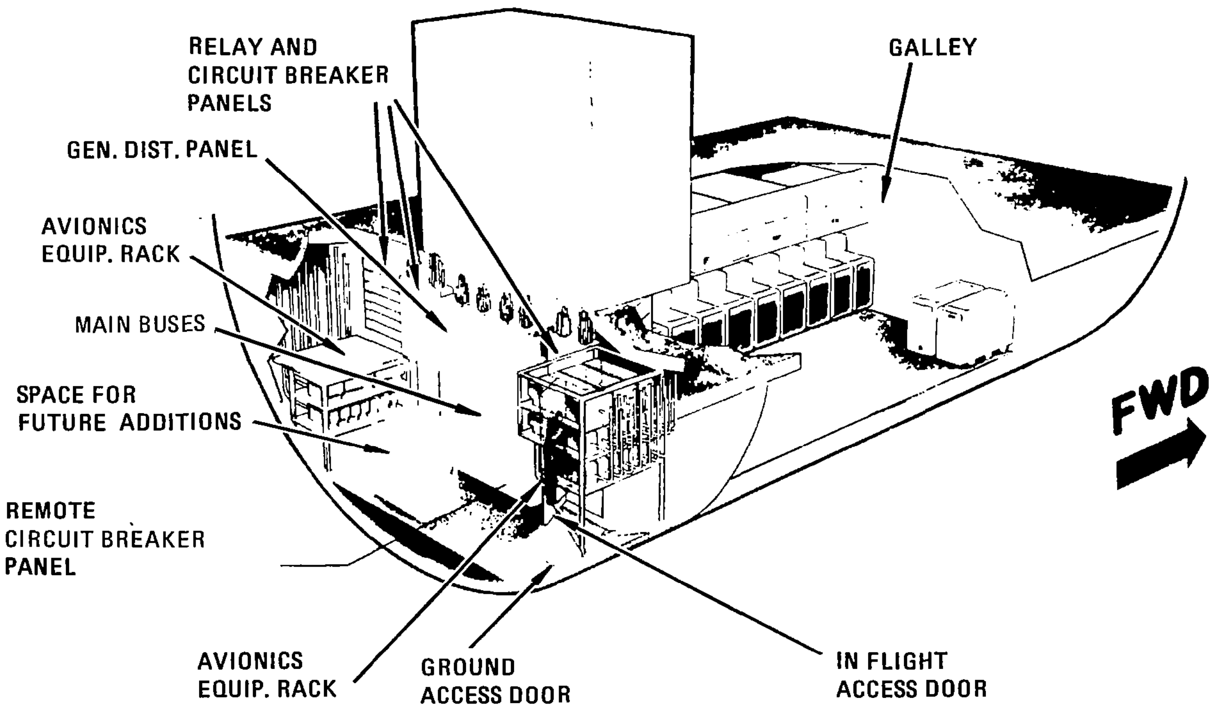


Figure 27. - Main electrical service center.

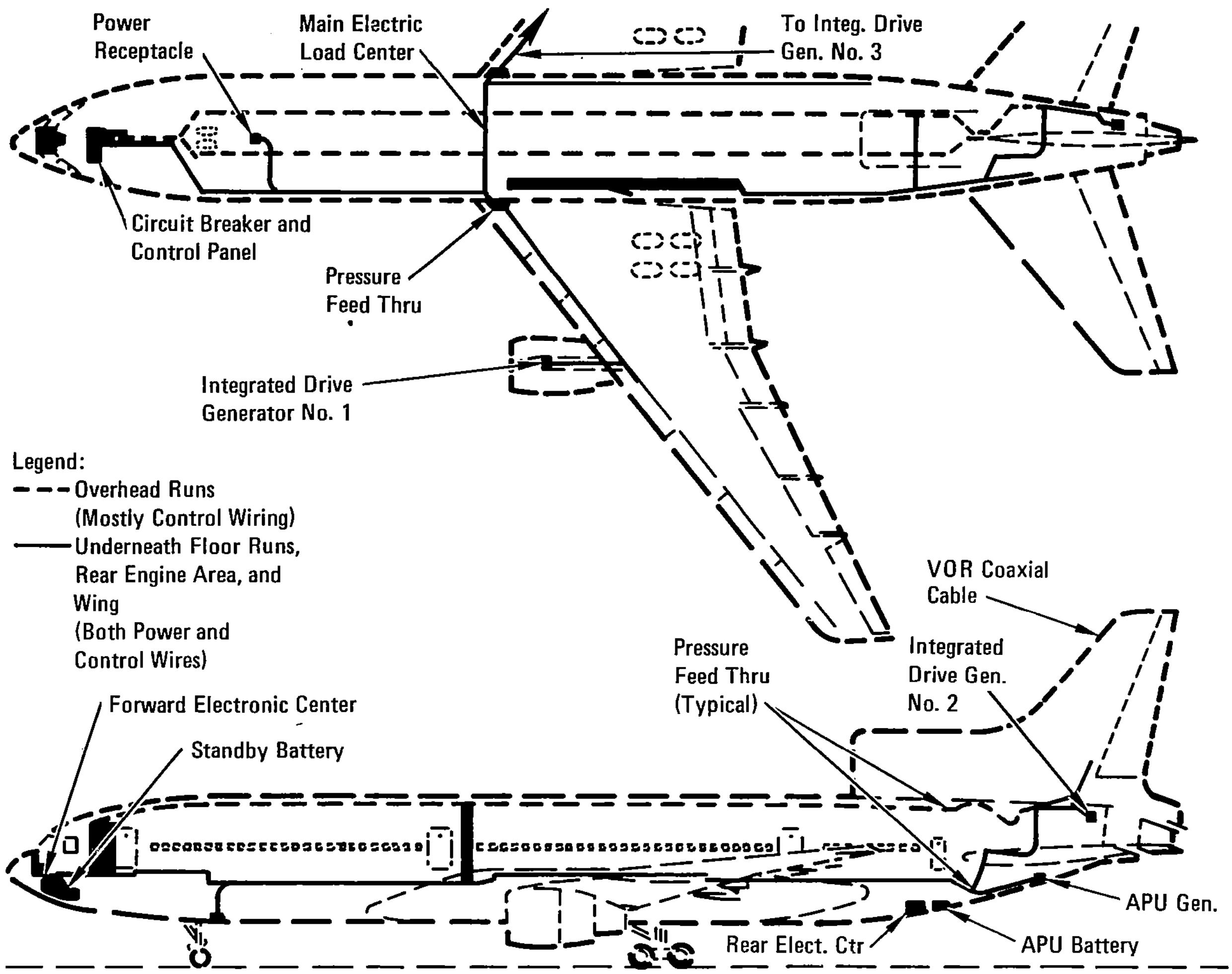


Figure 28. - Major wire routing and electrical equipment installation.

Some of the design features are:

- Two independent systems assigned to primary flight controls exclusively without utility subsystems attached
- Two of the four systems never cross an engine turbine blade plane
- One system is excluded from each wing
- Centrally located service center facilitates rapid servicing and replacement of components

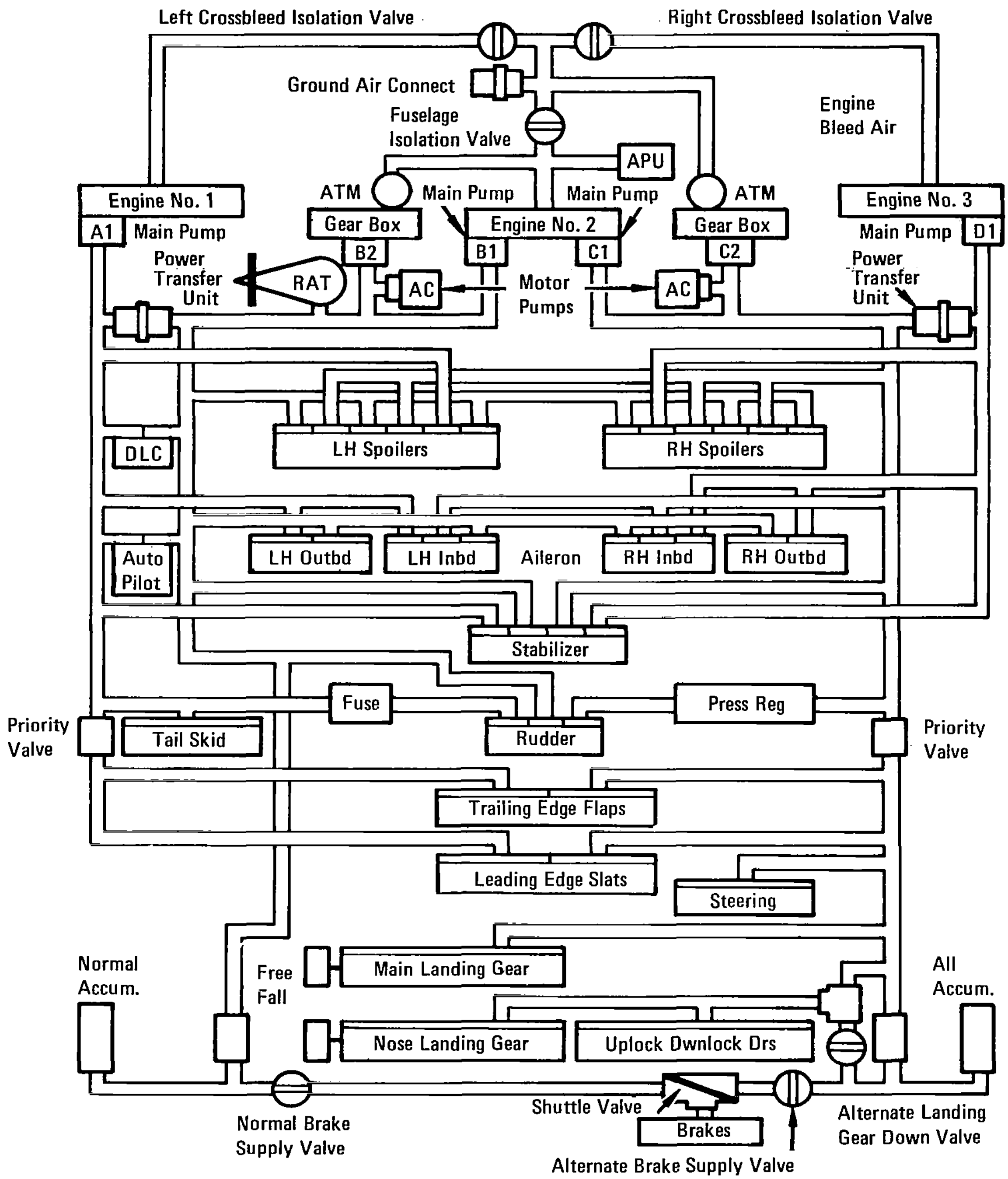


Figure 29. - Hydraulic system schematic.

- Greater system flexibility in the arrangement of four systems versus three systems

Systems functions are allocated to balance the work load and meet automatic landing performance standards for Category III all-weather landing capability.

The four independent systems are designed for maximum flight control safety and performance and have the following capabilities:

- One hydraulic system inoperative - the aircraft control capability or rate of control is not reduced
- Two systems inoperative - the aircraft can complete its flight plan
- Three systems inoperative - the aircraft can maintain safe control throughout the normal operating envelope and land safely. One hydraulic system is sufficient to operate the flight controls

If all three engines become inoperative, a ram air turbine (RAT) deploys automatically and supplies power to the flight controls to assure continued control of the aircraft.

The duties assigned to each of the four systems are selected on the basis of maximum assurance that a single failure of a system will not impair the performance of the aircraft and that no reasonably conceived series of hydraulic failures would cause loss of control of the aircraft. All four systems are used in combinations to power the primary flight controls. The main pumps are rated 2.9×10^{-3} m^3/s (46 gpm), at 2.07×10^7 Pa (3000 psi).

4.3.3 ECS and pneumatics. - The pneumatic system is similar to that for the L-1011 and provides compressed air for cabin pressurization, air conditioning, ventilation, engine starting, deicing and tubine driven supplementary hydraulic power. Compressed air is supplied to the system from the propulsion engines, from the APU or from ground support equipment.

The engine bleed air system is composed of three independent functionally identical subsystems, figure 30. Air from the intermediate pressure (IP) and high pressure (HP) stages is mixed in the ejector to give the required system pressure, a nominal 3.10×10^5 Pa (45 psig). Duct overheat devices limit temperature to approximately 260°C (500°F) by turning off the HP air.

The air conditioning system, figure 31, pressurizes, heats and cools the cabin. Three air cycle packs are used. The three are capable of supplying 0.009 kg/s (1.2 ppm) of fresh air per passenger. Cabin pressure is controlled by automatic outflow valves. The differential pressure is limited to 5.79×10^4 Pa (8.4 psi). This provides a cabin altitude of 2438 m (8000 ft) at an

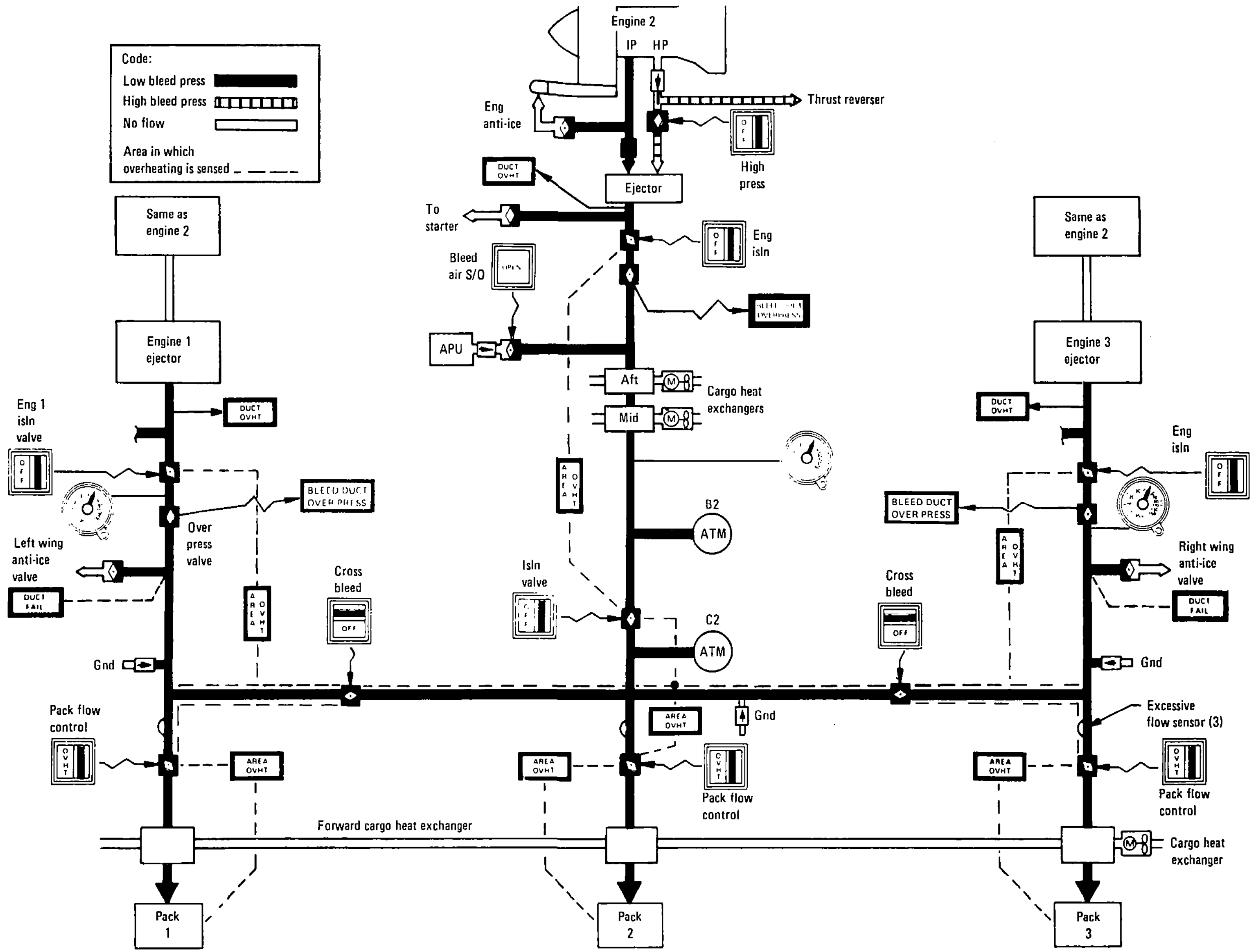


Figure 30. - Bleed air control system schematic.

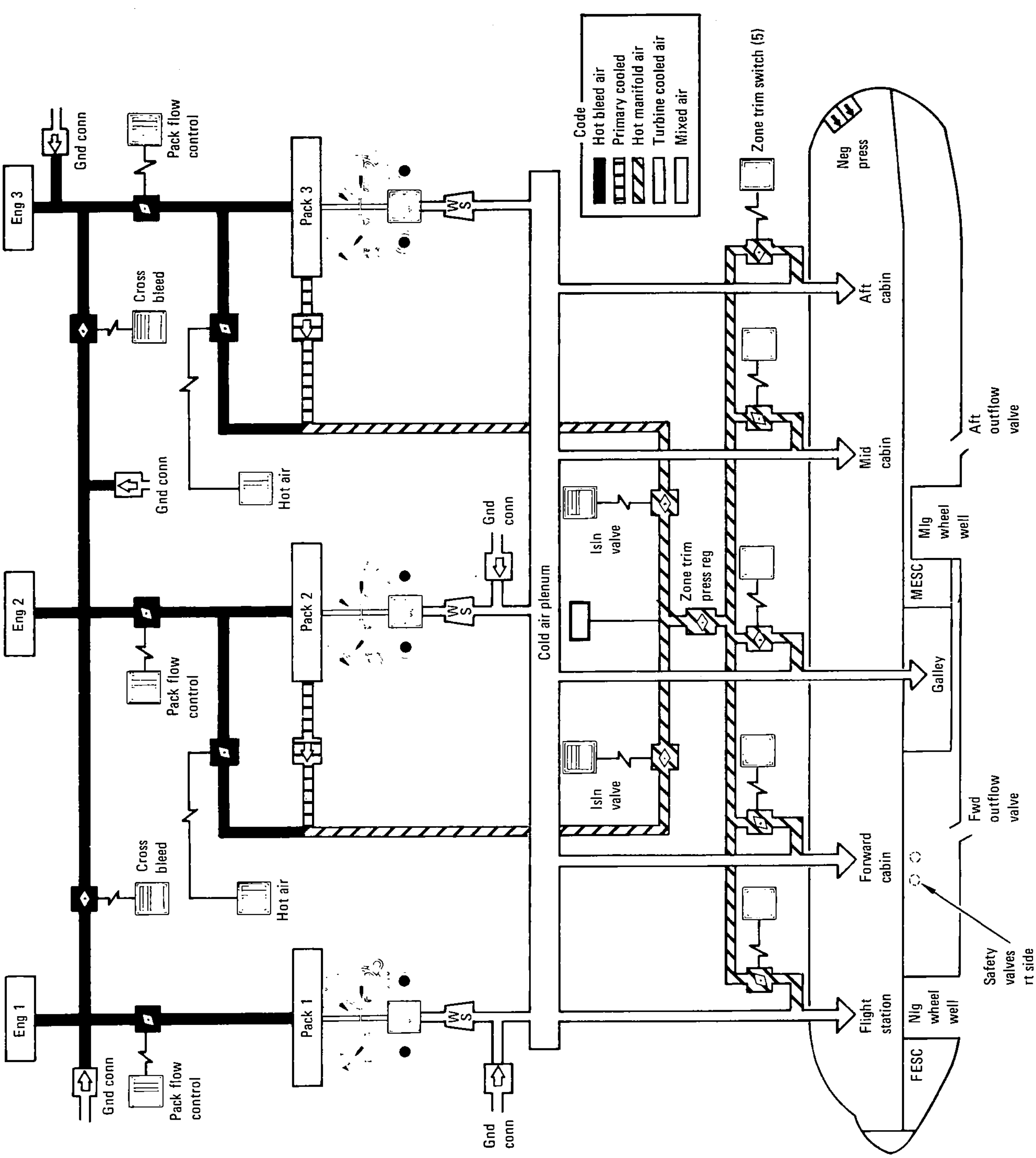


Figure 31. - Air conditioning schematic.

Figure 31. - Air conditioning schematic.

airplane altitude of 12 802 m (42,000 ft). The altitude rate in the cabin is limited to 2.54 m/s (500 fpm) going up and 1.52 m/s (300 fpm) going down.

Hot bleed air entering the air conditioning packs is cooled by ram airflow over a primary heat exchanger, recompressed to higher pressures and temperatures and then further cooled in the secondary heat exchanger before expansion through the turbine wheel. During normal cruise at altitude, the heat exchangers provide sufficient cooling of the bleed air for cabin conditioning by modulating the ram air exit doors. During operation in a warmer ambient temperature, the ram air exit doors will open fully and, if necessary, the turbine bypass valve will close and divert bleed air through the air cycle machine for compression and then expansion in the turbine for further cooling.

4.3.4 Flight controls. - The reference flight control system includes the primary and secondary flight controls including stability augmentation, autopilot, spoilers; and auto throttle. The reference system is similar to the existing L-1011 system but is sized for the reference aircraft and includes active ailerons for gust alleviation, maneuver load control, and elastic mode suppression. The reference system uses mechanical cable control of servo valves which control full power hydraulic actuators moving the aerodynamic surfaces. Figure 32 shows the location of the flight control surfaces.

Figure 33 is a simplified block diagram illustrating the relationship between the mechanical and electronic flight controls. Autopilot and stability augmentation inputs are applied in parallel with the column inputs in the pitch axis and dual mode servo valves in the roll and yaw axis.

Figure 34 is a simplified block diagram showing the electronic flight control system. The flight control computer is digital and quadruply redundant. The primary flight control computer is mainly analog and contains stability augmentation circuits, stall warning, altitude alert, system monitor, direct lift control, automatic ground speed brake, and fault isolation monitor. The trim computer provides dual segregated subsystems for manual and automatic pitch trim, Mach trim, and Mach feel. The interconnections to sensors, servos, and instruments are analog; the interconnection with the navigation computer is digital. The significant features of the flight control electronic system are:

- Roll and pitch attitude hold with control wheel steering
- Heading select and hold
- Altitude select and hold
- Vertical speed select and hold
- Indicated airspeed and Mach hold

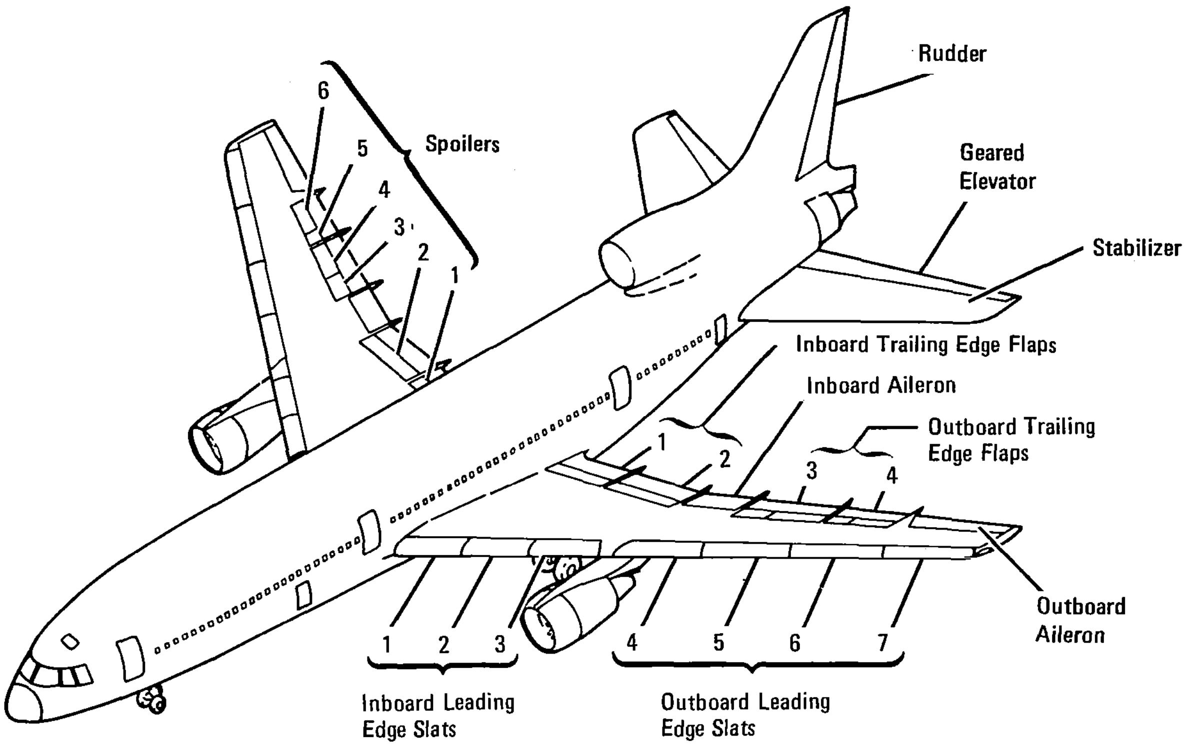


Figure 32. - Flight control surfaces.

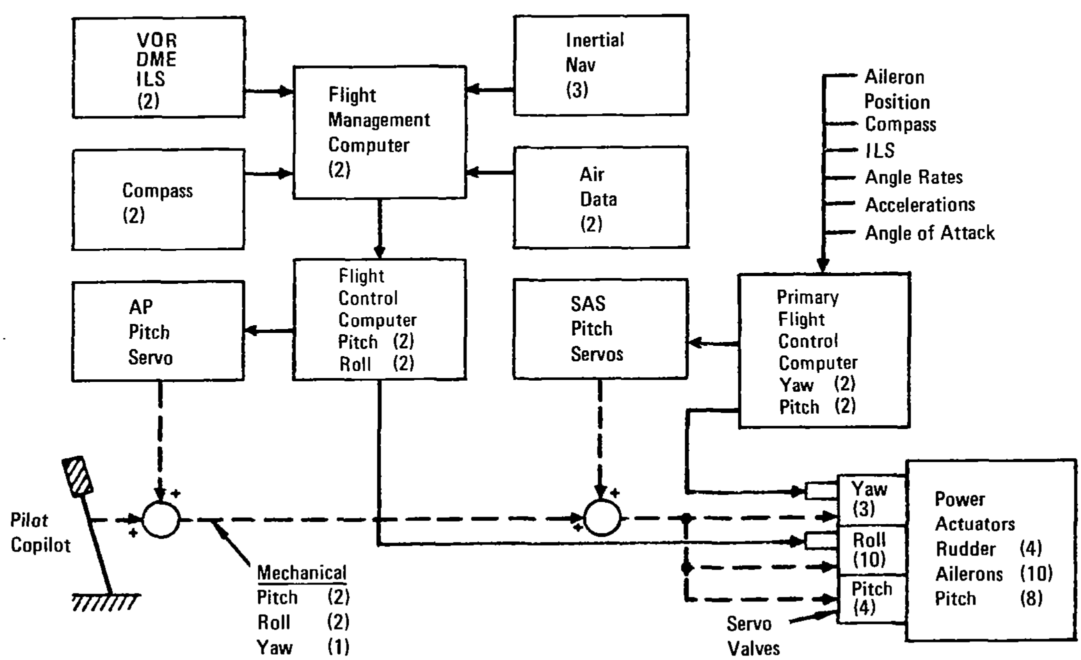


Figure 33. - Reference flight control and navigation.

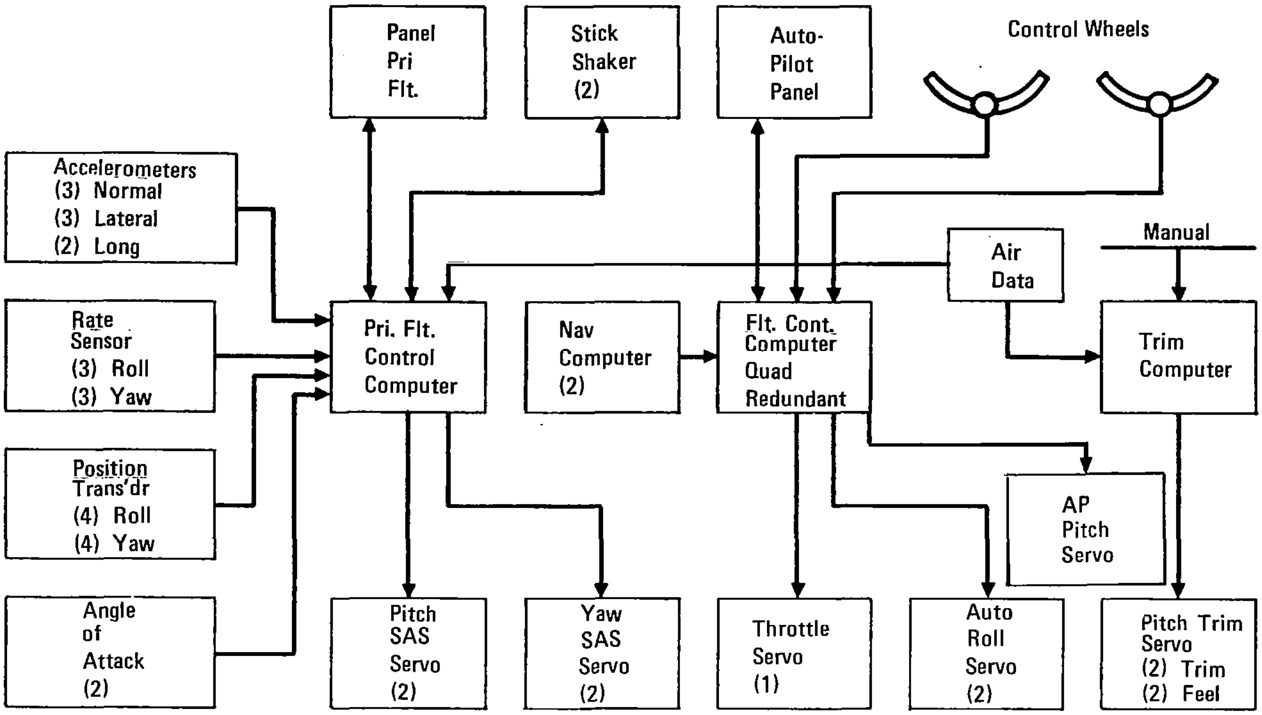


Figure 34. - Reference digital flight control.

- Auto control from VOR and area nav.
- Speed control and auto throttle
- Active symmetric aileron control for maneuver load alleviation and gust alleviation
- Cat III ILS auto throttle
- Takeoff and go-around guidance
- Yaw and nose wheel steering for rollout
- Lift compensation during turns
- Failure protection and warning
- Auto fault isolation

4.3.4.1 Pitch control system: The horizontal stabilizer rotates for pitch control and trim input. The elevator portion is geared to the stabilizer through a nonlinear mechanical drive train for added control effectiveness. Four parallel hydraulic actuators operate in unison to drive the stabilizer. The actuators are controlled by four servo valves each supplied by one of four hydraulic systems. The valves are combined in assemblies of two. Each assembly has one mechanical input linkage and two feedback linkages, one for each valve. The input is mechanically connected to the feedback linkages to close the servo loop. The primary control path is entirely mechanical up to the servo valves; however, this control is modified with powered limited authority inputs from the autopilot, trim system and feel system. The mechanical cable/push rod systems are dual, one for the pilot and one for the first officer (copilot). They are coupled so that both work in unison under normal conditions. The forward coupler can be disconnected manually by the pilot or first officer. The aft coupler located as a part of the stabilizer servo system, is electrically disconnected only when both servos on one side are de-energized. Decoupling, either aft or forward, is required in case of a system jam.

As the stabilizer leading edge moves from one degree up to 14 degrees down, the geared elevator moves in the same direction as the stabilizer from zero (faired) to 28 degrees trailing edge up.

- Pitch Feel and Trim System: The trim motor, operated by a manual switch on the control column, is primarily a combined series/parallel trim to decrease column excursion required for trimming. The pilot's feel force is the product of control column displacement from trim and the feel spring constant. The trim motor is also controlled automatically by the autopilot when engaged; and by the Mach number to compensate for movement of the aerodynamic center of pressure.

  The pilot may override the output of the trim motor with a manual trim wheel through cable, gears, and a ball clutch. The feel force is a maximum of 378 N (85 lb) at the column and can be overriden by the pilot. No matter where the trim is set, the pilot can obtain full excursions of the stabilizer with reasonable column forces.

- Pitch Monitoring System: A monitoring system detects jams and open links in the mechanical system. The sensing system consists of bungees (springs) in the cable systems and aft coupler that are instrumented to detect motion when the force exceeds bungee preload force, and cable integrity sensors instrumented to detect loss of continuity. A logic network uses the signals to determine the locaton of the jam or open and the appropriate action required. Warning lights direct the pilot to remove hydraulic power from the appropriate servos and manually disconnect the forward coupler. The aft coupler opens automatically when power is removed from the servo valves. Control is maintained by the redundant cable system and the remaining set of servos, however, the feel force is reduced to one-half of normal when the coupler is open.

- Stall Warning System: An artificial stall warning is provided by means of two shakers which vibrate the pilots' control columns whenever the aircraft speed is less than 1.07 times the stall speed. The stall speed is computed using a combination of air data, angle of attack, slat, and flap positions. The system is inoperative when the landing gear struts are compressed (aircraft is on the ground). The system commands the spoilers to retract when a stall warning is indicated. Sensor and power faults are annunciated in the cockpit, and channel selection capability is provided.

4.3.4.2 Roll control system: Pilot control inputs are communicated mechanically from the control wheels to the servo valves at the ailerons. Separate paths are provided from each control wheel to the inboard aileron on the corresponding side (left or right). In normal operation the control wheels are coupled and the left and right ailerons operate in unison asymmetrically. If a jam occurs, the wheels can be manually decoupled.

All four aileron surfaces deflect $\pm$ 20 degrees. Aileron roll control is supplemented by spoilers during low speed (flaps extended) flight. Spoiler deflection is a nonlinear function of aileron deflection with 40 degrees of up spoiler corresponding to 20 degrees of up aileron on the same wing. Similarly, 2.5, 12.5, and 17 degrees of aileron correspond to 0, 10, 20 degrees of spoiler, respectively.

- Aileron Servos: Three hydraulic actuators and three servo valves serve each inboard aileron; and two actuators and two servo valves serve each outboard aileron. Each actuator for a particular aileron is supplied by a separate hydraulic system. The servo valves for a particular aileron are assembled with a common input torque shaft. Two feedback rods are provided at each servo valve. Two input rods are provided at the inboard servo valves, one at the outboard. The dual input and feedback rods operate on opposite ends of the common input torque shaft for the servo valve assembly. In addition to mechanical commands, two of the three left inboard servo valves accept electrical commands from the autopilot. When on autopilot, the position of the left inboard aileron is fed mechanically to the other ailerons through the primary mechanical system.

- Roll Feel and Trim: Artificial feel and centering for the roll control system is provided by a single compression spring cartridge in the left control path. The ground point of the feel spring is shifted by the roll trim actuator, thereby providing parallel roll trim. Over-travel is provided so that full roll control is available irrespective of the trim actuator position. The trim system can provide up to +7 degrees of aileron travel. Spoiler operation is affected by aileron trim in the same manner as by other aileron inputs.

- Monitoring System: Two torque limiters and a cross-tie bungee are included to permit continued roll operation in the event of opens or jams in the mechanical control paths. The cross-tie bungee does not have a deflection switch but it does permit relative motion between the two ailerons. The torque limiters each permit relative motion between control wheels and cable system and contain sensors to detect deflection for use in the monitor display system. If a jam occurs downstream of the limiter in either control path, continued control is possible by overcoming the breakout force of the affected limiter and controlling through the other control path. Operation of the torque limiters is displayed to the pilot for manual shutdown of the affected aileron and spoiler actuators.

The modulating signal for direct lift comes from the autotrim transducer in the autopilot pitch servo. It does not depend upon selection or engagement of the autopilot and is essentially a stabilizer-out-of-trim signal. Altitude changes are thus produced largely from operation of the DLC spoilers rather than the stabilizer, with much reduced pitch attitude excursions.

Spoiler automatic operation for landing, rejected takeoff, go-around, and incipient stall is determined by logic in the flight control electronic system. Inputs are from flap handle, throttle levers, thrust reverser levers, stabilizer control system, landing gear control handle and landing gear strut compression. During a normal landing, landing gear is down, flaps are extended, landing gear switches indicate aircraft touch-down, computer asks for 12 degrees spoiler deflection after a half-second delay, struts fully compress, and spoilers extend to 60 degrees. If throttles are advanced and reverse thrust is not selected, a go-around will be assumed and spoilers retracted. In takeoff configuration, reverse thrust selection on any two engines will extend the spoilers. Operation of the stall warning system will retract the spoilers.

4.3.4.3 Yaw control system: Rudder pedals operate through a single mechanical control path to the rudder servo valves. The manual trim system provides a second mechanical path for rudder control. Jam protection is not provided since the aircraft can be safely flown without rudder control. Shutting off the hydraulic power permits the rudder to center by aerodynamic forces. Rudder deflection is limited as a function of airspeed and flap position. Limiting rudder deflections is accomplished by dual positive mechanical stops operated by solenoid operated hydraulic actuators. There are four rudder actuators arranged in two dual tandem sets. Three servo valves are provided assembled side by side with separate input push rods to each side of the common input shaft. Each servo valve has input from a separate hydraulic system (A, B, and C). One valve serves two actuators. Two of the valves have electrical inputs in addition to the mechanical input. The electrical input is used for yaw stability augmentation.

The rudder is controlled automatically for dutch roll damping and turn coordination during all phases of flight and for runway alignment and roll out during "Autoland." In the basic SAS, the control is independent of autopilot status and allows pilot inputs to be added via the rudder pedals. SAS and turn coordination are achieved by processing inputs from the three rate gyros and four aileron position transducers. For approach and land, the aileron signals are switched out. The runway alignment signal is a function of instrument landing system (ILS) error, heading error, altitude and yaw rate. The alignment scheme is a limited forward slip maneuver in which up to eight degrees of initial crab angle is removed by lowering a wing and slipping the aircraft. After touchdown, the autoland computation uses ILS error and yaw rate to direct the aircraft down the runway with rudder control and limited nose wheel steering.

4.3.4.4 Autopilot: There are four channels in each axis for approach and land, and there are only two which are active for cruise. The system has two dual computers, autopilot A and B which can be engaged independently or simultaneously, either in the autopilot mode (in approach/land only) or flight director mode. Thus, either or both flight directors may be used to provide flight director steering information to the pilot, with or without autopilot engagement. With autopilot engagement, the flight director may be used to monitor autopilot operation. Each pitch system (A and B) has a servo with mechanical input into the mechanical control. The roll output (A and B) is electrical, directly to the aileron actuator servo valves of the left inboard aileron. In either case, the autopilot outputs operate in parallel with the control wheel inputs. The pilot can mechanically overpower the autopilot servos through the control wheel.

The basic autopilot mode is "parameter hold" with the pilot able to input change through control wheel steering. The autopilot command mode provides automatic control in response to a computed guidance signal.

An automatic trim system acts to center the autopilot servos to prevent transients when the autopilot is either manually or automatically disengaged. There are two automatic pitch trim systems and at least one must be operative to engage either autopilot. The altitude signal for altitude hold and altitude select is a rate-and-displacement-limited barometric altitude error signal which is gain scheduled as a function of true airspeed. An integration path is provided to compensate for long term error signals. The control signal is mixed with pitch attitude and attitude rate signals for control loop damping. As the aircraft approaches the selected altitude, the altitude rate and altitude error are used to compute the point at which the maneuver to capture the desired altitude is initiated. At initiation, an exponential flare maneuver to capture the desired altitude is commanded. When the maneuver is completed, the altitude hold mode is automatically established and annunciated.

Roll attitude/heading hold is the basic roll axis autopilot mode. Upon engagement, the autopilot will maintain heading if the bank angle is less than five degrees and will maintain bank angle if over five degrees. Control wheel steering can be used to establish a new roll attitude or heading reference.

In the navigation mode, the autopilot will direct the aircraft to capture and follow a VOR beam or an Area Nav course, if these systems are operating.

The approach/land mode will capture the localizer beam, follow the localizer beam, capture the glide slope, follow the glide slope, align with runway at 45 m (150 ft) altitude, perform flare at 15 m (50 ft) altitude, and maintain heading down the runway on rollout.

The glideslope capture maneuver is inhibited until localizer track is established and glide slope deviation is less than 30 microamperes. The flare gain is scheduled as a function of radio altitude, radio altitude rate and normal accleration to essentially zero rate at zero altitude.

The turbulence mode is normally engaged when the aircraft is flying in turbulence. The autopilot reverts to the parameter hold configuration with reduced gains to provide softer control.

4.3.4.5 Active controls: The following are current active controls technologies, and are therefore included in the reference flight control system. Implementation of these technologies is by appropriate software additions to the digital flight control computer, and by usage of sensors such as accelerometers and rate gyros in the wings and fuselage.

- Maneuver Load Control (MLC): Maneuver Load Control is a method of reducing wing root bending loads by unloading lift at the wing tips by means of symmetric outboard aileron deflections at load factors greater than 1g. The ailerons are drooped 2^{o} in level flight, permitting the most efficient span loading. In maneuvers, however, the ailerons move to dump the lift in the outboard regions, keeping the design bending moments on an extended wing no higher than would exist with a shorter wing. This action allows the low cruise drag of the longer wing with the weight of a shorter wing - structural efficiency is improved.

- Elastic Mode Suppression (EMS): Elastic Mode Suppression is a means of using the ailerons to artificially dampen the first flapping mode of the wing. Oscillatory motions of aircraft structure can be occasioned by interchange of energy in the kinetic and elastic potential form. This usually occurs as a low frequency (1/2 to 2 Hz) in the wing structure, and can be dampened by proper application of aileron control forces. The L-1011-500 uses active ailerons for fatigue load reduction. Approximately half of this reduction is static load and half is due to the elastic mode. This suppression also acts to improve ride quality.

- Gust Alleviation (GA): Gust Alleviation, like MLC, is also a means of reducing wing root bending loads and reduces the number of high frequency bending cycles of the wings, thereby extending wing structural life. The symmetric aileron deflection increments are controlled in response to the wing-tip accelerations to reduce the high frequency wing deflections.

  With the optimization of the advanced wing to an aspect ratio of 12, the adequacy of the current active controls technologies to handle adverse loading of the wing roots, came into question.

  Analysis showed that gust loads predominated over maneuver loads, and that today's active control technology (GA) is at a level to adequately deal with the gust loading of AR 12 wings. The controls filtering and circuitry will have to be tailored to this advanced wing, however; and the ailerons may have to be increased in area to enhance the response.

4.3.5 Avionics. - The avionics suite is typical of a widebody, international range aircraft such as the L-1011-500 , and consists of the following subsystems:

- Communications

  VHF Transceiver (2)

  SELCAL

  HF Radio (2)

  Intercom

  Passenger Services

  Cockpit Voice Recorder

  Note: The communications system was not subject to trade off in this study. Information is included for background and to suggest future integration possibilities.

- Navigation

  Inertial Nav. (3)

  Flight Management (2)

  Omega

  VOR (2)

  ILS (2)

  DME (2)

  Marker Beacon

  Heading Reference System (2)

  ADF (2)

  Radio Altimeter (2)

  Ground Proximity Warning

  Weather Radar

  ATC Transponder (2)

- Primary Flight Control Avionics

  Autopilot (2)

  Air Data System (2)

  Instruments

The major avionics are mounted in equipment racks in conformance with ARINC 404 and are located in the forward bay below the flight station floor. Flight controls and autopilot are discussed in Section 4.3.4.

4.3.5.1 Communications: The basic communication systems are VHF, HF, a selective calling system (SELCAL), various audio systems and passenger entertainment.

The VHF communications consist of two ARINC 566 tranceivers, two low drag blade antennas, and two sets of controls and readouts. The transceivers are Collins type 618M-3. Frequency coverage is from 118 MHz through 135.95 MHz in 25 kHz increments.

SELCAL relieves pilots of the radio monitoring task. The system has two channels, each of which can monitor calls on any of the VHF or HF receivers. When a properly coded incoming call is received, a display lights and a chime sounds.

The HF radio consists of two tranceivers, a flush-mounted antenna, two antenna couplers and dual controls. The transceiver is ARINC 599, Collins type 628T-1. The antenna is located in the front spar of the vertical stabilizer.

Two intercom systems are provided, flight intercom and service intercom. The flight intercom has two channels, cabin intercom and galley intercom. The cabin intercom links the flight station and the ten flight attendant stations. The galley intercom links the galley and the principal service areas; fore, middle, and aft in the cabin. The service intercom links 20 major servicing areas throughout the aircraft for use during ground service functions.

The passenger address system has speakers in the flight station, cabin, galley, and lavatories. Two-way interconnections are provided with the passenger entertainment system. The passenger entertainment/service multiplex system provides stereophonic sound, hostess call, and remote controlled reading lights and air outlets. This is a digital multiplex system.

A cockpit voice recorder, ARINC 557, is in the aft fuselage. It records cockpit coversation. A flight data recorder, ARINC 5733, is also in the aft fuselage. The system records 32 analog and 30 discrete signals involving altitude, speed, acceleration, control surface positions, and engine operation.

4.3.5.2 Navigation: The navigation centers around the flight management system and the triple inertial reference system. Integrated into this system is Omega, VOR, and DME.

The inertial system consists of three sensor systems, ARINC 571. The three separate outputs of the navigators are input to each of the two flight management computers and are also available for manual selection and display.

The flight management system capabilities are in three categories:

- Performance management for fuel/cost conservation
- Navigation and guidance
- Assistance in the cockpit management task such as programming of communications, radio aids to navigation and engine and fuel management.

Performance management operates in cruise, climb, and descent modes. The cruise mode calculates optimum speed for a given altitude and aircraft weight. The speed is then held approximately by automatic throttle, and more precisely by slight pitch variations. These pitch variations do not disturb altitude more than ±15m (±50 ft). The optimizing calculation takes into consideration predicted winds and the desire for maximum cruise speed consistent with best fuel consumption for lowest cost. The system can display the optimum cruise altitude, taking into consideration length of flight and fuel to climb. The climb mode automatically and continuously adjusts pitch attitude while holding selected engine rating to give optimum fuel usage or cost.

A step-climb option is offered which provides:

- A prediction of the optimum time to go to the initiation of a climb to a more optimum altitude
- A determination of whether the climb is worthwhile based on cruise distance remaining and wind
- Automatic control of the climb and transition to new cruise altitude when initiated by the pilot

The descent mode provides an optimum descent profile taking into consideration predicted aircraft weight at start of descent, temperature, cruise altitude and speed, desired descent speed schedule, altitude capture geometry, and the desired end of descent position, altitude, speed, and time.

The navigation capability of the FMS is obtained by integrating the inertial systems, VOR, DME, and Omega. In the terminal area, the VOR and DME are the more accurate and when available are used to update, calibrate, and adjust the inertial. The FMS contains the logic to compare and select the outputs of the navigation subsystems for the most reliable and most accurate overall result. The navigation calculations are input to the performance management functions, and based upon the waypoints and desired arrival times at the waypoints, the FMS calculates and guides the aircraft in the optimum path in space and time. The present location and predicted path are available for display.

The pilot assistance (cockpit management) capabilities of the FMS include preprogrammed acquisition of the enroute VOR, DME, and communications facilities, and monitoring of the engines and fuel. The engines are monitored for out-of-tolerance temperature, pressure ratios, and fuel flow. The fuel is monitored and transferred for cg control. Aircraft weight and cg is continuously calculated starting with aircraft weight at takeoff obtained from load sensors in the landing gear.

The FMS has two separate computers, each of which performs all computations in parallel and compares the results. Each computer performs independent self-check at two cycles per second. Results of the comparison and self-check are presented to the pilot for selection of the controlling system.

- VOR/ILS: The VOR/ILS provides position and guidance signals to the pilots' displays, flight management system, and autopilot. Two VOR receivers, ARINC 547, and two ILS receivers, ARINC 578, are provided. Two remote manual controls are provided in the flight station as well as automatic control from the flight management system. Three dual antenna systems are provided; glide slope, localizer, and VOR. The VOR is Collins 622-3599-001, the ILS is Collins 792-6021-002, and the VOR preamp is Collins 792-6504-001.

- DME: Two DME interrogrator units, ARINC 568, are provided. Output is to the flight management system and also to two Radio Digital Distance Magnetic Indicators of the four digit type. Two L-band blade antennas are provided on the bottom of the aircraft.

- HRS: The horizontal reference system consists of two flux gate compass systems damped by the inertial system. The flux valve is accurately aligned to an indexing plate to permit rapid replacement without the need for a compass swing. The compass data is supplied to the inertial systems for initializing the alignment sequence, providing a signal for failure monitoring and for degraded mode operation.

- ADF: The automatic direction finder (ADF) radios are in accordance with ARINC 570. Two loop antennas, quadrantal error correctors, and extended-range sense antennas with coupler are located in the bottom of the fuselage. The ADF is low and medium (broadcast) frequency operating in the 190 to 1750 kHz frequency range. The receivers are Collins 51Y-7, the antennas Collins 137A-6 and the error corrector Collins 382C. The output is visual display only, with no input to the flight management system.

- Radio altimeter/ground proximity system: The altimeter operates with altitude above terrain from zero to 760 m (2500 ft). Two radio altimeters are provided, ARINC 552, Collins 522-3698-001. The two radio altimeters are independent except for a cross connection to prevent mutual interference. Failure monitors detect faults, activate flags, and signal the autoland system. The ground proximity warning computer is ARINC 594, Sundstrand 965-0376-070. The ground proximity warning computer detects abnormal altitude and altitude closure rates with respect to the terrain.

- Weather Radar: The weather radar is an X-band transceiver, ARINC 564. Two PPI indicators are provided for the two pilots. The antenna and associated waveguide assembly is in the nose radome. The radome is protected from lightning and erosion. The radome hinges allow one man to safely open the radome and service components within the radome area. Gain is automatically controlled on the basis of receiver noise level sampling. Antenna tilt is adjusted by a control accessible to both pilot and copilot. The operating modes are NORM., CONT., and MAP. The CONT. mode provides iso-echo contour mapping to indicate precipitation density in storm areas. In the MAP mode, a change in the antenna beam provides a ground-mapping presentation on the indicators. The maximum range is selectable; 93,278, and 556 km (50, 150, and 300 n.mi). The antenna is stabilized in two axes using attitude signals from the inertial navigator. A 180-degree forward sector is scanned. The radar is Bendix type RDR-1F.

- ATC transponders: Two transponders with altitude reporting capability, ARINC 572, are provided. Two L band blade antennas are provided on the bottom center line of the fuselage. The transponder can be set to Mode A (domestic identification and altitude) or Mode B (international identification and altitude). Control knobs and a code display are provided to enable selection of any of the 4096 codes for the A and B modes. An IDENT pushbutton allows the system to respond with the special position identification when requested. The transponders are Collins 621A-6A.

- Air Data: This system provides two air data computers. The inputs are pressure from the pitot-static tubes, and total air temperature. The outputs and their corresponding range of measurements are:

Pressure Altitude	-31 to +15 000 m (-100 to +50,000 ft)
Altitude Rate	0 to $\pm$ 102 m/s (0 to $\pm$ 20,000 fpm)
Altitude Hold	0 to $\pm$ 305 m (0 to $\pm$ 1000 ft)
Computed Airspeed	26 to 232 m/s (50 to 450 kt)
Airspeed Hold	0 to 10 m/s (0 to $\pm$ 20 kt)
True Airspeed	77 to 308 m/s (150 to 599 kt)
Mach Number	0.2 to 1.0 Mach
Static Air Temperature	-99^{o} to $+50^{o}$C

The computers are ARINC 565 and provide outputs for the air data instruments and recorders as well as the flight management system, the automatic flight control, the stability augmentation systems, and the Mach/trim feel. The computers are made by Sperry, and use digital computing techniques.

- Instruments: Flight instruments are standard electromechanical, conforming to ARINC 415-2. Dual instruments are used throughout. DC torquers are used in servoed instruments. An instrument warning system indicates malfunction and status of the basic attitude sensors and guidance systems. Warning is accomplished primarily through warning flags in each associated display or by retracting the display. Monitor coverage is continuous and automatic. No arming or resetting is required. Comparison monitoring is provided for the primary airspeed, attitude, and altitude systems.

4.4 Reference Propulsion System

4.4.1 Introduction. - This section describes the reference propulsion system used in the study. The GE CF6-50C engine was selected as the reference primarily to allow NASA's Energy Efficient Engine (E^3) study results to be used in defining the cost benefits of advanced technology gas turbine engines. Utilizing this approach promotes consistency between the Integrated Technology Wing Study and the E^3 program results. The GE E^3 study was also selected because GE was a primary participant in the NASA EET Propulsion/Airframe Integration Tests conducted at NASA LaRC, the results of which were used in this study.

4.4.2 Engine description. - The CF6-50C engine is a growth derivative of the CF6-6D engine and provides a 25 percent increase in takeoff thrust needed for the heavier weight long-range, wide body aircraft. The engine was certified in 1972 with additional improvements being incorporated later in the areas of reliability, maintainability, reduced noise and smoke.

The basic engine, shown in figure 35, is a high bypass ratio, twin spool turbofan which incorporates a single stage fan with an aerodynamically close-coupled three-stage booster, a 14-stage high-pressure compressor, an annular combustor, a 2-stage high-pressure (HP) turbine and a 4-stage low-pressure (LP) turbine. The HP turbine nozzle guide vanes and blades are cooled with compressor bleed air. The installation features a separate flow exhaust system consisting of a conical annular convergent nozzle for the bypass stream and a convergent divergent nozzle for the core stream. The original design included a thrust spoiler/reverser in the core nozzle. However, this feature was not retained by the airlines and is not included in the reference configuration for this study.

Engine and aircraft accessories are mounted on the bottom of the fan case to facilitate airline maintenance. The engine control utilizes a conventional hydromechanical unit which maintains desired core engine rotor speed from throttle command, manages compressor stator vane operating schedules, provides compressor discharge pressure (CDP) limiting schedules transient power changes, and operates the LP bypass valves during transients.

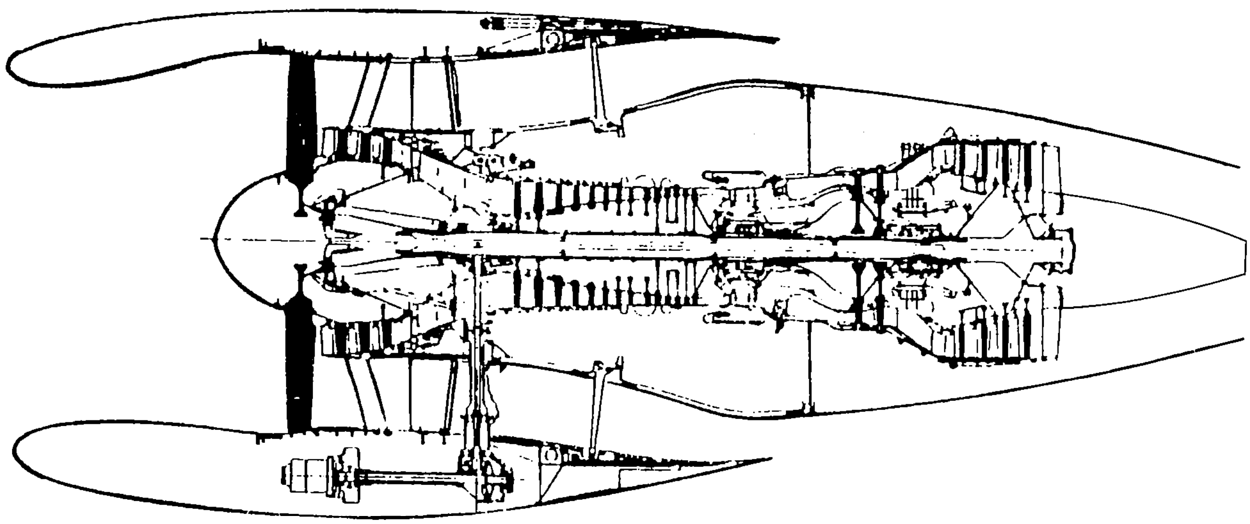


Figure 35. - Installed CF6-50C features.

A reference aircraft configuration was obtained in this study by optimizing thrust/weight and wing loading. Scaling data, provided by GE, were used to examine a range of various aircraft thrust to weight ratios to define an optimum size for the reference aircraft and engine. As a result of the aircraft sizing optimization studies the engine is sized at 242.8 kN (54,600 lbf) of SLS rated takeoff thrust. Salient characteristics of the engine are presented in figure 36. The weight buildup for a complete wing pod is presented in figure 37.

4.4.3 Propulsion system installation. - This section describes the reference CF6-50C propulsion system and propulsion system/airframe installation for the reference aircraft. The nacelle configuration for the resized CF6-50C engine is defined in figure 38. The corresponding propulsion system/separate flow nacelle dimensions show a maximum diameter of 303 cm (119.3 in.), a fan cowl length of 455.4 cm (179.3 in.) and an overall length of 672.8 cm (264.9 in.) excluding the core plug. The forebody section of the fan cowl is drooped 4 degrees to account for the estimated inlet flow angle resulting from the wing upwash effects.

The engine is installed on the reference aircraft in an underwing pylon mounted pod as illustrated in figure 39. This installation is based on detailed design studies previously conducted for use of this engine on the

GENERAL ELECTRIC CF6-50C TURBOFAN ENGINE

• TAKEOFF THRUST ~ kN (lbf)	242.8	(54,600)
• TAKEOFF FLAT RATED TEMP, ISA + ΔTEMP. ~ °C (°F)	15	(27)
• BYPASS RATIO (SLS)	4.35	
• FAN DIAMETER ~ cm (in)	228.8	(90.0)
• ENGINE LENGTH ~ cm (in)	452.2	(178.0)
• BARE ENGINE WEIGHT ~ kg (lbm)	4321	(9524)
• ENGINE CERTIFICATION DATE	NOV. 1973	

Figure 36. - Reference propulsion system.

BARE ENGINE	**4321 kg**	**(9524) lb**
INLET	**296**	**(653)**
FAN COWL	**139**	**(307)**
FAN REVERSER	**795**	**(1751)**
CORE COWLS	**92**	**(203)**
PRIMARY NOZZLE	**149**	**(329)**
ENGINE BUILD-UP	**382**	**(842)**
TOTAL	**6,174**	**(13,609)**

Figure 37. - Reference propulsion system weight CF6-50C reference thrust = 242.8 kN (54 600 lbf).

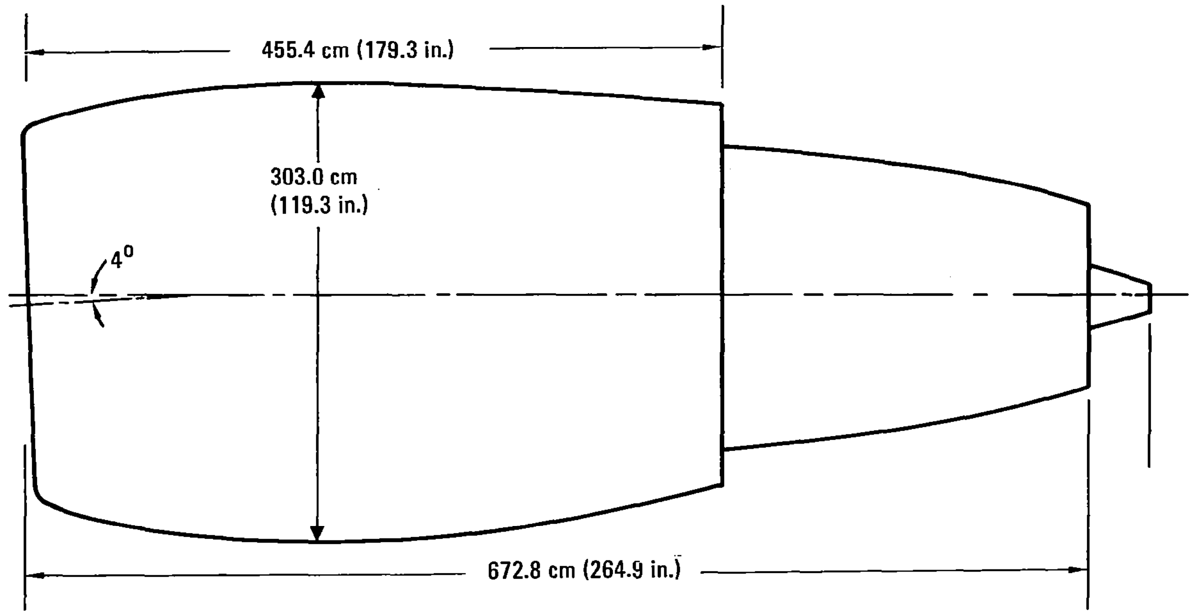
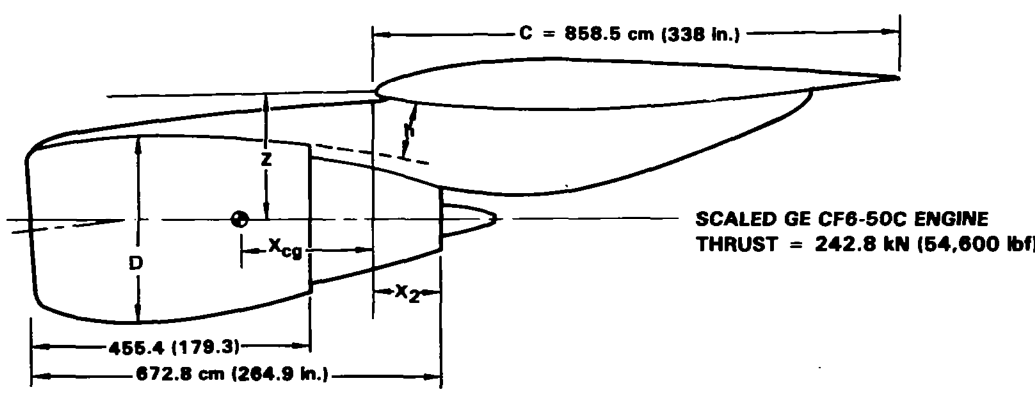


Figure 38. - Nacelle configuration for production CF6-50C separate flow exhaust engine-thrust 242.8 kN (54,600 lbf).



• NACELLE TYPE	SEPARATE FLOW
• PYLON SHAPE	SYMMETRICAL
• PYLON CANT	1.93° INBOARD
• NACELLE CANT	1.93° INBOARD
• NACELLE PITCH	2° UP
• INLET DROOP	4°

NACELLE INSTALLATION PARAMETERS

$h/X_2 = 0.80$

$X_2/C = 0.135$

$Z/D = 0.695$

$D/C = 0.353$

$X_{cg}/C = 0.207$

Figure 39. - Engine/nacelle installation for the reference aircraft.

L-1011 aircraft. The installation results in utilization of the existing aircraft pylon/wing structure and in a nacelle location relative to the wing that is acceptable from consideration of interference drag. The pylon cross-sectional shape is symmetrical. The nacelle/pylon alignment corresponds to a toe-in angle of 1.93 degrees and pitch up attitude of 2 degrees.

The propulsion system design for the reference aircraft is consistent with current existing configuration/installation technology levels. The configuration parameters commonly used to describe the location of the nacelle relative to the wing for purposes of identifying installed nacelle drag are defined in figure 39. These parameters include: z - the vertical displacement of the nacelle centerline from the wing reference plane, x - the fore and aft location of the engine fan and core exhaust relative to the wing leading edge, d - the nacelle size (diameter) relative to the wing size (chord) and h - the minimum channel width between the wing lower surface and upper fan cowl contour (or fan exhaust streamtube). Various ratios formed with these parameters have been used to correlate nacelle location to installed nacelle drag. Because of the complex nature of the three dimensional flow fields and the large sensitivity of drag to location and configuration design, extensive large amounts of test data are required to establish meaningful correlations.

Lockheed has used a nacelle spacing parameter, h/x_2 as defined in figure 39, to correlate installed nacelle interference drag. The correlations are based on data from aircraft scale model wind tunnel testing with flow-thru and powered nacelles. The estimated installed interference drag for the conventional wing aircraft is shown in figure 40. The interference drag presented here is the total installed drag minus the friction drag of the isolated nacelle/pylon. The drag coefficients are based on the nacelle maximum cross-sectional area rather than the wing reference area. Using the nacelle area is more convenient for the ASSET program wherein the engine and aircraft sizes are varied independently. In presenting the study results in subsequent sections nacelle drag as a percentage of aircraft drag is provided for reference.

The curve presented in figure 40 indicates that for a conventional wing aircraft, nacelle interference drag can be avoided if the spacing parameter, h/x_2 is greater than 0.8. A constant value of this parameter defines a locus of positions obtained by moving the nacelle forward and up or aft and down relative to the wing. The aft and down location is limited by required nacelle ground clearance, while the forward and up movement is constrained by locations that avoid upper wing flow disturbances that might originate from the nacelle/pylon leading edge intersection. In addition to the interference drag considerations, location of the nacelle also impacts the required pylon structural weight necessary to meet flutter criteria. This will be discussed in subsequent sections.

For the CF6-50C engine installed on the reference aircraft the nacelle has been positioned to provide an h/x_2 of 0.80 resulting in no interference drag penalty. The corresponding vertical location is such to provide sufficient ground clearance.

For the reference aircraft, a reduction in installed nacelle drag can be realized through propulsion/airframe integration efforts. This benefit results from proper cambering and area ruling of the pylon contours and possible contouring of the nacelle and/or sculpturing of the wing, to obtain favorable mutual interaction effects between the wing and nacelle flow fields. The benefits assumed for this study are shown in figure 41 and amount to approximately 0.8 percent of the aircraft drag. Although further reductions may be attainable through additional effort, the data present an average of the gains identified from various model tests.

4.5 Reference Structures and Materials

The reference aircraft utilized for this study is an L-1011 which incorporates materials that provide a maximum degree of corrosion resistance in proportion to the specific environment encountered. Selective use of materials and temper conditions with high resistance to corrosion, such as alclad sheet on exterior fuselage skins, high-strength clad plate for wing skins, precision die forgings with desirable grain flow and, exfoliation and stress corrosion resistant 7075-T76 or 7075-T73 products are utilized.

Aluminum alloys 7075 and 2024 are extensively used throughout the structure. The advantages of these alloys are shown in Table III.

In addition, the aircraft makes extensive use of 7075 in the corrosion resistant T76 and T73 tempers. The 7075-T6 products are restricted to applications of highly-loaded structural components where resistance to others or exfoliation corrosion is not an important consideration. High strength clad 7075 - T76 is used for both the upper and lower wing surfaces to avoid stress corrosion and exfoliation problems encountered with wing skins from thick 2024-T3 or 7075-T6 plate stock.

The 7075-T76 material used on the wing skins have an aluminum-zinc-magnesium (7008 alloy) layer on the external surface; a high strength clad that can only be applied to a 7000 series aluminum alloy. The 7008 cladding not only provides a more corrosion resistant surface, but also responds to heat treatment so that it approaches the hardness level of the base metal. Thus, the selective use of various skin materials is proving itself as the successful service history of the L-1011 continues to grow.

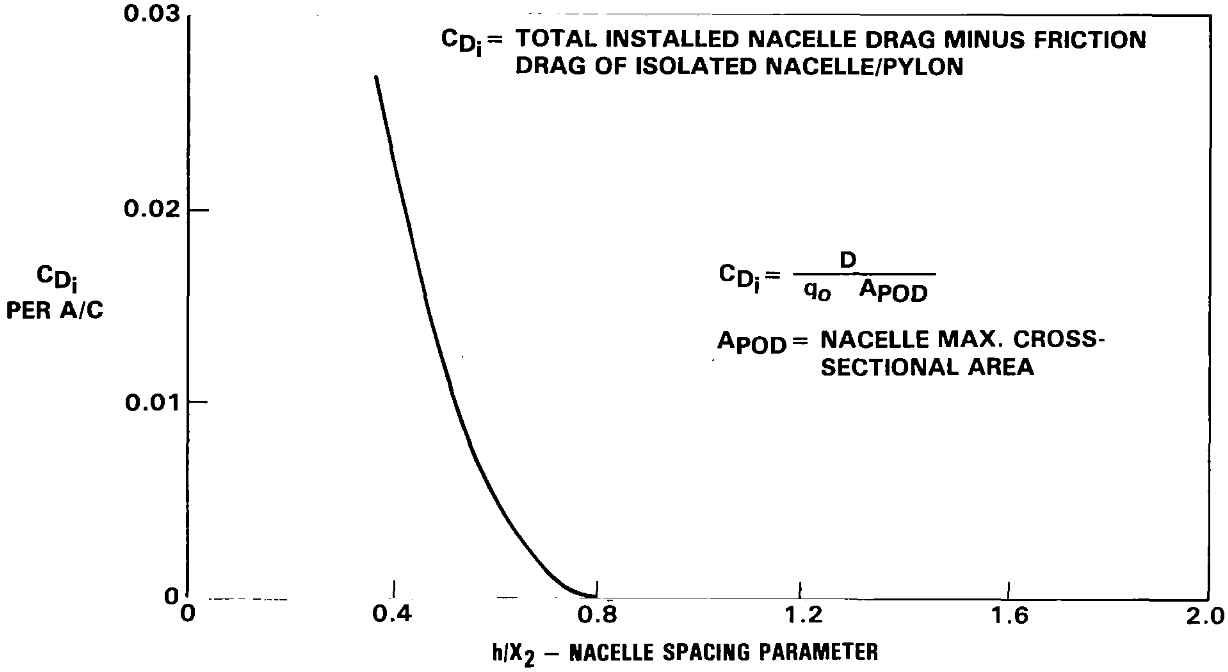


Figure 40. - Installed nacelle interference drag correlation for reference aircraft - symmetrical pylon.

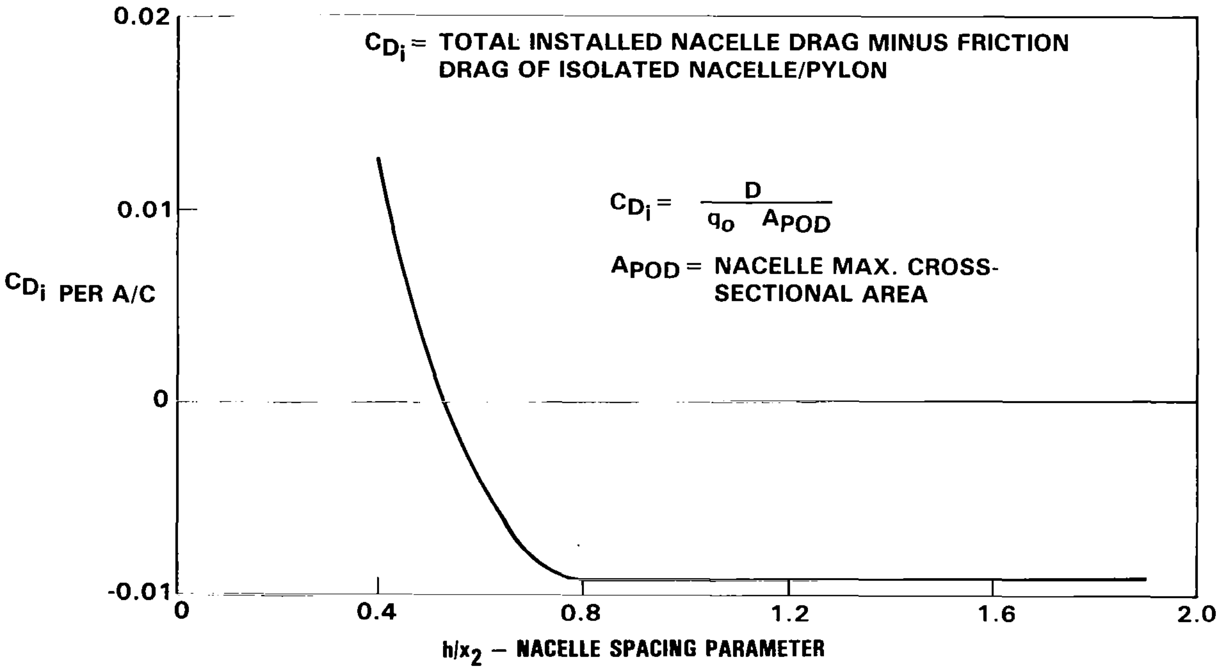


Figure 41. - Installed nacelle interference drag correlation for the reference aircraft - cambered pylon.

TABLE III. MATERIALS ON REFERENCE AIRCRAFT

Material	Characteristics	Typical Applications
7075-T6 (Alclad, extension, plate, sheet)	Highest strength with acceptable toughness.	Used in highly loaded structure where corrosive environment is not extreme in case of bare material.
7075-T76 (Alclad, extrusions, sheet, plate with high-strength clad)	High strength (close to 7075-T6). Good toughness properties combined with high resistance to exfoliation and stress corrosion.	Plate with high strength clad used for wing skins. Used in applications where high strength is required as well as resistance to exfoliation and stress corrosion.
7075-T73 (Forgings)	High resistance to exfoliation and stress corrosion. Good fracture toughness.	Used for parts where residual stresses could possibly be present.
2024-T3 (Alclad, sheet)	Good strength and excellent toughness properties.	Minimum gauge skins in pressurized fuselage. Lightly loaded skins such as those on control surfaces.

5. ADVANCED AERODYNAMICS

In recent years several technologies have developed which offer the potential for significant reductions in cruise drag of transonic aircraft. The design of future transports will employ a combination of advanced technology and careful optimization of the configuration of the aircraft. Improvements in structural technology, advanced materials and active controls for maneuver load alleviation will allow aspect ratios to be increased considerably. This in turn offers large reductions in induced drag throughout the flight regime. Aspect ratios which are currently about 7 to 8 will increase to 10 and may go as high as 14, reducing induced drag substantially. For a perspective view, figure 42 shows a comparison of aspect ratio 7 and 10 wings on an L-1011. Increases in aspect ratio may be facilitated by greater wing thickness allowed by advanced supercritical airfoil technology.

The predicted advances in aerodynamics are based on results from many experimental and theoretical studies. A bibliography which lists some of these studies is given at the end of this report.

5.1 Definition of Advanced Aerodynamics

Advances in aerodynamic technology will produce a large improvement in the specific air range factor, ML/D, for future transport aircraft. These advances will take the form of increases in aspect ratio, advances in airfoil technology and the reduction of trim drag by use of relaxed stability and active control.

The advanced supercritical airfoil offers the chance to significantly improve transonic cruise performance. This type of section has a significantly higher drag divergence Mach number or cruise lift coefficient than the older sections. This allows an increase in either cruise Mach number or wing thickness at the same drag level or a lower cruise drag at the original Mach number. The increase in wing thickness and/or decrease in sweep permitted by the superior wave drag characteristics of the advanced supercritical wing will improve high lift performance and allow a higher aspect ratio wing to be built at an acceptable structural weight. The increase in aspect ratio will significantly improve cruise and climb performance through reductions in induced drag.

The calculation of the aerodynamic drag of the configurations considered in this study was performed by the Lockheed developed PERTDRAG method which has been incorporated into the aircraft synthesis and evaluation techniques program, (ASSET), as a major subroutine. PERTDRAG is a perturbation method which calculates the drag of a specified aircraft configuration by systematic perturbation of an assemblage of aerodynamic data describing the characteristics of a tested reference configuration. Wave drag is perturbed using modified classical sweep theory. A cosine of sweep variation is used based on

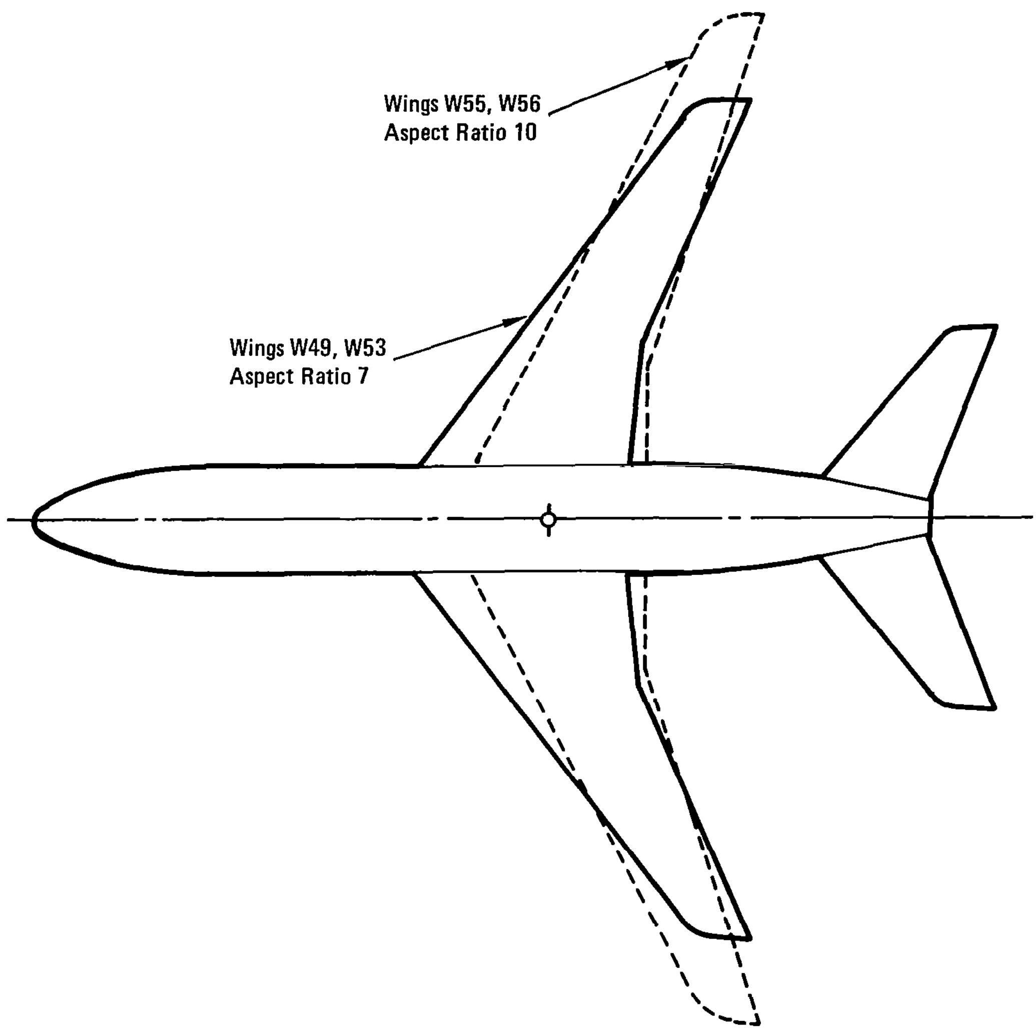


Figure 42. - Wing planform comparison on L-1011 model.

the area weighted average 60 percent chord sweep rather than the quarter chord sweep. This sweep is used because it more closely approximates the sweep of the shock front. The effect of wing thickness on wave drag is calculated using a transonic similarity formulation. Skin friction is calculated by a Van Driest adiabatic wall method. Classical aspect ratio theory is used to compensate for aspect ratio changes and the span efficiency is adjusted for sweep.

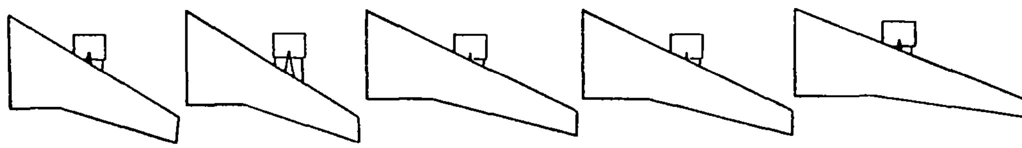
In addition, PERTDRAG has an accurate trim drag calculation subroutine which takes into account the effects of changes in tail geometry, fuselage length and center of gravity position. The trim drag feature has been extensively tested and is of particular value since it facilitates evaluation of a configuration employing relaxed static stability and active controls.

Since PERTDRAG is a perturbation method it does not account for changes in airfoil technology level internally. Variations in airfoil characteristics are contained in the input or reference data sets. In performing the calculations for this study, two data bases were employed. The first of these represented flight test measurements for the L-1011 aircraft as it is currently in service. The second data base, designated the 1986 technology readiness data base represents the characteristics of an airplane having the same geometry as the L-1011 with the exception of the incorporation of an advanced airfoil section having the same thickness as the L-1011 airfoil. The drag rise tables used in the later data base were produced from a combination of L-1011 flight test data, NASA-Ames wind tunnel results summarized on figure 43 for an advanced supercritical wing and predictions based on the rate of drag divergence improvement observed during Lockheeds ongoing wing development program. Figure 44 is a comparison of a PERTDRAG predicted drag polar, using aspect ratio 7 W53 as a database, to NASA-Langley experimental data from an aspect ratio 12 supercritical wing. This figure demonstrates the ability of the PERTDGAG method to predict accurately the drag of configurations which are significantly altered from the base data set.

5.2 Benefits of Advanced Aerodynamics

5.2.1 Airfoil and wing design. - The development of the advanced supercritical airfoil offers several opportunities for the reduction of overall fuel consumption. The advanced supercritical wing has a higher drag divergence Mach number or cruise lift coefficient than current wings of the same thickness and sweep, as indicated on figures 45 and 46. This allows aircraft with an advanced technology wing to either fly faster at the same thrust or to fly at the same speed at a lower thrust level. Both will decrease overall block fuel consumption. The improved drag rise characteristics of the supercritical airfoil permit the wing to be thicker for a given level of drag rise and cruise Mach number, figure 47. The increase in thickness allows an increase in aspect ratio or a decrease in wing weight both of which will decrease block fuel consumption. In general, the increase in aspect ratio is far more beneficial than the decrease in wing weight, particularly for long-range aircraft.

The fuel savings offered by the combination of supercritical airfoils and increased aspect ratio are substantial. Lockheed has demonstrated, in the wind tunnel, a wing which would provide a 20% improvement in L/D for the L-1011 aircraft. This wing, designated wing W55 (figure 43), employed a combination of increased aspect ratio, reduced sweep and advanced supercritical airfoil sections. Since it was intended as a technology development program it does not necessarily represent a mission optimized wing and therefore may not represent the greatest block fuel improvement possible with supercritical airfoil technology. Further improvements, both in airfoil technology and mission optimization of the wing design, are possible and an intensive program of theoretical and experimental development work is necessary to obtain these performance gains. The ASSET studies undertaken as part of this



	W49	W53	W55	W56	W57
AR	7	7	10	10	14
Λ	35^0	35^0	25^0	25^0	25^0
t/c (%)	10	10	12	13	16
M_D	0.84	0.84	0.80	0.80	0.74
C_{L_D}	0.45	0.50	0.60	0.60	0.75
$\% \Delta \frac{L}{D}$ Goal	0	5	20	20	42

Figure 43. - Transonic wing technology development.

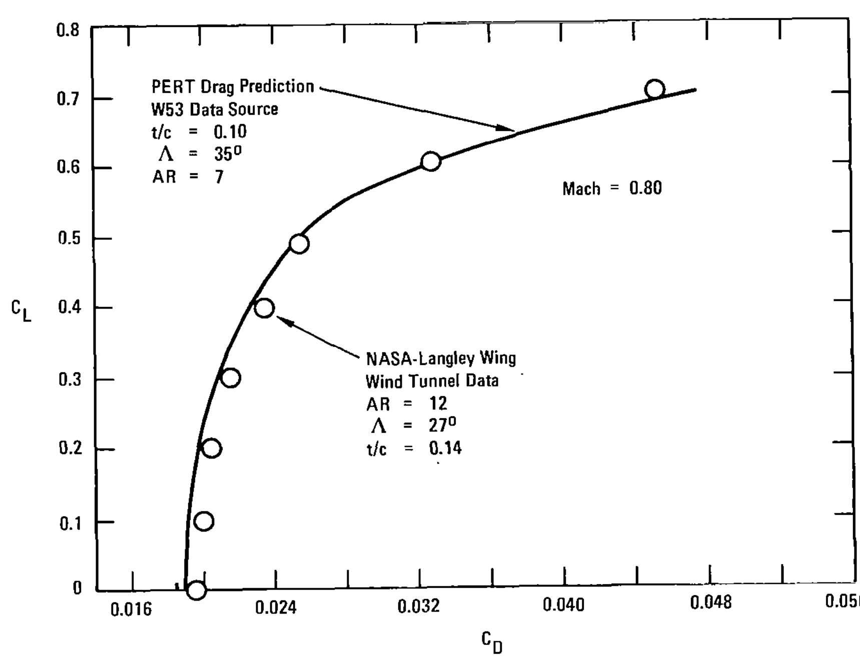


Figure 44. - Substantiation of PERTDRAG prediction.

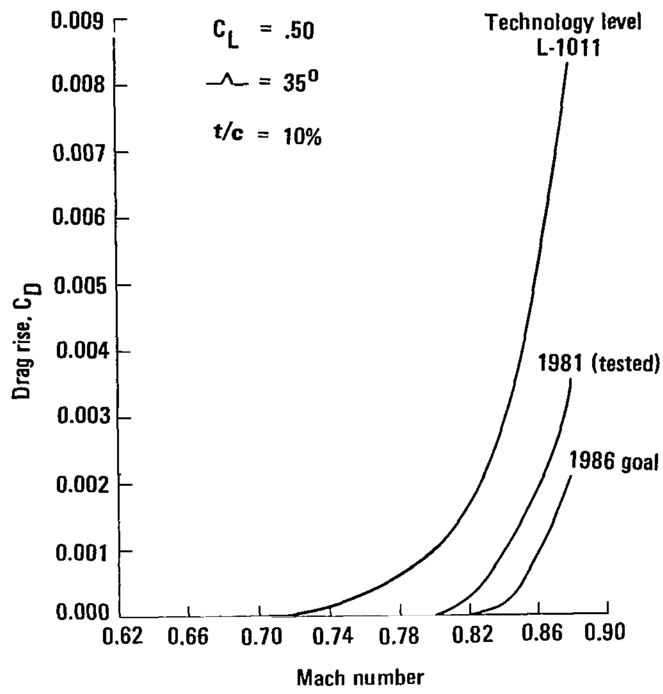


Figure 45. - Drag rise comparison, sweep = 35^o t/c = 10.05% C_L = 0.5

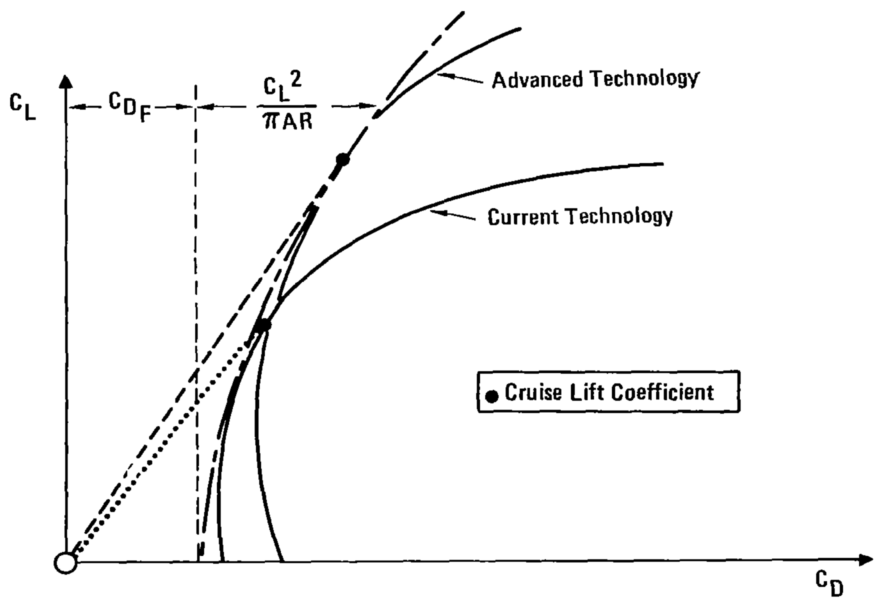


Figure 46. - Benefits of aerodynamic wing technology integration.

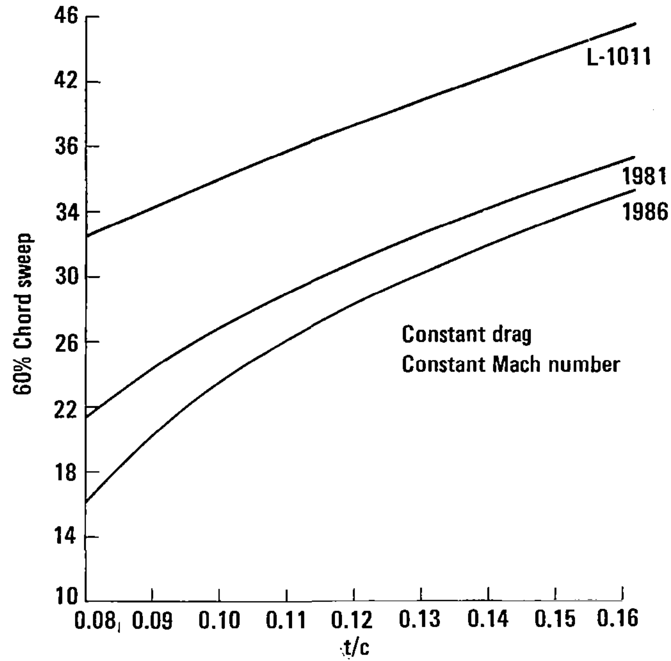


Figure 47. - Sweep vs t/c tradeoff.

contract show that increases in aspect ratio alone, using conventional airfoil technology, can yield a block fuel improvement of approximately 6% over the reference configuration. The addition of supercritical airfoils and a reoptimization of the wing design yields a further 6% block fuel improvement. These performance gains are for aircraft employing conventional center of gravity positions and stability margins.

5.2.2 Aspect ratio. - The effects of aspect ratio upon the cruise drag of airplanes is well documented. At best L/D the induced drag of an airplane is half of its total drag. Since induced drag is inversely proportional to span squared or aspect ratio it is desirable to increase aspect ratio as much as permitted by other design constraints. High aspect ratio is not a new technology and the effects of increased aspect ratio have been known for a long time. The use of higher aspect ratios involves the blending of several advanced technologies to optimize the aircraft. Advanced airfoil technology allows for increased wing thickness and hence structural efficiency, and therefore impacts the aspect ratio at which the aircraft optimizes.

5.2.3 Relaxed stability and active controls. - Supercritical airfoils exhibit a higher negative pitching moment than older sections resulting in a greater than previously encountered trim drag penalty. However, the advanced supercritical wing offers significant improvements in performance even for aircraft employing current stability margins and center of gravity positions. These improvements can be maximized by reducing the trim drag penalty. This can be accomplished by moving the cg aft and using active controls to produce the desired flying qualities. The benefits of aft cg and active controls are highly dependent on the details of the configuration of the airplane, tail arm and size, but can be as high as a 4% reduction in cruise drag. Some secondary benefit in trimmed $C_{L_{MAX}}$ and approach speed can also be expected from the decrease in tail download for trim due to the aft cg position.

5.2.4 High lift technology. - The ASSET evaluations performed on the various configurations considered in this study have shown that there is a requirement for a trimmed maximum lift coefficient of about 3.0 to meet airport and approach constraints. While this level is somewhat greater than is currently exhibited on most aircraft in service it is well within the realm of possibility for "advanced mechanical" high lift systems. These systems would include more equal flap and vane chords, improved leading edge devices such as the rotated leading edge flap shown in figure 48 and the possible elimination or drooping of the inboard aileron. The increased aspect ratio of the advanced configuration aircraft will make it easier to satisfy the second segment climb requirement due to the decrease in induced drag during climb.

5.3 Plans and Costs

5.3.1 Aerodynamic technology progress.

5.3.1.1 Advanced airfoils: Considerable progress has been made toward the 1986 technology goals. Figures 45 and 47, of Section 5.2.1, show the current state of the art as compared with the L-1011 and 1986 technology goals in terms of drag rise and sweep vs t/c for a given level of drag rise. Figure 49 is a "roadmap" of the projected wing development program. Although the technology benefits and risks are discussed separately in terms of aspect ratio and airfoil it is not expected that the two avenues will be investigated independently. It has been and will continue to be the policy of Lockheed to design each development wing with a combination of the best available technologies and to consider realistic constraints in order to generate a viable wing for a possible production aircraft. Because of this the projected wings may exhibit excursions from previous wings in aspect ratio, sweep, thickness and cruise design point.

Although it is desirable to design each test article as a viable wing, it is also desirable to be able to compare the performance level of the various airfoil technologies on an equal basis. This is somewhat complicated by the fact that each wing is unique in thickness, sweep and airfoil technology, therefore its drag rise and C_{D_o} characteristics are also unique.

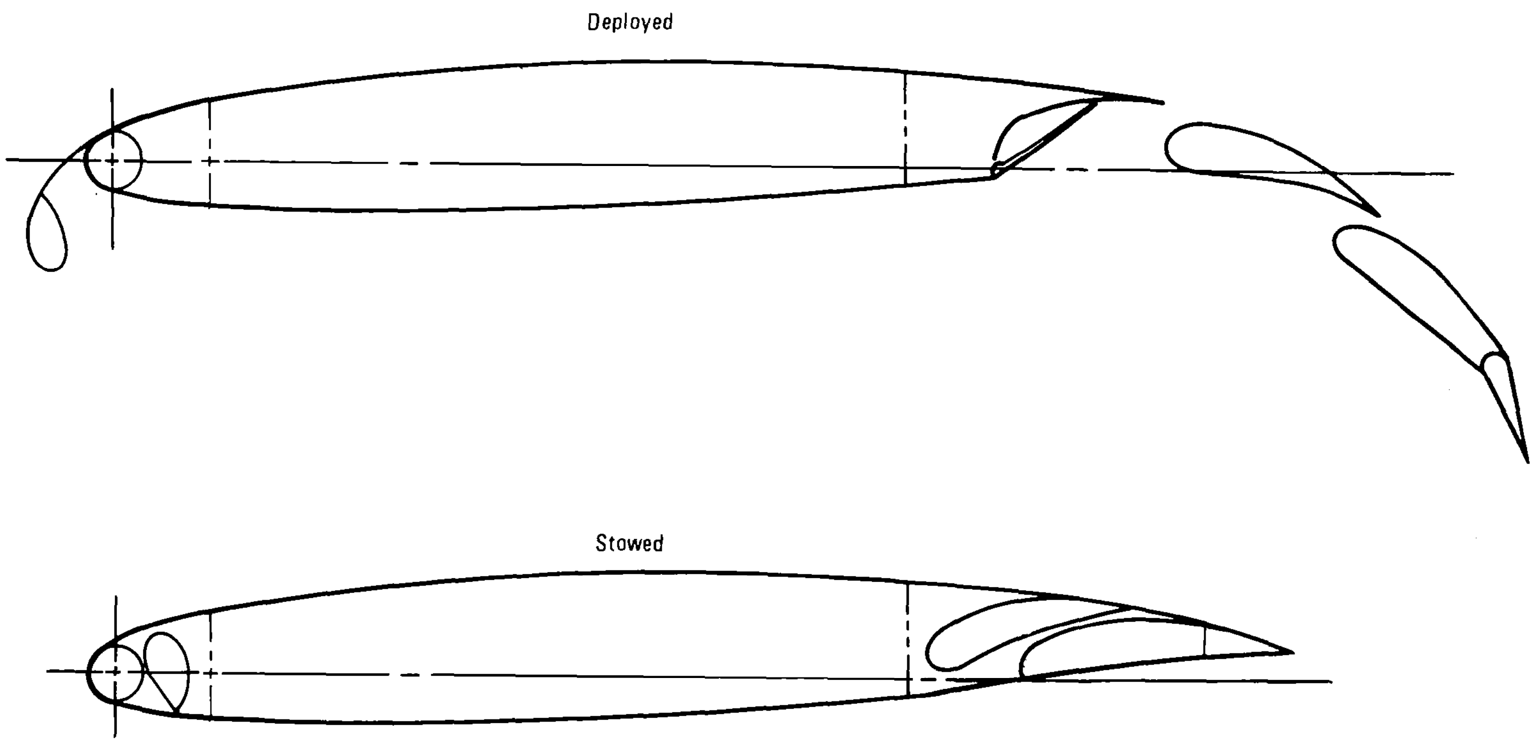


Figure 48. - High lift system.

Tested NASA Ames 14 foot tunnel					Projected				
Wing	Technology	AR	Λ	Mach	Wing	Technology	AR	Λ	Mach
49	L-1011	7	35	0.84	56	CAS 80	10	25	0.80
50	L-1011	9	30	0.8	57 A B	CAS 80	14	25	0.74
51	Early Super Critical	9	30	0.8	58 A CRYO	1983	?	?	?
52	CAS	9	30	0.8	59 A B	1986	?	?	?
53	CAS	7	35	0.84					
53B	CAS	7	35	0.84					
55	CAS 80	10	25	0.8					

CAS = curvature airfoil shaping

Figure 49. - Wing development program.

The PERTDRAG technique is most useful in this regard since it allows the changes in wing performance due to thickness and planform to be accurately calculated. Using PERTRAG the polars and drag rise curves of all wings undr evaluation can be normalized to a single reference planform and thickness, allowing direct comparison of the technical advancement of the airfoils used.

As previously stated, the advanced supercritical technology wing data base is derived from wind tunnel tests. There is a scarcity of full scale or actual flight test data. Full scale data would provide a high confidence level in the advanced aerodynamic technology.

5.3.1.2 High lift system: The integration of the high lift system into an advanced supercritical airfoil does not appear to present any unusual problem from the stowage or performance points of view. Careful attention will have to be paid to the effects of the stowed leading edge device gaps and any actuator or hinge fairings on the high speed performance of the aircraft. Figure 48, Section 5.2.4 shows a projected high lift system in both the deployed and stowed configuration. Advanced supercritical airfoils, by virtue of their increased camber, are generally superior in performance to conventional peaky airfoil sections with flaps down. The shape of the aft portion of the airfoil will allow more cambered flap elements to be stowed. The larger leading edge radius of supercritical sections also contribute to better high-lift performance. The Lockheed designed rotated leading edge flap will offer an easily stowed device with a superior leading edge shape. Since the rotated flap can be stowed under the leading edge, it will cause a minimal disruption in the supercritical upper surface flow and offers a potential drag reduction by virtue of the elimination of the air leakage which tends to occur under a conventional slat type leading edge device.

5.3.1.3 Relaxed stability and active controls: Advanced supercritical airfoils exhibit much higher negative pitching moments than the airfoils currently in use. This in turn leads to a greater download on the tail and an increased trim drag penalty. To reduce this tail download, the center of gravity of the aircraft can be moved aft and the stability of the airplane augmented or provided entirely artificially by active controls. The cruise drag benefits of active controls and aft cg placements are highly configuration dependent. The benefits are largest on short coupled configurations where the tail download required for trim is large and much smaller for long bodied configurations which require smaller tail downloads. The primary benefit of aft cg is a reduction in the required wing lift coefficient. Care must be taken to insure that the tail does not carry a large upload, or the wave and induced drag of the tailplane will offset any improvements produced by the decrease in wing C_L. Landing gear placement and similar constraints may force compromises in wing design or cg movement and reduce the potential benefits of relaxed stability technology.

5.3.1.4 Airframe/propulsion integration: The combination of higher bypass ratio, greater diameter engines, and higher aspect ratio, narrower chord wings may lead to problems in the integration of the wing and powerplant installation. The first area which requires study is interference between the airflows over the nacelle and the wing. The greater diameter of the newer engines will require that they be mounted higher with respect to the wing than previous installations in order to maintain the necessary ground clearance. This will cause the flow leaving the nacelles to impinge more strongly on the wing than before. This impingement may impact the performance of the aircraft in all flight regimes, but will have the greatest impact at high angles of attack encountered during approach and second segment climb. Testing will be required to evaluate the magnitude and importance of these effects.

As aspect ratios increase, the chord of the wing at the engine location will decrease. This will cause the pylon to wing intersection to extend over more of the wing chord than is currently the practice. The pylon intersection will extend into the region of adverse pressure gradient on the aft portion of the wing underside, possibly leading to separation and intersection drag difficulties. The pylon may also interfere with the operation of the high lift system or inboard aileron.

5.3.2 Wing technology development plan. -

5.3.2.1 Low Reynolds number program: The general flow chart of the program designed to develop the technology and configuration of the future transport wing system is shown in figure 50. Design and testing of advanced technology wings will proceed as outlined in the wing design plan in figure 49, Section 5.3.1.1. Testing will be performed in a conventional transonic tunnel such as the Ames 14 foot or Calspan facilities. This testing will lead to an optimized configuration. At this point the work will split into two distinct areas of investigation:

1. High lift development

2. High Reynolds number verification program.

5.3.2.2 High lift development: The wing configuration development in the low Reynolds number program should be sufficiently close to the projected final configuration to allow the commencement of a high lift system development program. This program will combine theoretical and low speed wind tunnel work and address the problems of maximum lift coefficient, drag in climb and design of flap systems, including stowage. As development of the high speed configuration proceeds, design changes which will impact the design of the high lift system will be incorporated into the high lift design process.

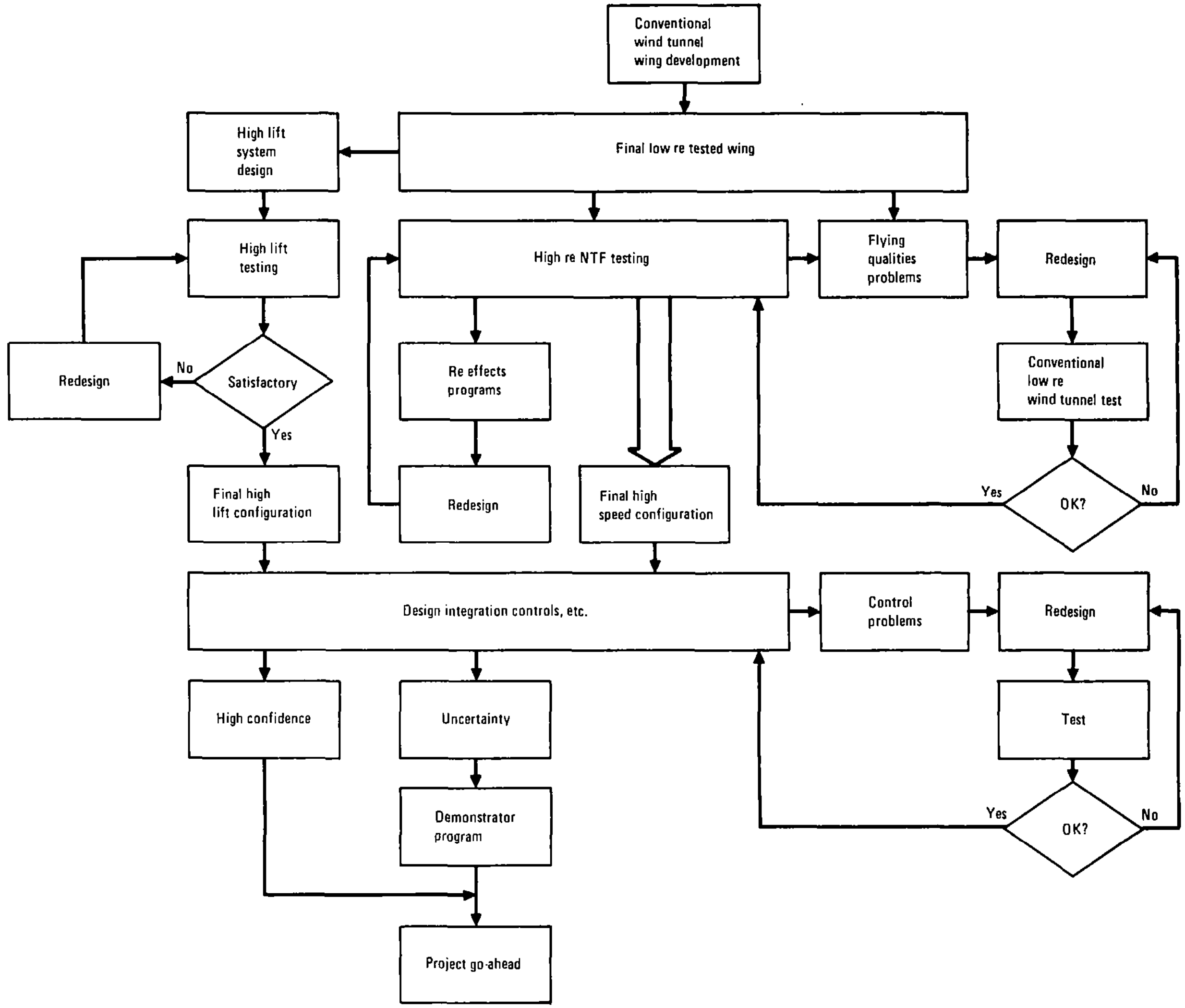


Figure 50. - Configuration development flow chart.

5.3.2.3 High Reynolds number program: Concurrently with the development of the high lift system, a program of refinement and verification testing of the cruise configuration will proceed. The final low Reynolds number configuration will be tested at flight scale Reynolds number in the National Transonic Facility (NTF) cryogenic wind tunnel at NASA Langley. Several risk areas will be addressed at this point in the testing. There is the possibility that Reynolds number effects may cause the performance of the wing to be less than was predicted by the lower Reynolds number testing. If this is the case, the design of the wing will be tailored, refined and the new configuration tested until the desired performance level is achieved.

5.3.2.4 Flying qualities development: The possibility that the wing may have acceptable drag characteristics but unacceptable flying qualities will also have to be addressed. This situation may occur in either the low or high Reynolds number phase of the test plan. If the wing does exhibit unsatisfactory flying qualities and it is determined that these insufficiencies cannot be compensated for by control system technology, it will again become necessary to make some design and testing iterations to tailor the flying qualities characteristics of the aircraft.

5.3.2.5 Design integration and control surface design: Concurrent to the final high speed configuration, and high lift system testing and design, will be the integration of the control systems. It may be necessary to perform several iterations on the design of the control system in order to obtain satisfactory control effectiveness and manufacturability.

5.3.2.6 Demonstrator vehicle program: At this juncture, there are two courses of action available. If there is high confidence that the results of the wind tunnel testing accurately reflects the performance levels achievable by an in service aircraft then the program go-ahead decision can be made and guarantees written. If there is still uncertainty as to the accuracy of the testing, or concerning other factors such as manufacturability, structural distortion in flight, and surface quality, it may be desirable to proceed with a demonstrator vehicle program in order to obtain flight test data to resolve these problems. The satisfactory completion of the demonstrator program would then ensure a sufficient confidence level for a program launch.

5.3.3 Cost assessment. -

5.3.3.1 Wing technology, low reynolds number testing: There have been a total of seven model wings designed and tested by Lockheed at the NASA Ames 14-foot tunnel to bring the state of the art from the reference (L-1011) level to the current (Wing W55) level at a total cost of 6 million dollars. It is anticipated that two more models and four additional wings will be required to advance the technology to the level predicted for 1986. Costs 1980 dollars are as follows:

Engineering and Computational:	$ 5,207,500	
Model Fabrication:	800,000	
Testing:	2,600,000	
Total	$ 8,607,500	1982 to 1986

A total of thirteen wings will have been built and tested by the time 1986 airfoil technology readiness has been achieved yielding a total cost for conventional transonic wind tunnel testing and development of $14.6 million.

5.3.3.2 Wing technology, high Reynolds number testing: To achieve a confidence level which will allow a program go-ahead decision to be made, advanced technology wings must be tested at flight scale Reynolds number. It is anticipated that this testing will be done at the NASA Langley NTF cryogenic tunnel facility. It is currently anticipated that the cost of this testing will be as follows:

Model Fabrication:	$ 1,000,000	
Testing:	1,000,000	
Total	$ 2,000,000	1982 to 1986

The total costs are for a single configuration test. If more than one configuration must be tested the cost will rise commensurately.

5.3.3.3 High lift development: Development of the high lift system will require that two models and four additional high lift configurations be designed and tested in the 1982 to 1986 time period. Costs for this program will be:

Engineering and Computing:	$ 3,030,000
Model Fabrication:	800,000
Testing:	190,000
Total	$ 4,020,000

or to 1982 $500,000 has been spent on high lift development. The total cost for the high lift development program would be approximately $4.5 million to achieve a 1986 technology validation.

5.3.3.4 Flying qualities development: There is considerable uncertainty concerning the pitch instability in an aircraft employing an advanced supercritical wing. Flying quality characteristics will be monitored during all phases of the configuration development process. Of particular concern is the certification requirement that the aircraft exhibit linear stick force per g characteristics up to buffet onset. Although there is no strong indication that an advanced supercritical wing will have worse characteristics than conventional wings this area remains one of significant risk potential. Much of the solution to any pitchup problem will undoubtedly take the form of control system modification. It may, however, prove necessary to directly tailor the aerodynamic design of the wing to achieve satisfactory pitch characteristics. To do this may require that additional wings be tested in conventional transonic and low speed tunnels and the final result be validated by high Reynolds number testing in the NTF. Costs for this type of program would be similar to the unit costs of the testing used to develop the airfoil and high lift technology. Contingency costs for this program will be:

Engineering and Computational:	\$3,672,500	
Model Fabrication:	1,200,000	
Testing:	2,200,000	
Total	\$ 7,072,500	1982 to 1986

5.3.3.5 Full scale demonstrator vehicle program: If it is deemed necessary to proceed with a demonstrator vehicle program to resolve uncertainties related to manufacturing tolerances, surface quality, flight distortion, leading edge high lift device gaps, etc. the following costs will be realized:

Engineering and Computing	\$ 40,300,000	
Vehicle Fabrication	10,000,000	
Testing (part 1980)	0	
Total	\$ 50,300,000	1982 to 1986

This cost is assumed to be a contingency for the purpose of cost analysis.

5.3.4 <u>Plans and costs summary</u>. - The series of charts, figures 51 through 57, show the time-phase blending of the wind tunnel tests and associated 1980 dollars required to meet the 1986 aerodynamic technology readiness date. The high speed development program including the flight Reynolds number NTF testing will cost, in 1980 dollars, \$10,607,500 for the five year period of 1982 through 1986. The breakdown in costs between wind tunnel, engineers, and computers is shown on figure 51. This development program will reach a

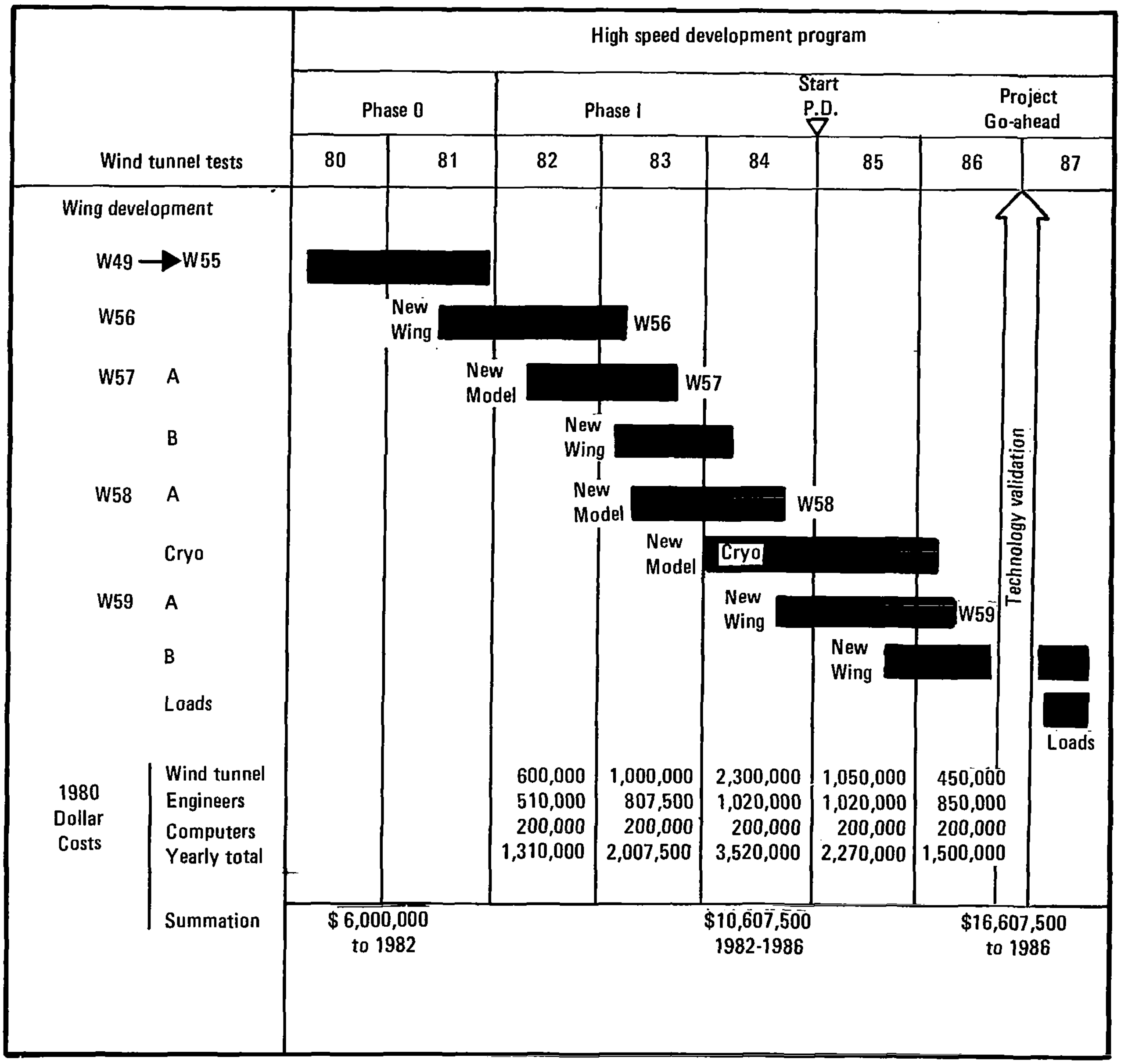


Figure 51. - Advanced aerodynamic technology high speed development program, wind tunnel tests.

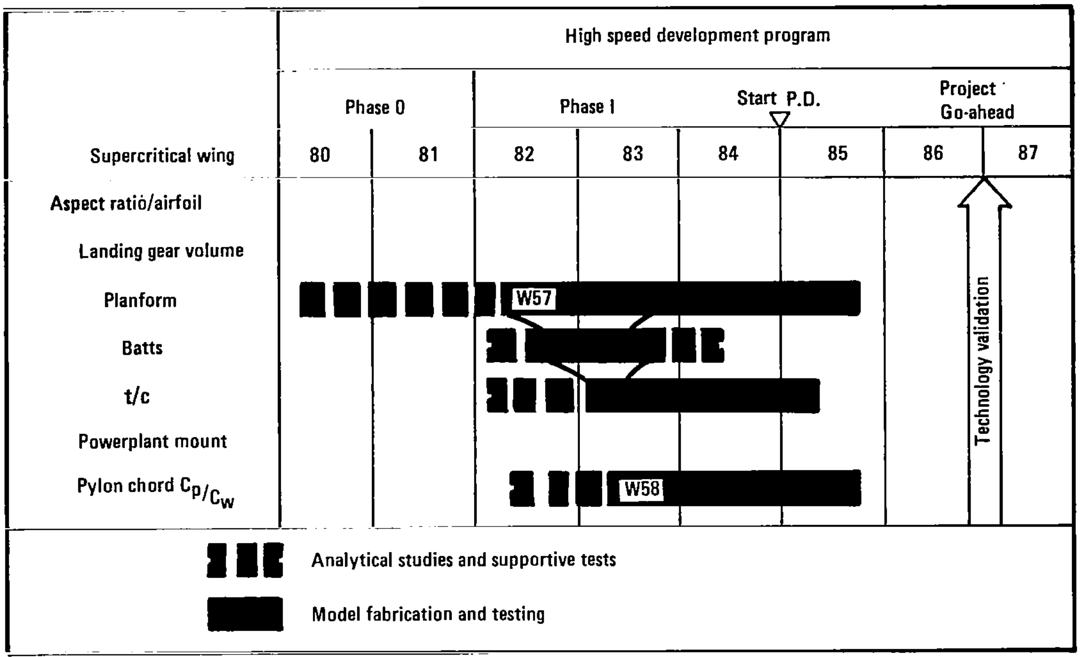


Figure 52. - Advanced aerodynamic technology high speed development program, supercritical wing - aspect ratio/airfoil.

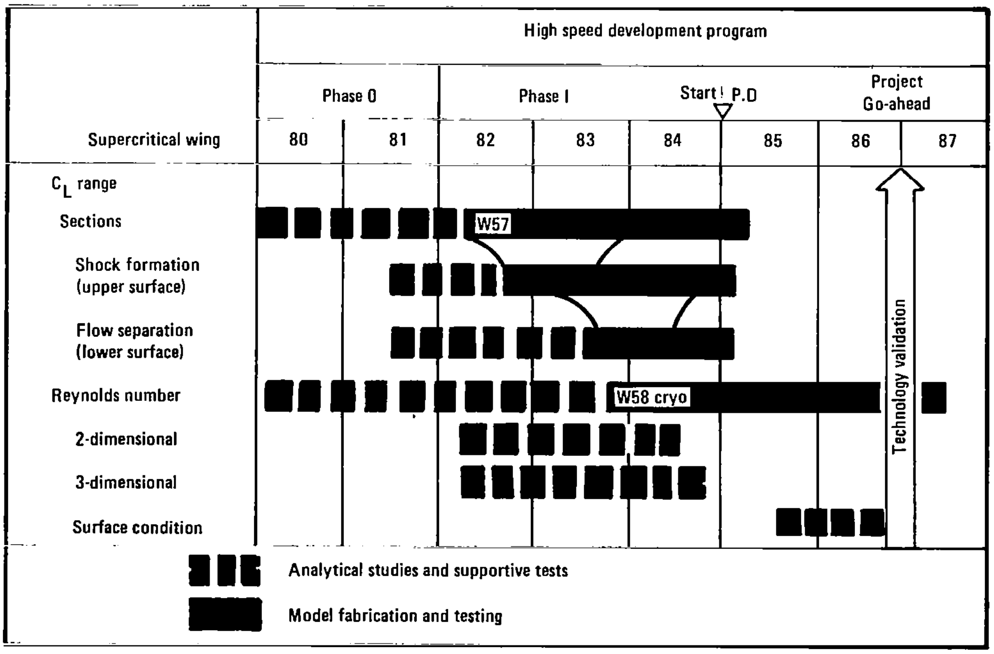


Figure 53. - Advanced aerodynamic technology high speed development program, supercritical wing - C_L range.

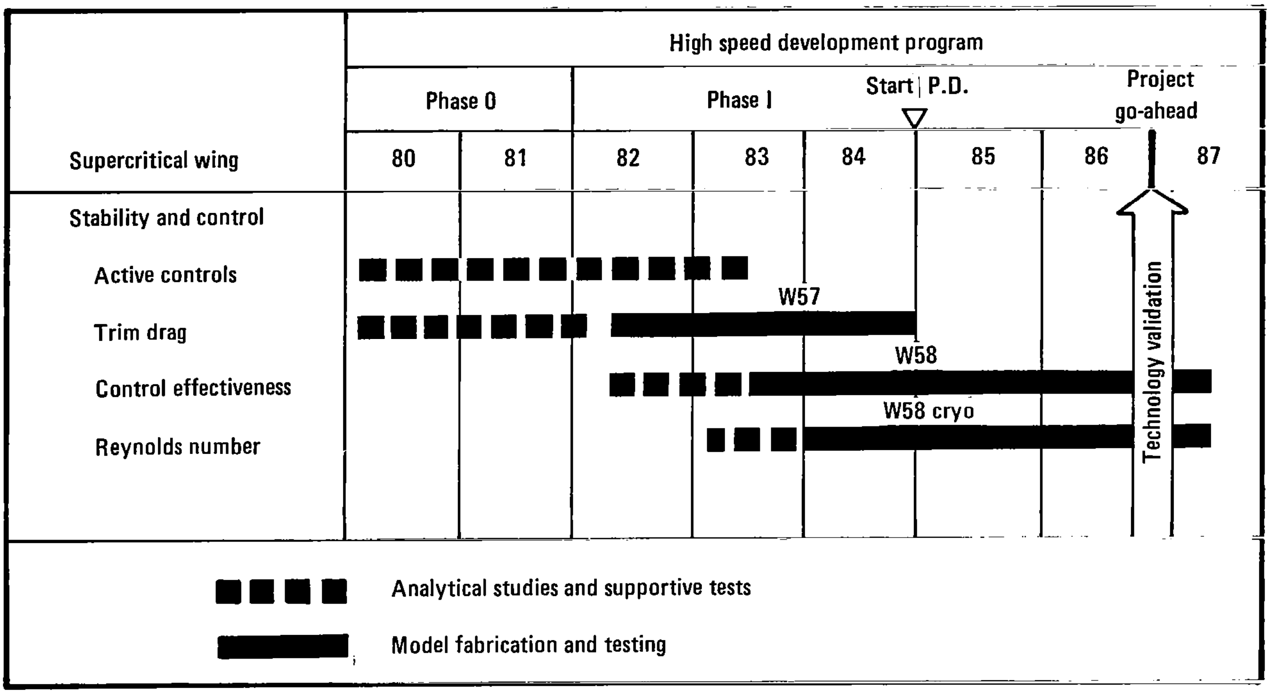


Figure 54. - Advanced aerodynamic technology high speed development program, supercritical wing - stability and control.

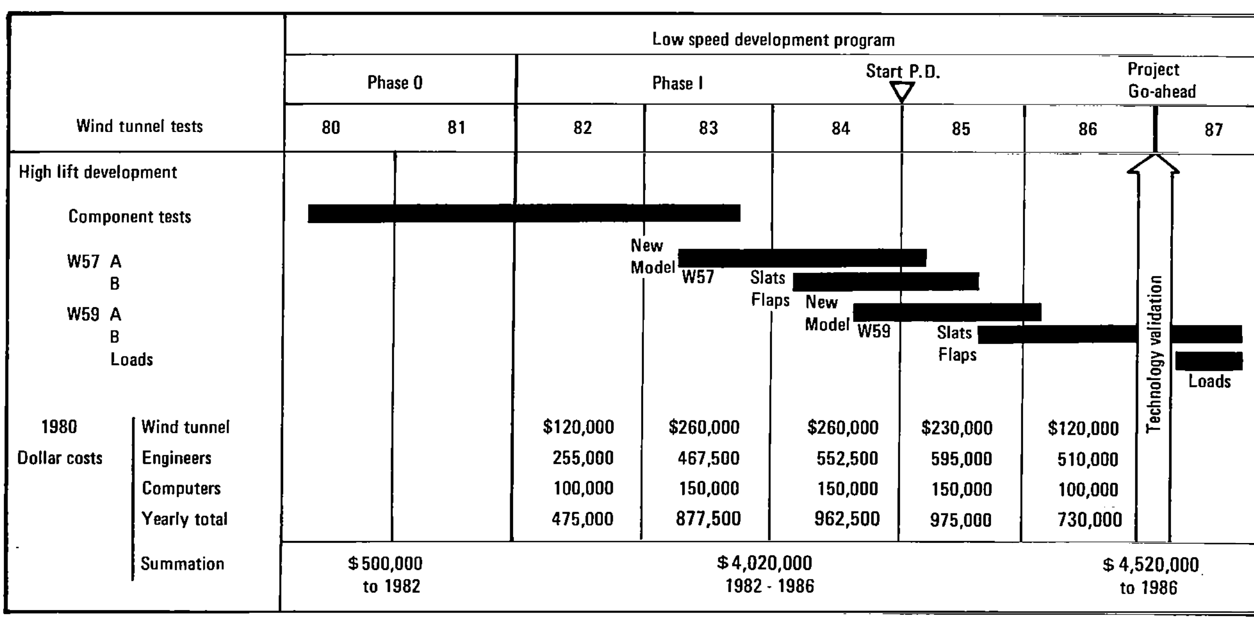


Figure 55. - Advanced aerodynamic technology low speed development program, wind tunnel tests.

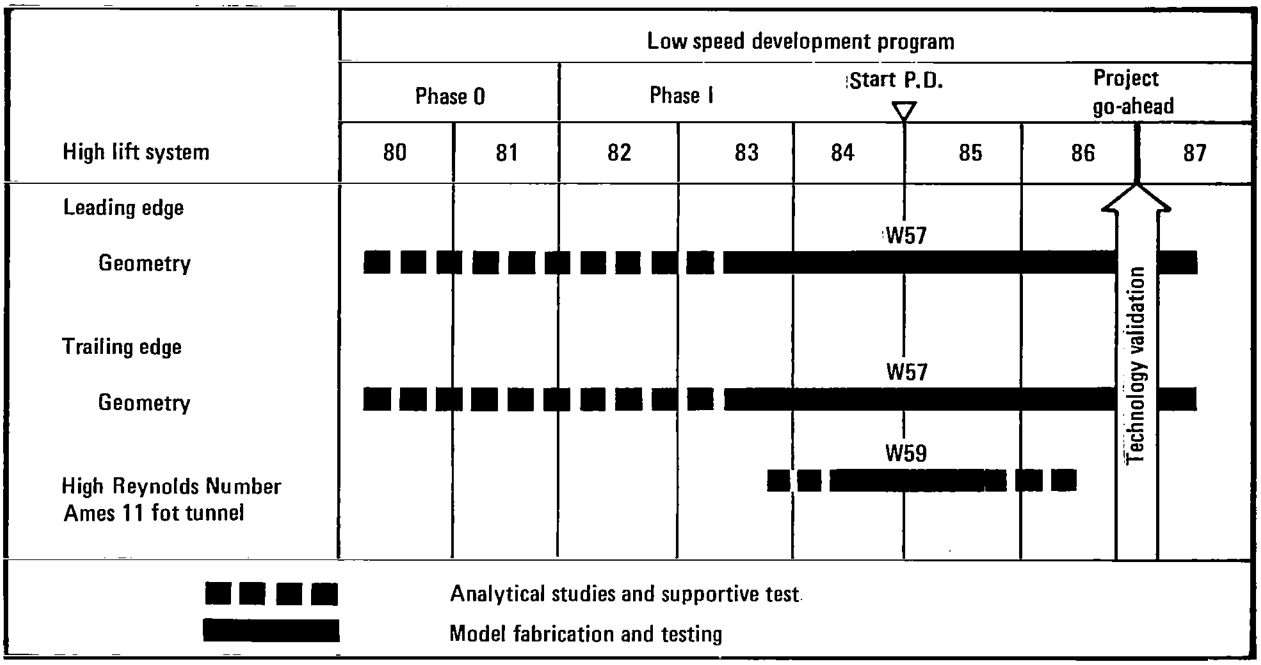


Figure 56. - Advanced aerodynamic technology low speed development program, high lift system.

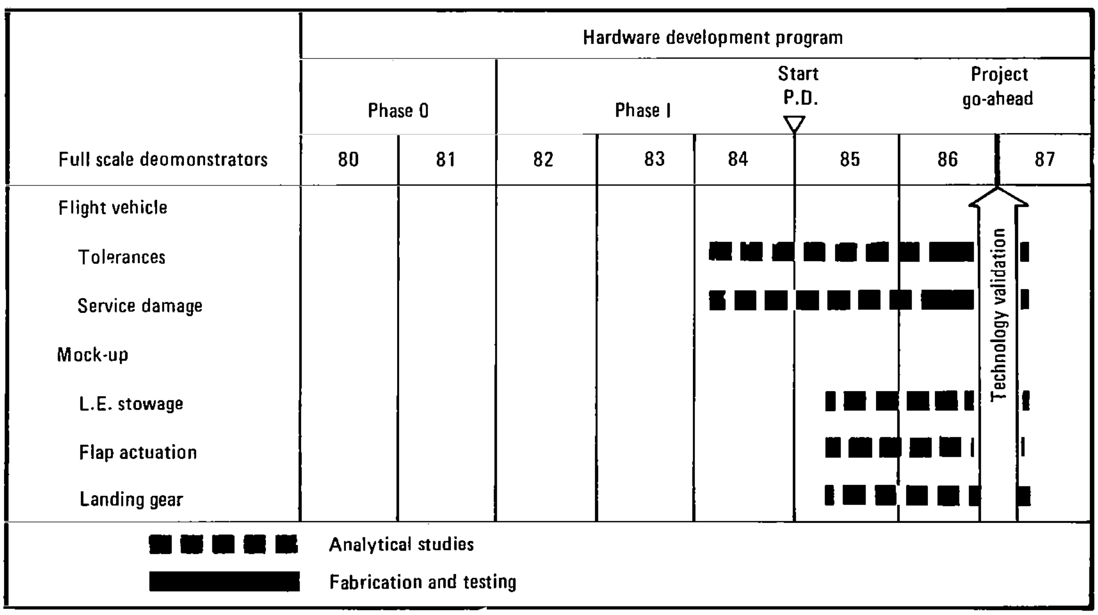


Figure 57. - Advanced aerodynamic technology hardware development program.

peak manloading of 12 man-years in 1984 and 1985 with a total program involvement of 49.5 man-years as tabulated on figure 58. Including pre-1982 costs the high speed development program will cost $16,607,500. The cost requirement probability is 100 percent, i.e., the costs are absolutely required for basic advanced supercritical wing technology development.

The phasing of the tasks required to reach a technology readiness status in the cruise or transonic flight regime is shown on figures 52, 53, and 54. The inter-relationship of the required tasks is inseparable; W57 for example, will be used for planform studies, thickness effects, cruise C_L variation and trim drag evaluation.

The total low speed development program, including pre-1982 work will cost in excess of $4,500,000 to obtain technical readiness in the 1986 time period. The cost breakdown by years and time-phasing of the low speed wind tunnel program is shown on figure 55. Time-phasing of the major tasks is shown on figure 56. The low speed or high lift development will require 28 man-years of effort with peak requirement of 7 man-years in 1985 as tabulated on figure 58.

Full scale mock-up demonstrators will be required by the project to solve hardware related problems. Major aerodynamically related mock-up items are shown on figure 57 for continuity purposes but the associated costs are not included in this report. However, the cost of a flight vehicle demonstrator is included with a probability cost index of 25 percent. If required, planning for the flight vehicle would commence in 1983 with first flight in 1986. This schedule is shown on figure 57 with a total man-loading requirement of 472 man-years, figure 58. The cost of a flight demonstrator would be $50,000,000 for rewinging a Jetstar or similar aircraft with an advanced supercritical wing.

Cost spread summaries depicted on figures 59 and 60 show a cumulative expenditure of $14,627,500 from 1982 through 1986 with a 100 percent cost index probability. The peak expenditure would be in 1984 just prior to the preliminary design phase of the development program. Figure 60 includes two major contingency costs: (1) additional flying qualities development, 50 percent cost probabilities, $7,000,000 and 24 man-years and (2) rewinged Jetstar vehicle demonstrator, 25 percent cost probabilities, $50,000,000 and 472 man-years.

The 1986 aerodynamic technical readiness costs and benefits are summarized on figure 61 as a 14 percent M(L/D) improvement at a cost of $21,127,500, including pre-1982 development work.

	Future manpower requirements, engineering Manyears								
	Phase 0		Phase I		Start P.D.		Project go-ahead		
Technology task	80	81	82	83	84	85	86		
Transonic wing			6	9.5	12	12	10	Technology validation	49.5
High lift			3	5.5	6.5	7	6		28.0
Contingencies					Required manyears				77.5
Flying qualities			3	4	5	6	6		24
Demonstrators			0	12	40	210	210		472
					Required + contingencies Manyears				573.5

Figure 58. - Advanced aerodynamic technology future manpower requirements, engineering.

5.4 Risks

5.4.1 High aspect ratios. - Technical difficulties associated with high aspect ratios are primarily in the structural and aeroelastic technologies. In particular, an area of uncertainty is the relationship between wing weight and aspect ratio for values of aspect ratio above 10. Although there are no specific technical difficulties which can be defined, there is divergence of opinion in the industry as to the weight penalties to provide a wing which will not flutter. Also, secondary effects become significant as aspect ratio is increased beyond 10. Among the secondary major problems to solve are landing gear placement and integration of power plant mountings on to the wing. In both cases the reduction of the wing chord and possible reduction of spar depth present problems. Wing/pylon intersections may have to extend over the full chord of the wing, possibly causing interference drag problems which at present can only be resolved by extensive wind tunnel work. No significant problems with gate restrictions are expected. The reduction in gross weight resulting from the application of advanced technologies, plus higher wing loading, means that the wing span of the advanced configuration is only 2.6m (8.6 ft) greater than the span of the Boeing 747.

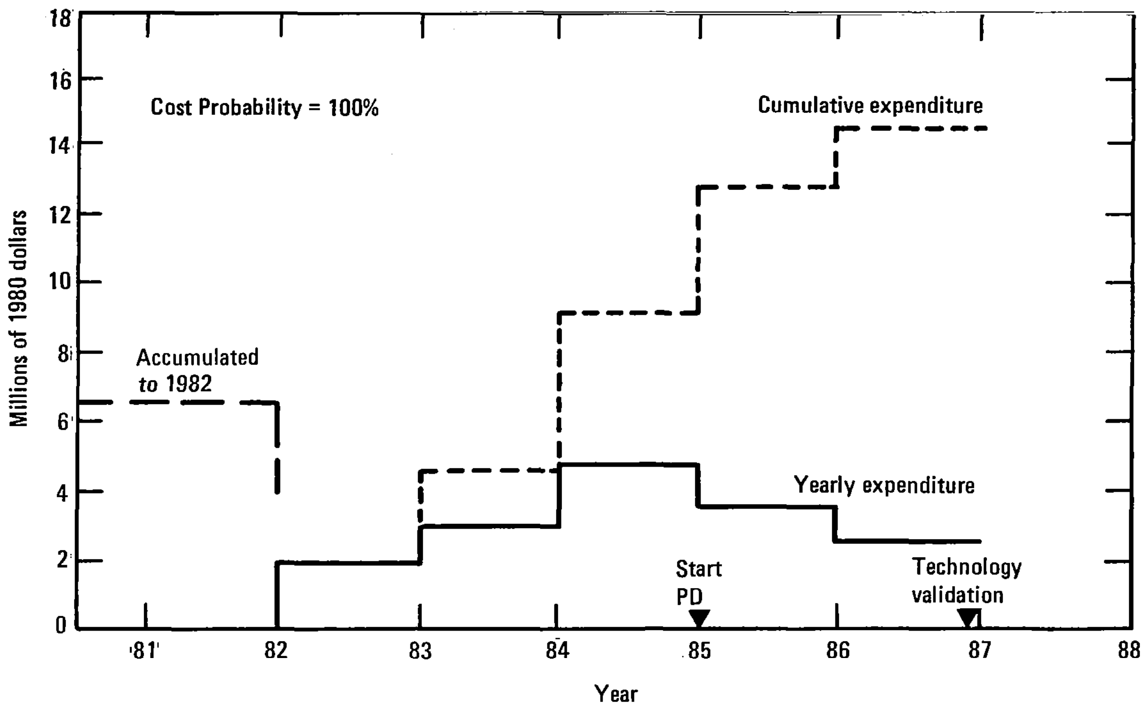


Figure 59. - Advanced aerodynamic technology cost summary.

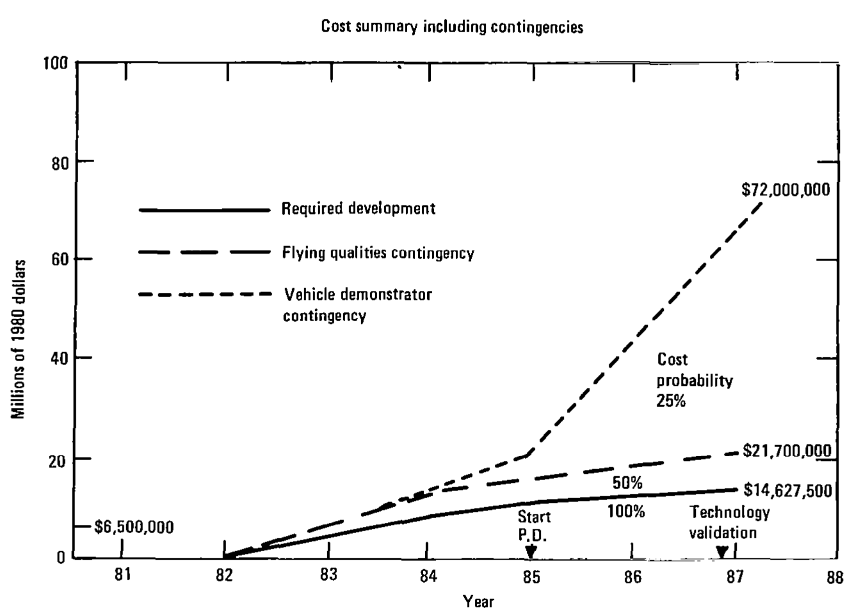


Figure 60. - Advanced aerodynamic technology cost summary including contingencies.

Technology application	Tech dev cost	$\Delta \frac{L}{D}$
Transonic wing planform	Conventional transonic $ 12.6 M High Re $ 2.0 M Flying qualities $ 7.1 M	up to 20%
High lift planform	$ 4.5 M	–
Aerodynamics	$28.2M	up to 20%

Figure 61. - Summary of technology costs and benefits.

The aerodynamic uncertainty associated with high aspect ratios is primarily in the area of secondary effects. While there is little doubt that high aspect ratios will decrease induced drag there are several effects which come about as a result of increased aspect ratio which may exact a parasite drag penalty and certainly require closer examination.

There is some risk inherent in the interaction between aspect ratio and lift coefficient for best L/D. As aspect ratio increases the lift coefficient for best L/D also increases. To achieve these higher cruise lift coefficients, the wing loading of the airplane must be increased. While this will not have a direct adverse affect on cruise performance, increased wing loading will increase the performance requirements for the high lift system to meet approach and landing constraints. Higher wing loadings and cruise lift coefficients may also have a deleterious effect upon drag rise. As lift coefficient increases, the drag divergence Mach number of an airfoil tends to decrease. To take full advantage of the drag benefits offered by increased aspect ratio, airfoils will have to be optimized at higher than currently used lift coefficients. Considerable progress has already been made in this area but the tradeoff between thickness and aspect ratio will require additional study to define the most efficient configuration. It should be noted that the potential benefits of high aspect ratios are large even if the design is forced to fly at a lift coefficient other than optimum. The wing design "roadmap" shown in figure 49, Section 5.3.1.1, shows the approach being followed by Lockheed to resolve this question. A series of wings will be designed at a variety of aspect ratios, thicknesses, sweeps, design lift coefficients, and design Mach numbers. Each of these wings will provide additions to the PERTDRAG database and the data thus gathered will be used by ASSET to refine the optimum configuration as the mission and technological maturity of the design change. This step by step development will permit the designer to track the progress of demonstrated technology towards the 1986 goal.

Another secondary aerodynamic effect of increased aspect ratio is the reduction of local wing chord Reynolds number at which the wing will fly. This may have adverse effects on boundary layer separation and skin friction drag of the wing. Flight scale Reynolds number testing is required to evaluate fully this type of effect. There has been some indication in the wind tunnel that supercritical wings may be more Reynolds number sensitive than conventional wings. The location of the laminar to turbulent boundary layer transition in particular has a large effect on wing performance in low Reynolds number tests. It is not anticipated that these Reynolds number effects will prove to be a serious problem; however, high Reynolds number testing is essential in order to achieve a high confidence level in wing performance prior to a production go-ahead.

5.4.2 Landing gear integration. - The reduction of the wing root chord presents a serious problem for the landing gear designer if the current type of gear placement and design is to be retained. Since the root chord is smaller, the gear must be placed at a more aft x/c position to prevent tip-up. This effect is accentuated by the more aft placement of the gear required by the aft cg location envisioned for relaxed stability active control airplanes. In addition, with the limited space available to house the gear, the aft spar must be made very heavy to take landing loads. The geometric changes which must be made to house the gear in the wing may induce unacceptable aerodynamic penalties.

Solution of the airframe/landing gear integration problem may require a combination of the following:

- Use of batts or similar planform alterations
- Design of wing root sections with gear constraints
- Redesign of the placement and structure of the landing gear itself

Investigation of the first of these indicates the addition of a batt to a wing adversely impacts the wave drag chacteristics of the wing and requires the sweep of the wing to be increased. This will in turn exact a structural weight penalty. Wing leading edge gloves can help alleviate the unsweeping effect of the batt and add root depth to the wing. If the gear is to be housed in the wing and retracted into the fuselage in the conventional manner, a wing will have to be developed which incorporates some combination of batt and glove in order to give an acceptable combination of gear housing, wing weight, and wave drag characteristics.

Secondly, it may be possible to alleviate the gear mounting problem by developing wing root sections with unusually large thicknesses in the aft portions of the airfoil. Such a section would have a large aft spar depth and more room for gear housing than currently envisioned airfoils. It has not been determined whether this is a viable approach or whether a section of the type suggested would have acceptable aerodynamic characteristics. A combination of theoretical and wind tunnel testing will be required to evaluate this approach.

A third solution to the landing gear problem may be the use of an unconventional landing gear design to relax the constraints imposed upon the wing design by the landing gear installation. Although this is an area which must be evaluated primarily by disciplines other than aerodynamics, the integration of the wing and any new landing gear installation will require the coordination attention of both aerodynamicists and designers.

The landing gear placement problem will require extensive study to produce a viable configuration that integrates acceptable landing gear design, airport performance, and cruise performance. A preliminary quantitive assessment of landing gear design and placement options is given in Section 9.4.

5.4.3 Airfoil/wing aerodynamic design. -

5.4.3.1 Aerodynamic limits: It is conceivable that some physical limit will be reached before the drag rise characteristics predicted for 1986 technology are achieved. The pressure distribution on the airfoil is constrained by two phenomena, shock formation and flow separation, which limit the amount of lift which can be developed by the wing before unacceptable drag rise or buffet appears. It may be difficult to achieve the lift coefficients and Mach numbers envisioned without encountering one or both of these constraints. It is unlikely that the level of cruise performance envisioned for 1986 will prove to be impossible to attain. It is far more likely that problems of wing sensitivity to surface roughness and narrow usable C_L range will have to be overcome. As the combination of thickness, design lift coefficient and design Mach number increase, the airfoil tends to become more sensitive to off-design conditions. The large cambers required to develop high lift coefficients while maintaining shock free flow in transonic flight tend to make lower surface design more critical, particularly at low off-design lift coefficients. The range of C_L below the design point at which the lower surface flow remains well behaved decrease steadily with increasing camber and thickness. At present, airfoils are designed to have subcritical flow over the entire lower surface, but it may prove desirable in the future to develop sections which exhibit supercritical shock free flow on both the upper and lower surfaces of the wing.

Just as lower surface flow constraints tend to become critical at sub-design lift coefficients, upper surface flow constraints become critical at C_L values above the design point. As C_L increases above the design point the Mach number of the flow over the wing upper surface increases and shock formation occurs. It is necessary to design a wing which will have a sufficiently large band of low drag lift coefficients to allow for variations in aircraft loading and cruise altitude and to prevent turbulence induced drag rise from becoming a problem. To achieve these goals it may be necessary to resort to some form of variable geometry airfoil if a rigid section cannot deliver an acceptable combination of drag rise and useable C_L. Theoretical and experimental research is required to evaluate and extend the limits of airfoil performance.

5.4.3.2 Scale effects: Supercritical airfoils display a greater sensitivity to surface irregularities and Reynolds number than earlier technology sections. Small surface imperfections or gaps may cause the shock to form early, increasing the drag of the wing and lowering the drag divergence Mach number. Boundary layer transition location changes have caused large changes in measured performance in wind tunnel tests. The amount of aerodynamic data available for supercritical sections at flight scale Reynolds number is small. Preliminary results of two-dimensional airfoil testing in the NASA-Langley 0.3 meter cryogenic facility are encouraging but more flight Reynolds number testing, particularly of three-dimensional configurations is necessary. Model testing at a high Reynolds number cryogenic facility such as the Langley NTF will be required in order to produce the desired confidence level for supercritical airfoil technology. While this type of testing is considerably more expensive than conventional low Reynolds number testing, it is important to have a good database for the design of a full scale wing at flight Reynolds number. However, some questions may be resolvable only by flight testing. It is exceedingly difficult to model flap gaps, rivets, oilcanning of the skin and similar irregularities in the scale commonly employed for wind tunnel models.

In addition to the drag level,the stability and control characteristics of supercritical wings must be investigated. This is an area in which the Reynolds number sensitivity of the advanced supercritical wing will make flight scale Reynolds number essential to achieve a high level of confidence that an advanced supercritical wing will exhibit acceptable flying qualities.

5.4.3.3 Manufacturing considerations: The commercial viability of advanced supercritical airfoil technology also hinges on the manufacturability of the supercritical wing. The increased sensitivity of supercritical flow to perturbations will have an adverse impact upon the manufacturability and in service performance of aircraft using supercritical wings. This is one of the major area of technological risk for the advanced airfoil technology. The ability of the supercritical wing to be manufactured and perform well has not yet been well established. This is an area of particular concern when considering a program go ahead decision. Although there is little doubt that an advanced supercritical wing will perform better than a conventional wing even in the presence of surface irregularities, it is vital to know what level of in service performance can be obtained before making performance guarantees.

Manufacturing techniques and tolerances must be evaluated. The use of composite wing construction will allow much smoother surfaces to be produced and this may prove to be necessary to achieve the predicted performance of the advanced supercritical wing. It is in the area of manufacturability where a high level of technological risk lies. The vast majority of supercritical wing tests to date have been at wind tunnel scale and Reynolds numbers. All have been smooth models without systems integrated into them. Of particular importance is the tolerance of supercritical wings to minor in service damage and surface maintainance. It is essential to know what effect long-term surface degradation, dirt, icing and similar unintended but inevitable changes in the wing contour will have on the drag characteristics of the wing. The effect of structural deflections and skin distortion due to flight loads are of particular importance since these are inevitable even if the manufacturing process allows a very smooth wing to be built. This is one area in which a demonstrator vehicle program may prove to be the most effective and accurate way to attack properly the in service problems mentioned.

The stowage of a high lift system into supercritical wings has been demonstrated to be feasible. There has been considerable wind tunnel work done on the performance of high lift systems on supercritical wings and the results indicate that good high lift performance and $C_{L_{MAX}}$ values can be achieved. The supercritical wing may be superior to the current technology wing with respect to its performance with the high lift system deployed. What remains to be evaluated is the effect of the stowed high lift system on the cruise drag of the wing. Gaps and irregularities caused by the flaps and leading edge devices may be sufficient to induce shocking in the flow over a supercritical wing. Although this problem can almost certainly be overcome by the design of tighter fitting leading edge and trailing edge flaps, and better fairings and doors, the need for meticulous design may adversely impact the cost and maintainability of the resultant aircraft.

5.4.3.4 Nonlinear aerodynamics: On an airfoil exhibiting a rooftop type of pressure distribution such as that used by advanced supercritical sections, the position of the shock is much less stable than it is on a conventional section. Relatively small changes in angle of attack could conceivably cause relatively large changes in shock location and, consequently, wing lift. This shock oscillation could provide a powerful aerodynamic force contribution to an aeroelastic instability.

Another problem which must be addressed when designing a supercritical wing is the distinct possiblity that the effects of control surfaces may be highly nonlinear. Most supercritical sections exhibit adverse pressure gradients over the aft portion of the airfoil raising the possibility that aileron nonlinearity or even reversal could result. The shock instability discussed in the previous paragraph and the general sensitivity of supercritical flow to perturbations could lead to similar nonlinearities in the effectiveness of spoilers and similar surfaces. Considerable effort must be expended to develop a control system which will provide acceptable controlability and flying qualities for the advanced wing aircraft with supercritical wing technology.

6. ADVANCED AIRCRAFT SYSTEMS

6.1 Benefits

Early in the study it was decided to organize advanced technology systems into two groups for integration into the advanced wing: one with a focus on active controls, and the other contributing to the "all-electric airplane." The technologies selected for each group are listed here:

Active Controls	Advanced System & Controls
Relaxed Static Stability	Starter-Generator System
Fly-By-Wire	Solid State Power Controllers
MUX for Flight Control	Power Distribution
Cg Management	Fly-By-Wire
	Advanced ECS
	Electric Deicing
	Motor/Controller
	EMAS

6.1.1 Active controls. - Active controls technologies (ACT) are aircraft flight control systems technologies which can provide benefits of structural weight saving, reduced fuel consumption, or expanded operating envelope. An ACT system can be described as a system of control surfaces activated by computers. The ACT computer software enables the processing of sensor output information regarding aircraft states and control surface movements. The control surfaces are then commanded to counter adverse loading of aircraft structure, or to counter adverse aircraft attitude changes due to instability. There are several ACT concepts available for aircraft, three of which are currently being used on the L-1011-500 for revenue service. These concepts, maneuver load control (MLC), elastic mode suppression (EMS), and gust alleviation (GA) are considered conventional ACT technologies, and are discussed in the reference systems section of this report, section 4.3.4.5.

Flutter suppression was not included in the active controls group. Flutter is a vibration of lifting or control surfaces caused by oscillatory aerodynamic loads. It may be divergent and destructive within a few cycles and is controlled by structural stiffness and/or viscous damping. The problem increases with speed because of the increasing aerodynamic forces, and there is usually a threshold speed for flutter design. It has been proposed that flutter could also be controlled by proper control surface inputs, thus reducing the structural weight required for stiffness. Such a solution would require far higher frequency response than in present control systems and also would require more analytical knowhow than is presently available. Flutter suppression is therefore not included for active controls in this study since that technology will not be validated by 1986.

An ACT which is being vigorously pursued by Lockheed is relaxed static stability (RSS). RSS was chosen to be the focal point technology for active controls. Other technologies defined for this configuration are a pitch active control system (PACS), cg management, fly-by-wire (FBW), and multiplexing (MUX) for flight controls.

6.1.1.1 RSS/pitch active control system: To relax the static stability of an airplane means to reduce its static margin by shifting the cg to a more aft than normal location (see figure 62). RSS serves to reduce the aircraft drag due to trim, resulting in improved fuel economy.

Application of RSS to an airplane with a supercritical airfoil wing, yields a higher drag reduction benefit than if applied to an airplane with a conventional airfoil wing. Figure 63 shows the difference in range factor between a current technology wing (L-1011 type) and an advanced wing (supercritical). The curves, which were made from recent wind tunnel data, indicate a 15 percent range factor benefit for the advanced wing. The comparison is made for cg locations which produce zero loading of the horizontal tail, or a "tail off" balancing condition. The benefit of drag reduction is relected in terms of range factor, M(L/D), the product of Mach number and lift-to-drag ratio.

In figure 64, the cg's have been moved forward to cg range positions which provide for conventional balancing of the aircraft: a static margin of about 18 percent at the midpoint or "guarantee point" cg location. The aft limit of cg movement still provides for a positive static margin. The advanced wing shows a 13 percent benefit compared to the current wing when both are balanced conventionally. The reference cg position will be a point of departure for demonstrating the effect of RSS in the following charts. Figure 65 is the "current wing" curve for range factor benefit vs. cg location. It shows that by shifting the cg range aft, and thus relaxing the static stability, the most benefit obtainable for current wing technology is about two percent. This is the benefit expected for stability relaxed from a design cg of 25 percent to a new design cg of 32 percent. This aft movement of the reference cg also moves the cg range aft and defines new forward and aft limits. It should be noted that the "rebalanced aft" cg range limits still allow the airplane a positive static margin and a design point (average) margin of about 8 percent. Because the aft limit of this cg range is at the neutral point, full time avionic stability augmentation system (SAS) is needed to give the airplane desirable flying qualities. It is this degree of RSS that is proposed for the active controls aircraft (configuration 5). Figure 66 shows the benefit obtainable for an airplane configured with the advanced wing featuring supercritical airfoil technology. This graph shows that a greater amount of range factor benefit, 4%, is obtainable by shifting the cg back beyond the neutral point.

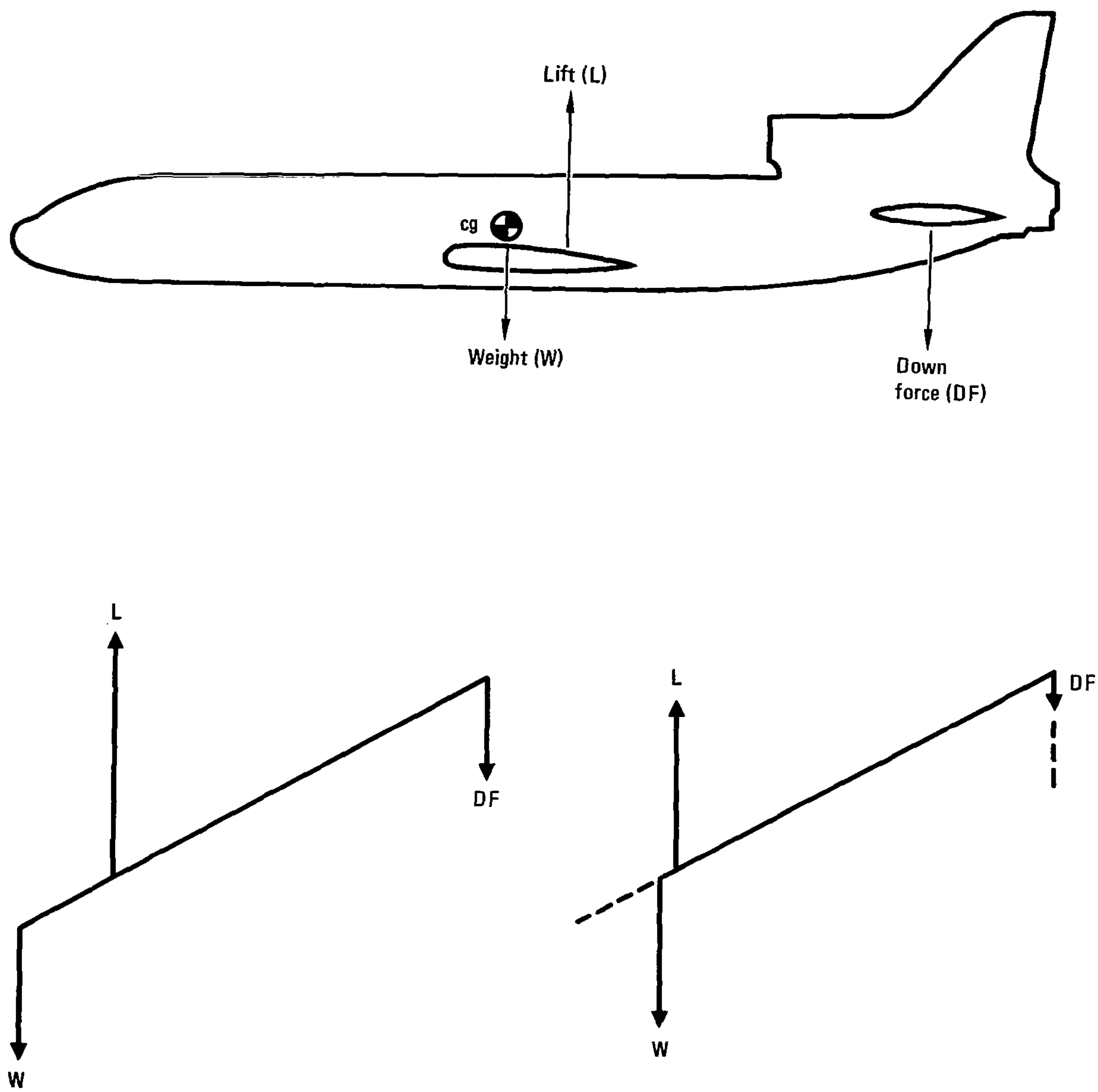


Figure 62. - Relaxed static stability.

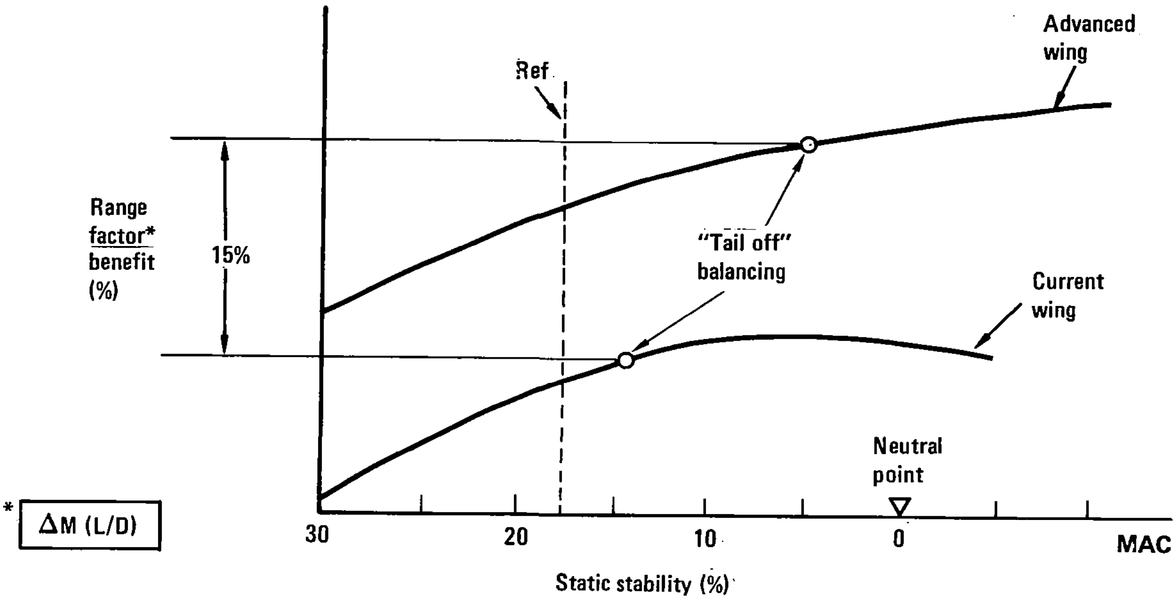


Figure 63. - Advanced wing benefit.

The benefit of RSS as shown in figure 65 for the current wing, will be assessed in ASSET for configuration 5, and the advanced wing benefit of figure 66 will be assessed for configurations 14, 15 and 16 (refer to figure 4).

The most practical mechanization for the PACS is a digital FBW system. To take advantage of minimum trim drag, the aircraft with the advanced wing must be approximately 6-10 percent unstable whereas the maximum a pilot can handle, even for a short time, is around 3 or 4 percent unstable. Thus the pitch CAS must be flight-critical. Since it is critical, any kind of mechanical input primary flight control system for backup in the event of CAS failure would be useless; hence FBW technology is a natural companion for a full authority CAS.

Figure 67 is a functional block diagram of the active controls flight control system for the pitch axis of the advanced configuration. It includes a side-arm controller for pilot input, advanced sensors needed for input to the computer for PACS processing, a quad redundant digital Flight Control Computer (FCC) programmed for both FBW functions and PACS functions, and electro-hydraulic actuators to receive the shaped command signals and effect the required movement of the stabilizer.

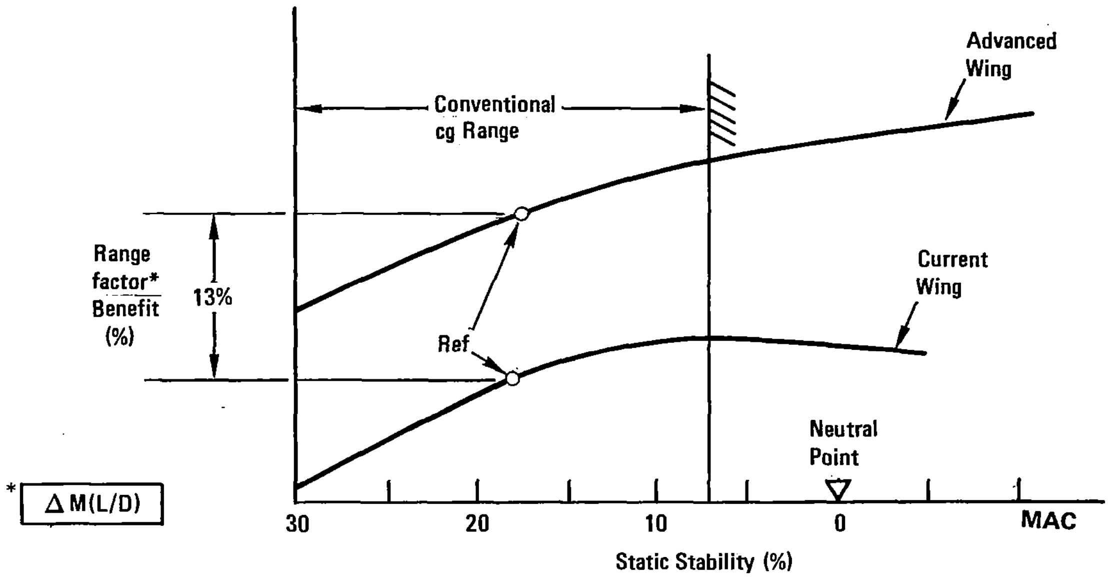


Figure 64. - Advanced wing benefit conventionally balanced.

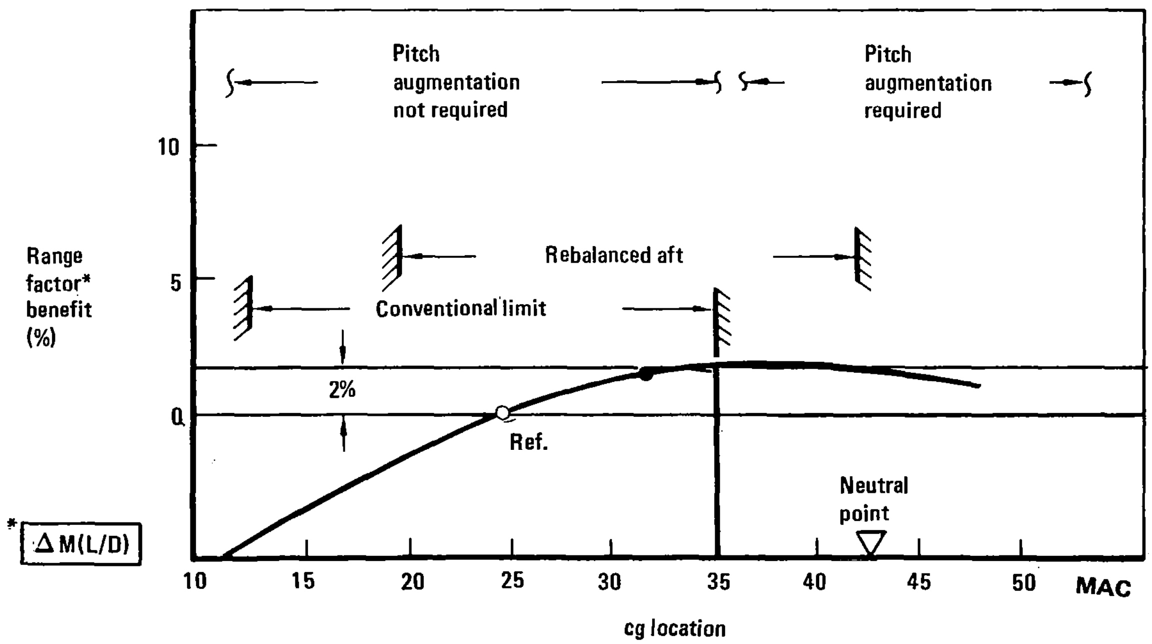


Figure 65. - Relaxed static stability, current wing (L-1011 wing geometry, no WLA).

Another benefit of RSS is that it allows the down-sizing of the horizontal stabilizer for reduced parasite drag. With stability and control in the pitch axis being augmented by PACS, tail volume can be reduced by decreasing the tail surface area. The tail volume coefficient has been reduced from 0.95 (reference aircraft) to 0.78. Analysis, wind tunnel tests, and flight testing has shown that a 2.6 percent fuel savings is possible due to an aft cg position and a 2.0 percent savings is possible from down-sizing the tail.

6.1.1.2 Fly-by-wire (FBW): The reference flight control system, taken from the L-1011 and typical of present-generation wide-body aircraft, uses 624 kg (1375 lb) of mechanical cables, rods, springs, etc., as the mechanical input and feedback portion of the primary flight control system. It includes sophisticated mechanisms to allow mixing and nonlinear proportional control of the various surfaces. These devices are eliminated in the FBW system.

Removing the mechanical FCS and replacing it with a FBW system using digital computers, and electrohydraulic secondary actuators which drive the hydraulic primary power actuators, will yield a weight savings of 426 kg (940 lb).

For the active controls configuration No. 5, with a conventional wing and moderate RSS (performance static margin of +8 percent), a mechanical system would be a useful back-up in the event of a full failure of the stabilization system, however, it was decided to remove it to obtain the weight savings and the benefit of reduced maintenance.

The use of electronics for flight critical controls is becoming more acceptable and advances in large-scale integration (LSI) of semiconductor circuitry has made large amounts of redundancy feasible. The resultant advances in system and software architecture could soon make it feasible to design electronic systems which are as reliable as the mechanical system and as immune to external hazards. A cautious approach will be required with extensive laboratory and flight testing, however. It must also be an evolutionary approach which does not give up the mechanical backup until full-time electronic flight controls have demonstrated reliability in millions of hours of commercial transport flight and until users are convinced that the electronics will not fail.

Reliability calculations of a projected electronic flight control system indicate that triple or quadruple redundancy is required to meet the necessary reliability for a full-time electronic FBW system. The triple system places severe requirements on on-line monitoring to provide the necessary fail-operational performance after two channel failures. It is considered then that a quadruple system such as shown in figure 68 provides the necessary redundancy in the achievable system, using a combination of built-in-test, on-line monitoring and parallel voting to isolate failures and continue operations. The four digital flight control computers each calculate control signals which are combined in the secondary actuators. Each computer shutdown, either manually or automatically as directed by the monitoring

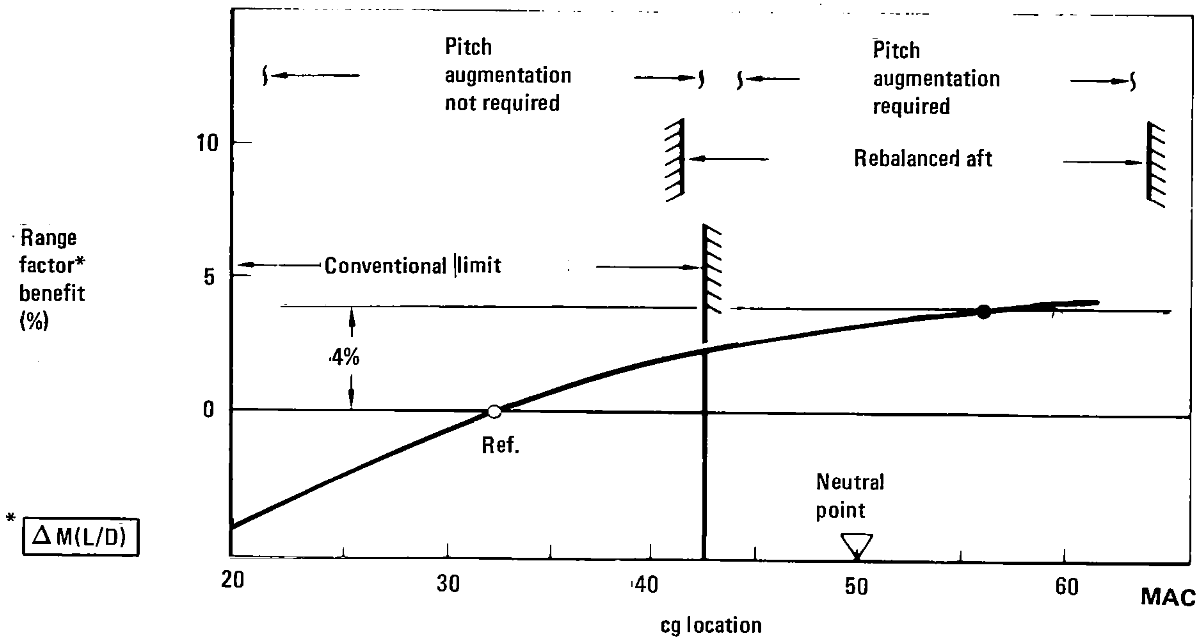


Figure 66. - Relaxed static stability advanced wing (L-1011 wing geometry, no WLA).

system, will not result in an actuator being deactivated. Each computer receives the signal from each of the others, rejects out-of-tolerance signals, and takes the median value as an output. Outputs of all computers are cross-strapped to all flight control actuators so that three of the four flight control computers can fail and still leave all flight control surfaces active.

A side arm controller is used instead of the conventional control column for command inputs. Packaging of the redundant elements and wire routing must be controlled to eliminate the possibility of common accidents disrupting the redundant functions. The probability of catastrophic failure of the flight control system is designed for less than 1×10^{-9} failures per flight.

The use of multichannel digital systems for a FBW application places great emphasis on the validity of the software. This concern has resulted in a) use of analog back-up channels to allow takeover in event of a software problem, or b) the use of dissimilar software programs in the individual channels of the digital system. Each of these techniques has significant drawbacks and much industry/government effort is being expended on validation and verification of software so that the above crutches can be eliminated.

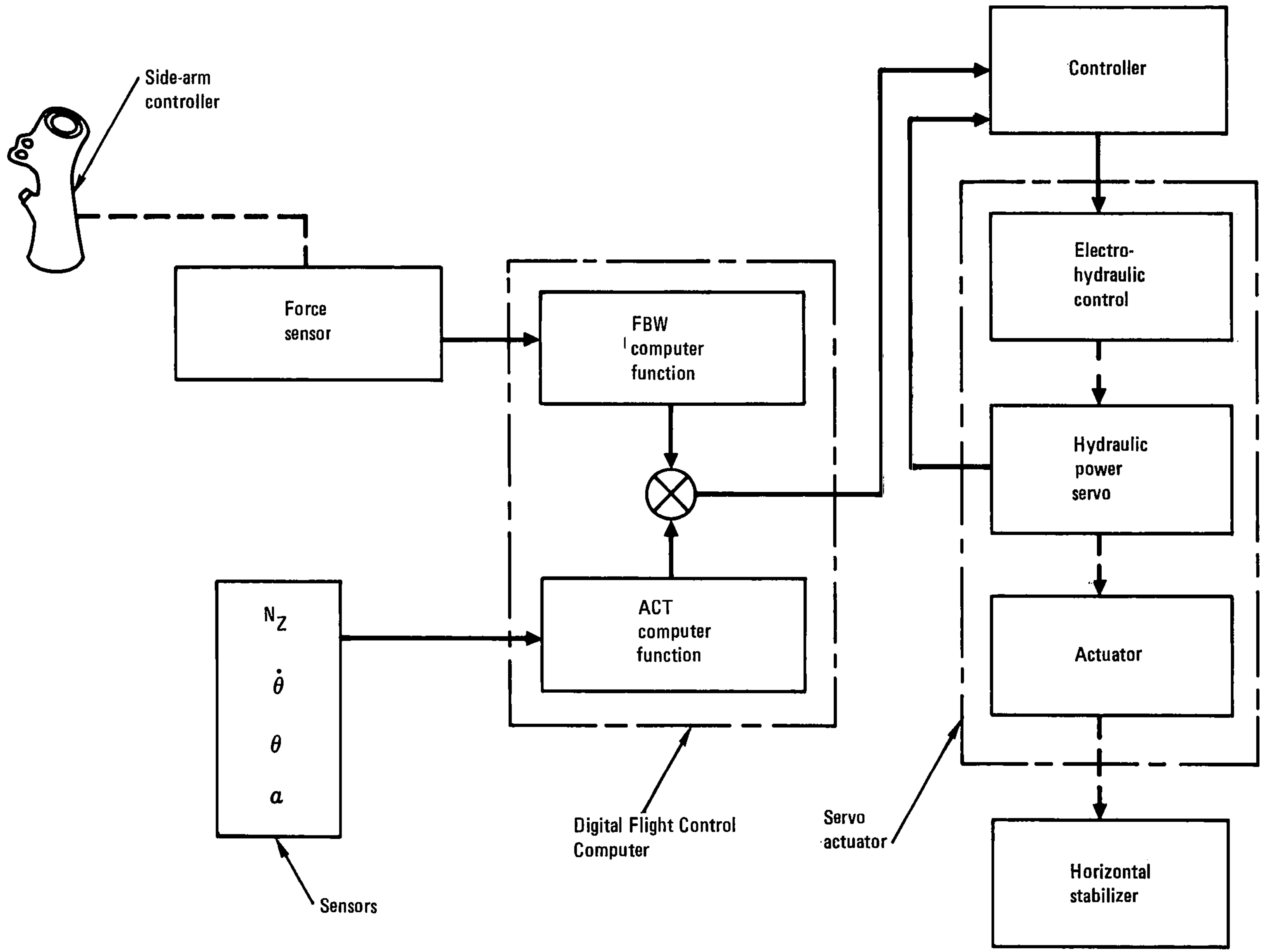


Figure 67. - Active controls flight control system - pitch axis.

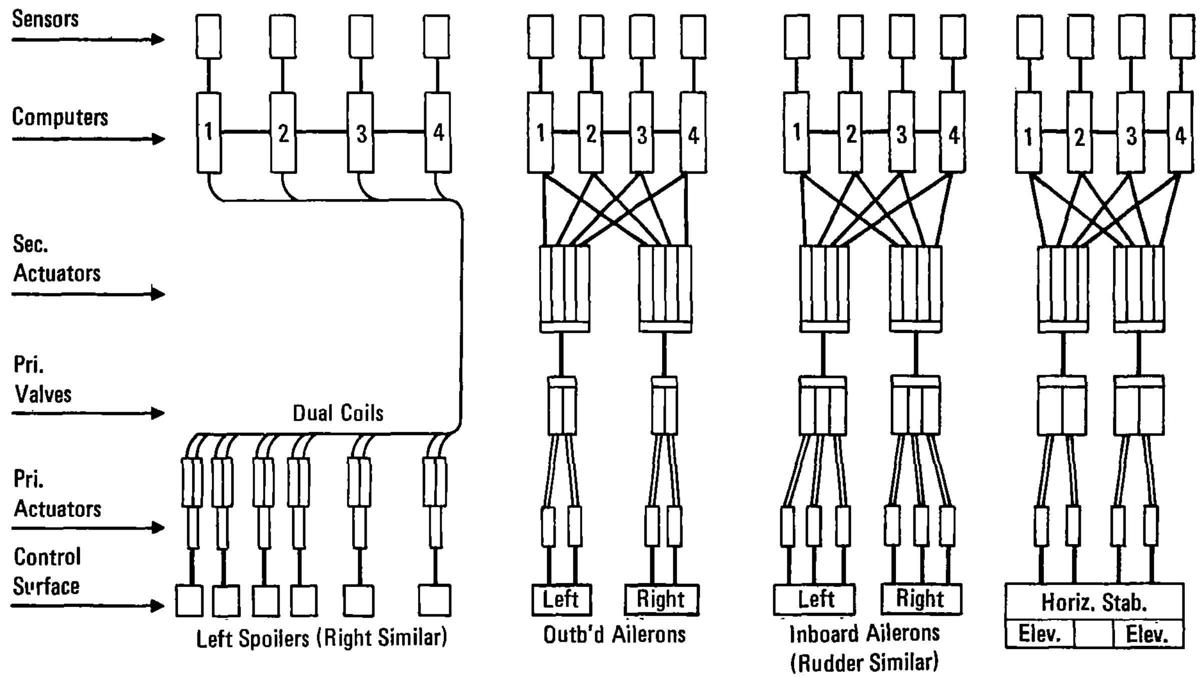


Figure 68. - Fly-by-wire diagram.

6.1.1.3 Multiplexing (MUX) for flight controls: The FBW commands could go to each actuator via multiple wires (for monitoring circuits, feedback circuits, and switching circuits in addition to the position commands) or multiple messages can be sent over one pair of wires. With MUX technology, the latter method can be used. MUX can be digital or analog, frequency or amplitude modulated, time shared or frequency multiplexed. There can be any number of wires (buses), shared in a variety of ways. Buses can be one-way or two-way. In each case, there must be a multiplex/demultiplex (MDM) function, that is, the input signal, whether it is analog or digital, must be put into proper format (code, signal level, time slot, identifying code, address, etc.) to go on the bus and be injected into the data stream. At the other end, the receiving equipment must identify the messages and put them in the proper format for use at the intended equipment. In full MUX, these MDM units would be put at each utilizing piece of equipment (actuator for example), whereas area MUX would put the MDM in an area to service a number of actuators. The full MUX takes full advantage of the wire reduction potential of MUX. Area MUX takes only partial advantage but eliminates some problems of packaging electronics for use in hostile environments. For the near term, area MUX will be used. Then, when electronics packaging is improved, the benefits of full MUX can be approached. Full MUX, as a technology for application to a commercial transport, could be proven by 1986 with determined development.

The benefit of using full MUX for this configuration is a weight payoff due to reduced wiring. MUX technology applied to the baseline flight control wiring system would not significantly impact the system weight, but changing the conventional flight control system (FCS) to a FBW flight control system approximately doubles the amount of wiring, and provides a good reason to apply MUX technology. An estimated 244 kg (538 lb) is saved by utilizing MUX.

A schematic of the MUX system for this configuration's FCS is depicted in figure 69. For this system there are 21 MDM units; nine within each wing and three in the tail. Each bus is a two-way, shielded, twisted pair of wires, designed for MIL 1553 digital transmission.

The transmission of data from sensors to the flight control computer (FCC) and from the FCC to actuator locations is by quad redundant multiplex buses.

Each channel is contained in a separate MDM box with heat conducted to the ribbed exterior and then cooled by natural convection. The flight control computers are provided with serial data exchange buses so that the four computers can interchange input, output and status signals.

An inherent benefit of MUX is that changes in signal content and flow can be made through modification of the software at the sending and receiving units without the necessity to make major aircraft wiring modifications.

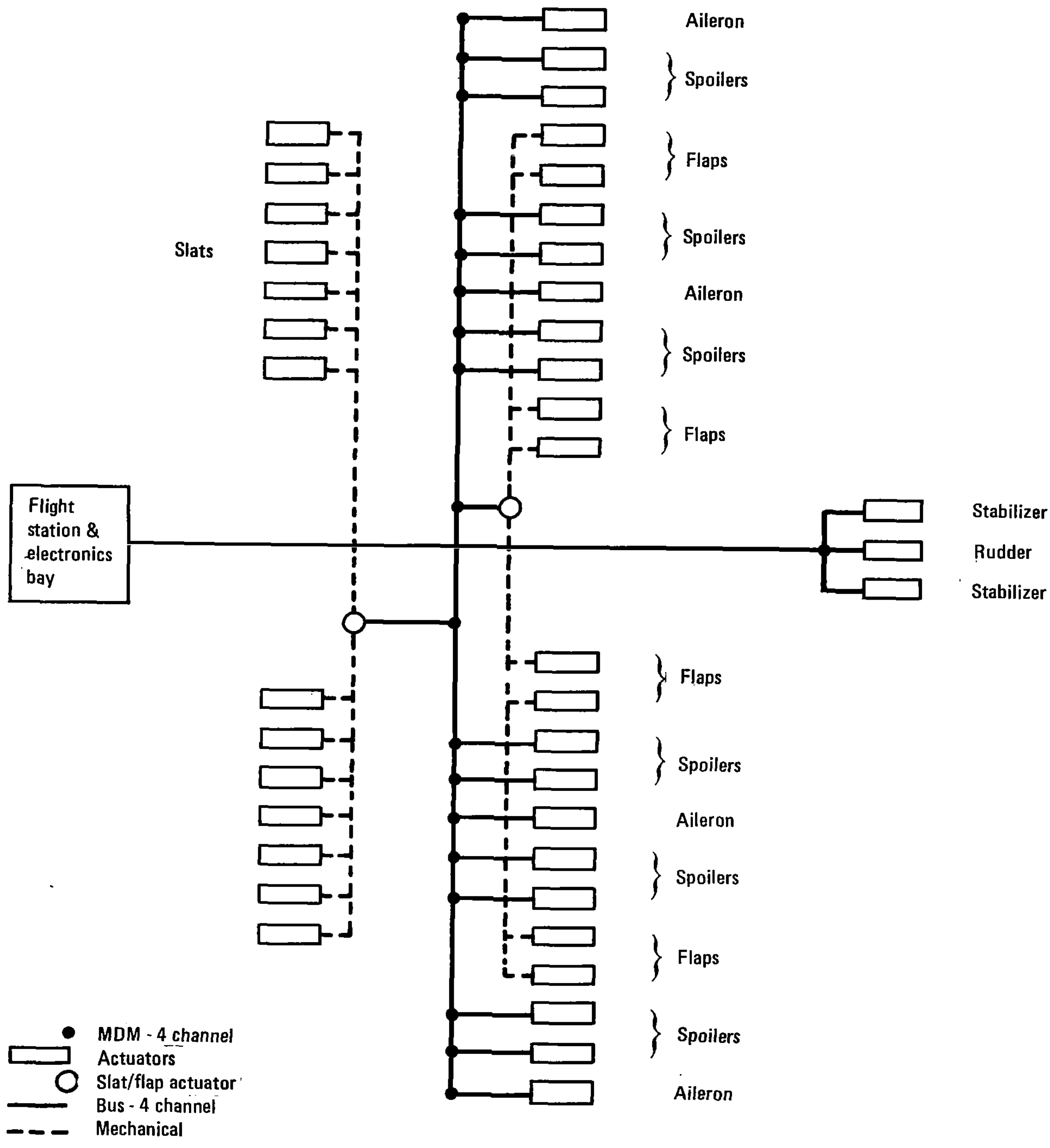


Figure 69. - Multiplexing for flight controls.

Similarly, new units can be added as necessary, tapping into the communication bus structure without the necessity for the major wiring changes of a conventional point-to-point communication network.

6.1.1.4 Cg management (CGM): To locate the cg aft to the most efficient location (for a supercritical wing configuration) would require relocation of the main landing gear further aft for ground operation. This would result in a prohibitive weight and cost penalty due to increased MLG support structure and gear complexity. The alternate solution is to add a CGM system by which the cg can be shifted in flight through fuel pumping. Figure 70 shows the proposed trim-fuel tank location within the reference aircraft tail section. CGM is not included for configuration No. 5 (See table IV) as the degree of RSS does not warrant it. However where active controls are combined with supercritical airfoil wing configurations (configurations 14, 15, 16), CGM is included.

Table IV shows the defined cg range limits and cg performance points for six different configurations. The L-1011 cg information is provided for comparison. Taking row 'C' from this table as an example: this reference configuration has a current technology wing and no RSS. Neutral point for this airplane is at 40 percent of the wing MAC. For the loading of passengers, fuel and cargo, the forward and aft cg limits are 17 percent and 34 percent respectively. For performance calculations then, a median cg of 25 percent was chosen, which gives the airplane a typical static margin of 15 percent. The range percentages, when applied to the MAC length of 8.53 m (28 ft), limit the cg range length to 1.46 m (4.8 ft). This is less range than currently being used by airlines, but it is anticipated that user airlines of the 1990s will be placing more importance on cargo loading for optimum cg location.

The active controls configuration (No. 5) has RSS. The moderate degree of RSS does not warrant usage of a CGM system to rebalance for takeoff and landing. Figure 71 illustrates the cg range and performance points as percentages of the MAC for the active controls (No. 5) airplane.

A design point cg location of 32 percent MAC for the current wing provides the maximum payoff.

A cg management system will be required to accommodate the high degree of RSS called for in the combined technology element configurations (No.'s 14, 15, and 16).

A design analysis was conducted to define the size of the trim-tank necessary to displace the cg from the 30 percent chord position to the 55 percent chord position for the advanced wing, a travel of 1.49 m (4.9 ft). The sketch below illustrates the cg points of interest.

Work done in 1980 during an IR&D study for retrofit of a trim-tank in the L-1011 tail was used to help in this analysis since both have a similar size afterbody/vertical tail. Detailed work was done in the L-1011 study to define the size of a "dorsal tank" and the structural modification to the tail.

The dorsal tank was sized for a capacity of 4763 kg (10,500 lb) of fuel. Further study has since been done to consider fuel storage in the vertical fin and horizontal stabilizer. A total fuel capacity of 11 929 kg (26,300 lb) is needed in the afterbody tanks to move the cg the required 1.49 m (4.9 ft). Figure 73 shows position of trim-tanks for CGM. The tank indicated by the number '5' is the dorsal tank. Tanks '1' through '4' indicate positions of the integral trim-tanks within the vertical fin volume; tank '6' defines the trim-tank within the horizontal tail volume. For a retrofit tank design, analysis showed that tank capacities are as listed below in table V.

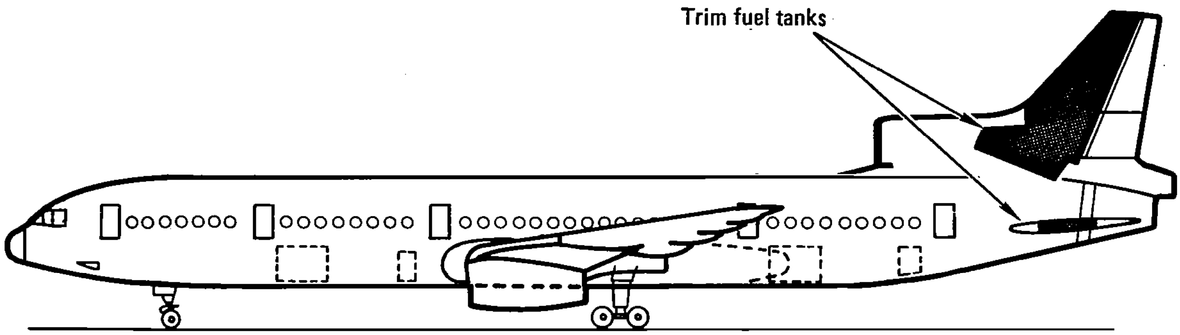


Figure 70. - Cg management.

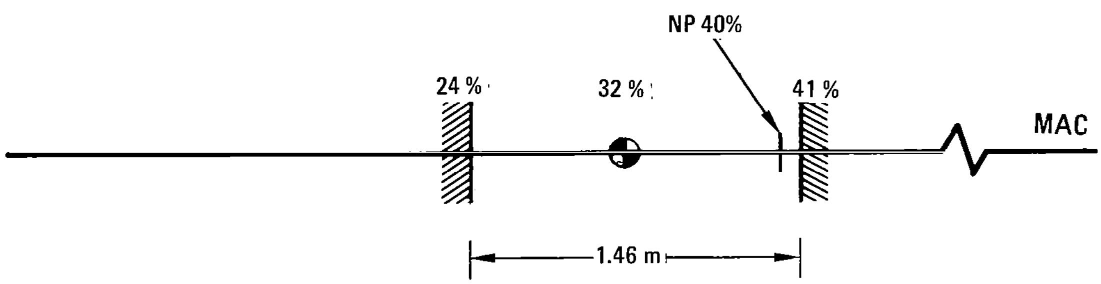


Figure 71. - Conventional wing cg range; RSS, no CGM.

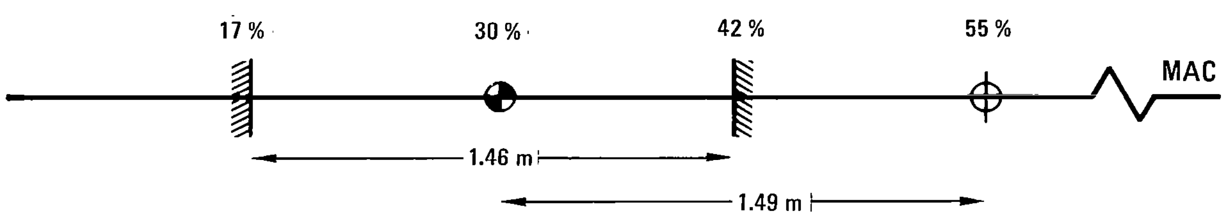


Figure 72. Advanced wing cg range; RSS, CGM.

TABLE IV. - CG RANGES FOR PERFORMANCE CALCULATIONS

	Configuration	RSS	Neutral point ~%MAC	Static margin for performance ~%MAC	cg for performance ~%MAC	Forward cg for ~%MAC	Aft cg ~%MAC	Static margin at aft cg ~%MAC	MAC ~m (ft)	cg range ~m (ft)
A	L-1011 with active ailerons	No	40%	15%	25%	12%	35%	5%	7.16 (23.5)	1.65 (5.4)
B	L-1011 with active ailerons	Yes	40%	-3%	32%+	20%	43%	-3%	7.16 (23.5)	1.65 (5.4)
C	Configuration 1 with current technology wing	No	40%	15%	25%	17%	34%	6%	8.53 (28.0)	1.46 (4.8)
D	Configuration 5 with current technology wing (no cg management)	Yes	40%	8%	32%	24%	41%	-1%	8.53 (28.0)	1.46 (4.8)
E	Configuration 13 with advanced technology wing	No	45%	18%	27%	14%	39%	6%	5.94 (19.5)	1.46 (4.8)
F	Configuration 14, 15, 16 with advanced technology wing (with cg management)	Yes	45%	-10%	55%+	17%*	42%*	3%	5.94 (19.5)	1.46 (4.8)

* For ground operations +Fuel pumping holds aftmost cg at optimum value

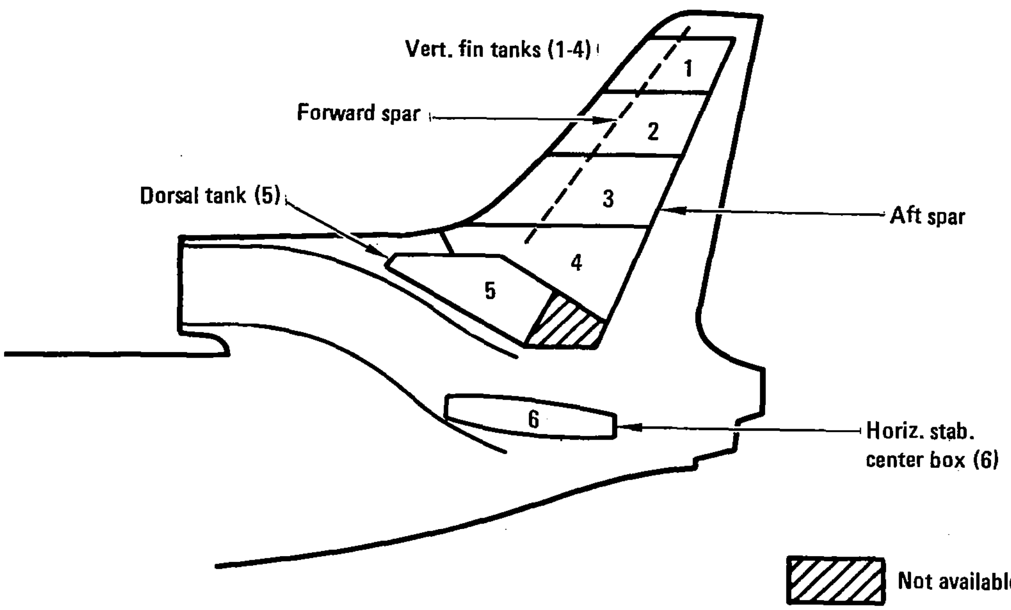


Figure 73. - Afterbody trim-tank locations.

TABLE V. TRIM-TANK CAPACITIES

Trim-tanks	no.	Fuel ~ kg (lb)	Capacity available ~ kg (lb)
Vertical fin	1-4	4944 (10,900)	4944 (10,900)
Dorsal	5	4763 (10,500)	4763 (10,500)
Horiz stabilizer	6	2223 (4,900)	5216 (11,500)

The vertical fin trim-tank tank volume is defined as being forward of the aft spar and including the leading edge volume. The vertical tail skinpanels form the walls of the tank. Previous studies found that a capacity of 5216 kg (11,500 lb) of fuel is possible for an integral fuel tank in the center box of the horizontal stabilizer; 2223 kg (4900 lb) of fuel for the required cg movement to 55 percent chord may be accommodated without problem.

The trim-tank is divided into five sections to reduce the hydrostatic pressure exerted upon the bottom portion of the tank structure. Each tank will have a fuel line and valving leading to the main fuel-pumping system. The system will ensure that no two tanks will be hydraulically linked.

Each tank should allow a vent box volume that is at least 2 percent of the total tank volume. A weight penalty of 454 kg (1000 lb) is the estimated weight addition to the reference airplane for the additional tank structure, fuel lines, valves, pumps, etc.

6.1.2 Advanced systems and controls. -

6.1.2.1 Advanced secondary power system: As with the baseline, the secondary power system (SPS) considers the following:

- Engine bleed air
- Engine driven compressors
- Engine driven hydraulics
- Pneumatic power
- Emergency power
- APU power
- Engine starting

The SPS is normally involved with the utilization of engine bleed, hydraulic, electric, and pneumatic power. The basic philosophy of the advanced systems and controls airplane configuration however is that the engine-bleed, pneumatic, and hydraulic services will all be performed electrically. As a consequence, the advanced SPS will eliminate the use of engine bleed-air and pneumatic power. Also, the flight control system (FCS) will be all-electric and the hydraulic power distribution and actuation system will be replaced by a power-by-wire (PBW) system. This configuration will therefore be an "all-electric airplane." Electrical systems shall power the functions that have traditionally been provided for with engine bleed air (cabin pressurization, cabin heating, deicing, engine starting, thrust reversers, etc.). EMAS will replace HMAS for all mechanical operations such as primary and secondary FCS, main/nose-wheel gear operation, nose-wheel steering, cargo/inlet-doors, and all other utility functions.

Major and significant improvements will result from the elimination of the engine driven hydraulic pumps and the distributed (high pressure) hydraulic lines in the powerplants, pylons, wings, fuselage, as well as the engine-bleed provisions, and the bleed ducts.

A major simplification results in the producibility, logistic, and maintenance-support aspects of this airplane. This all-electric airplane will therefore embody the synergistic benefits and pay-offs, that were identified in the NASA JSC/LaRC Study, reference 7.

6.1.2.1.1 Electric power system trades: For this advanced airplane the following candidates were considered:

A Advanced constant speed drive-generator concepts (such as the IDGS)

B VSCF (variable speed constant frequency) systems using cycloconverter or dc link technology

C 270 Vdc, using brushless (samarium-cobalt, SmCo) generators with integral phase-controlled rectifiers (SCRs)

D DDGS (direct driven generator system)

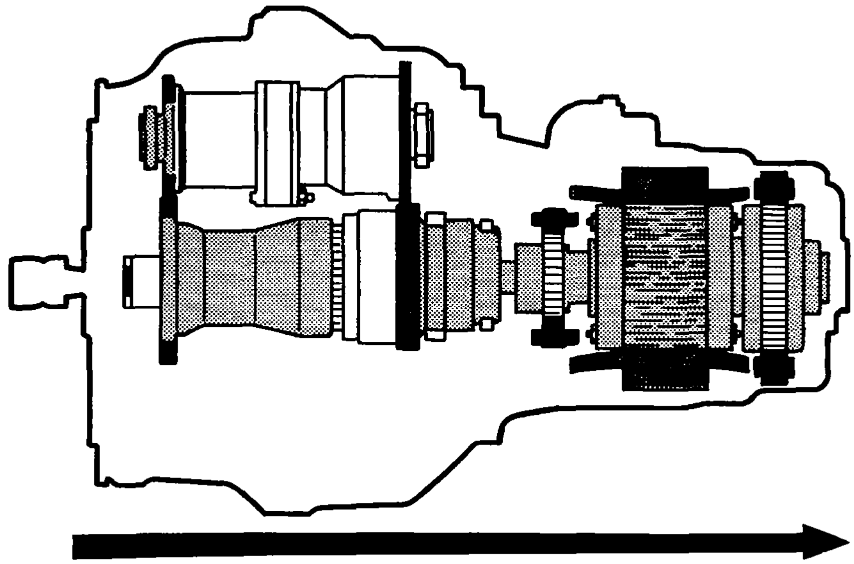
CSDs: candidate (A): Figure 74 shows the salient physical differences between an advanced CSD-generator (IDGS) at the bottom and its IDG (integrated drive generator) predecessor at the top. As evident, the main features of the IDGs (on the left) are that its side-by-side configuration is conducive to a more compact mechanical configuration: its cg and overhung moment are also less than the conventional IDG. In addition, Sundstrand projects improvement in the thermal management aspects of the IDGs, and somewhat overall higher transmission efficiency vis-a-vis the conventional IDG. The other main features of the advanced CSD system are that its modular design/packaging concept permits easier replacement of the component parts along with a prospective improvement in the maintenance support costs.

In perspective, the CSD development has been protracted and pervasive because of the difficulties in achieving a constant speed output over widely-varying input speed/acceleration conditions of the aircrafts' engines. The hostile environment of the power plant, coupled with the high hertzian stresses (incident upon the operation of small volume/high speed hydro-mechanical components), also resulted in a long and difficult development cycle for the CSDs. As a consequence, the maintenance support and operating costs of the drives (IDGs, etc.) have been historically high.

VSCF cycloconverter: candidate (B): The emergence of the VSCF power system promised to overcome some of the basic shortcomings of the CSD systems in that this electric/electronic approach to the generation of constant frequency would eliminate the use of highly-stressed wearing parts and it would offer prospectively-better reliability. Primarily, however, the VSCF power systems offer the potential for improved power-quality and lower life-cycle costs. Another favorable and projected aspect of the VSCF is that it will benefit from the rapidly advancing technology in semi-conductors and new electronic packaging techniques. Modularity in the design of the power-conversion electronics for example, permits the electronic subassemblies (cards, etc.) to be removed and replaced quickly with new assemblies. As a result, lower mean time to replace (MTTR) and lower life cycle costs (see figure 75) are expected for the VSCF power systems.

The two primary VSCF types are cycloconverter and dc link. In the former case, the variable voltage/variable frequency of the direct-driven generator is converted to constant voltage/constant frequency by synthesizing a low frequency (400 Hz) wave from the high frequency power source (figure 76): in these cycloconverter systems the generator, at its minimum speed, must generate a frequency of approximately three to four times the output frequency. A legacy of this system, therefore, is that it must develop say 1200 Hz at 50 percent speed and 2400 Hz at take-off/cruise-flight engine speeds: this requires a generator which operates at high speed and has a high number of poles. To date, with a few exceptions, accessory gearboxes (on the engines) do not provide a high enough speed, so front-end gear ratios must be inserted in the input drive of the generator. However, it is to be noted that the cycloconverter VSCF power systems have a longer history of development and, through the AFWAL/NADC programs, they have been successfully developed in capacities up to 150 kVA. More pertinently, the General Electric Company has pioneered and developed the system to permit operation of the generator as a synchronous motor (engine) starter. These starter generators are therefore capable of starting engines in the 18 144 kg (40,000 lb) to 22 679 kg (50,000 lb) thrust class.

The mechanical design/installation aspects of the VSCF technology are important, when it is compared with CSD and other electric system technologies, but it is relevant that the VSCF "cycloconverter" power systems, built to-date, have over 600,000 flight hours of laboratory and A-4 flight experience and they have demonstrated high TBO/MTBF rates. Additional flight hours are being obtained on the F-18 aircraft. More importantly, the systems demonstrate high electrical power-quality in that the transient response characteristics and voltage balance, etc. are superior. Figure 77 are test data from oscillographic recordings, taken during testing of a 20 kVA VSCF power system in Lockheed's Rye Canyon Electrical Research Laboratories. The left-hand diagram shows the reduced level of the voltage-transient (and the faster recovery to steady-state conditions) of the VSCF when full-load is applied and removed from the system. Similarly, the right-hand diagram illustrates the superior frequency response of the VSCF vs the IDG (and an APU). The unique



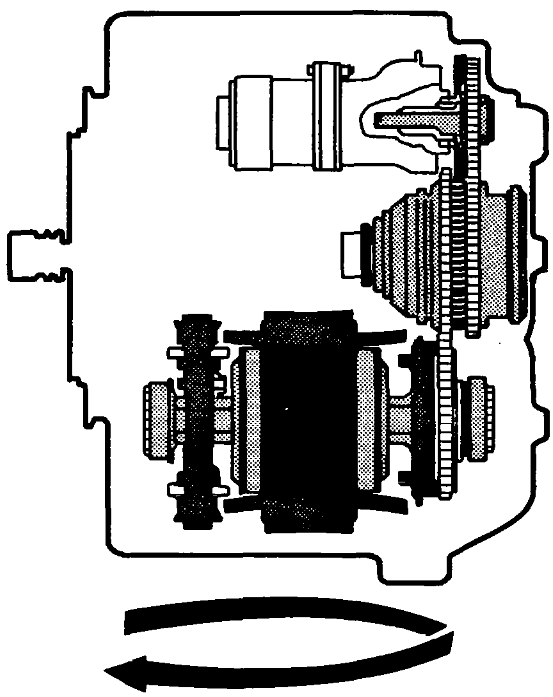


Figure 74. - Constant speed drive configurations.

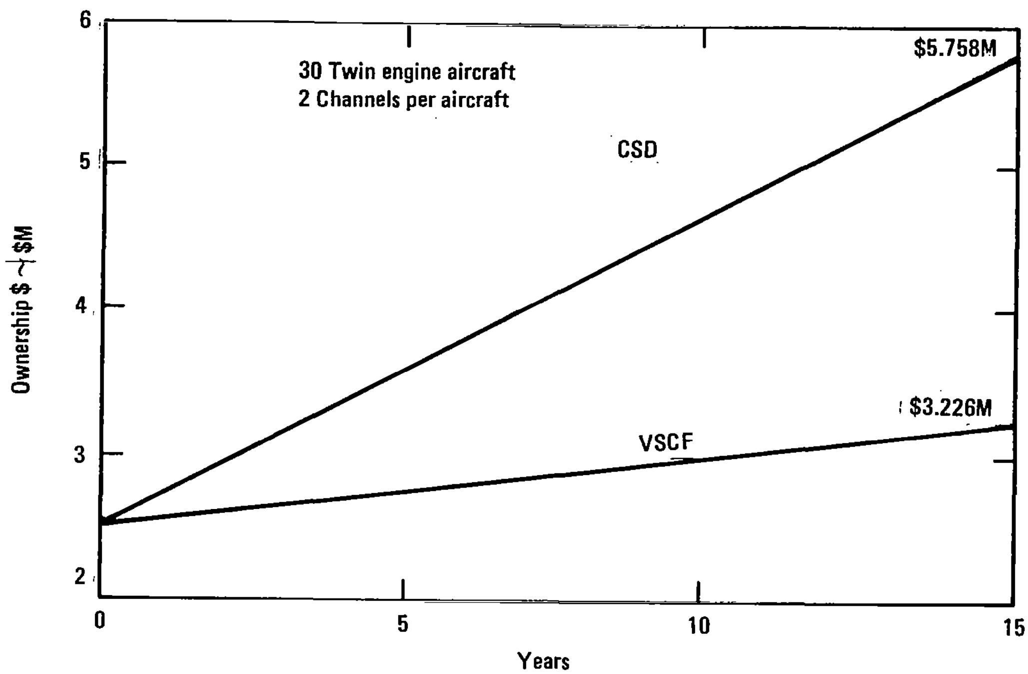


Figure 75. - CSD vs. VSCF life cycle costs (from GE Data).

characteristic of VSCF shown here is that, theoretically and empirically, the VSCF system is free of transport-lags that are typical of mechanical and hydromechanical servo systems. In the case of the APU, the large speed-regulation droop and speed overshoot (on full load application and removal) are typical of the characteristics of a small gas turbine power unit (GTPU). These curves show that the performance of the APU-generated system is much poorer than the VSCF and IDS systems.

VSCF dc link: candidate (B). The development experience with dc link VSCF systems is less than that of the cycloconverter VSCF, but the technology is still well established. The primary difference is that the dc link approach is a dc to ac (inversion) system, while the cycloconverter is an ac to ac (conversion) system: also, today, the power-capacity of the dc link system is somewhat more limited than VSCF-cycloconversion. For example, the present dc link power systems have been limited to 20 to 40 kVA capacity, because of the present unavailability of very high current/high voltage transistors. No 90 kVA or 150 kVA dc link inverters are therefore available (as are the VSCF-cycloconverter systems), because such capacity systems would require the paralleling of many power transistors. This, in turn, would give rise to current-balancing problems between the paralleled transistors: VMOS technology would ameliorate the current-balancing problems, but the availability of VMOS power devices (in the current/voltage capacity required) is even farther

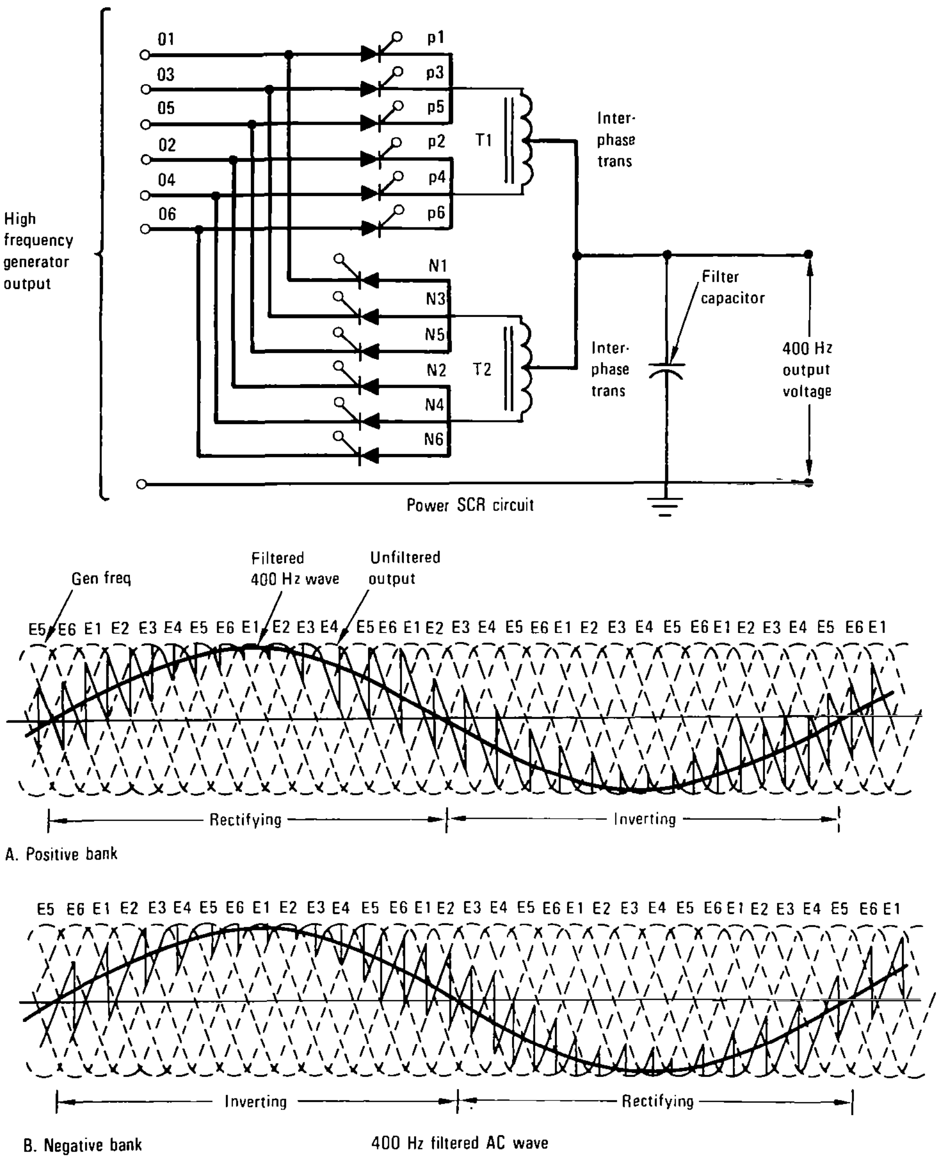
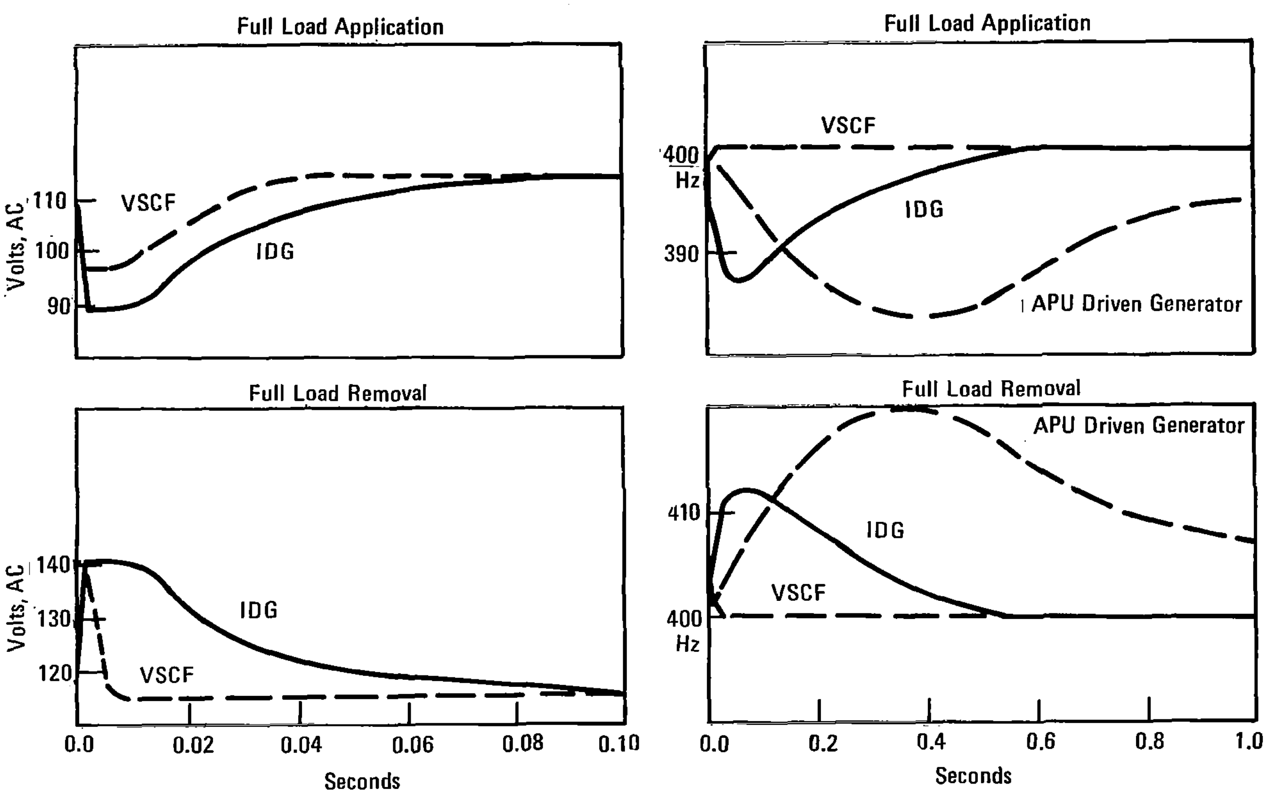


Figure 76. - VSCF Cycloconversion.



Voltage Response Comparison Between VSCF and IDG Systems

Frequency Response Comparison Between VSCF, IDG, and APU-Driven Generator

Figure 77. - VSCF system performance.

downstream. Large capacity dc link inverters will therefore depend for some time on the development status of high-current power-transistors, although it is a development which is proceeding very rapidly. Figure 78 is a schematic of dc Link VSCF Power System.

Production applications of cycloconverter VSCF technology is presently limited to the A4D, the F18 and, prospectively, the A10 aircraft. General Electric supplies these systems and while they have been primarily involved with cycloconverter-technology, they are also prepared to supply dc link VSCF systems. In the interim, Westinghouse, who has also been involved with cycloconverter and dc link technology, has recently received a production- contract for a 40 kVA dc link system on the F5G aircraft. This will be the first such production contract VSCF-dc link system for Westinghouse.

270 Vdc: candidate (C): The 270 Vdc power system technology is largely the result of NADCs development programs. The U.S. Navy, having to be concerned with supporting airplanes from aircraft-carriers, etc. saw the facility for powering the aircraft from 3-phase 200 V 60 Hz power supplies which are readily available on these ships. The U.S. Navy also saw the prospective simplicity of paralleling dc machines, as opposed to the sophistication required with CSD and VSCF power systems. More pertinently, however, the Navy claims that many electronic systems can operate directly with 270 Vdc, so the elimination of the front-end rectification of 3-phase 200 V 400 Hz power is possible.

The foregoing are points in favor of 270 Vdc, but the problems reside in switch-gear, required to interrupt prospectively high fault currents and coping with the high-voltage recovery-transients incident upon the release of such faults. It is also necessary to invert a fairly large amount of the 270 Vdc power to 3-phase 200 V 400 Hz power, because of the world-wide availability of many 400 Hz electronic equipments, instruments, sensors, etc. For large horsepower motor-drives, power-electronics are also required to interface the brushless (permanent-magnet) motors with the 270 Vdc input power system. Thus, the 270 Vdc system cannot directly power the many motors now in use in aircraft, and as a consequence, electronic-inverter-assemblies are necessary to synthesize a rotating field for each of these motors. Where a programmable power supply is required for a motor to give variable-speed operation etc., then the penalty of the inverter cannot of course be levelled against the 270 Vdc system concept.

DDGS: candidate (D): The direct-driven generator system is really a variant of the VSCF power-systems and it was the one that was selected for the 500 passenger advanced technology aircraft (ATA), studied under the NASA-JSC contract (reference 7).

In this system, maximum utilization is made of the direct-driven generator power, and dedicated power supplies (viz: 270 Vdc, 3-phase 200 V 400 Hz and 28 Vdc) were provided by static power conversion/inversion technology.

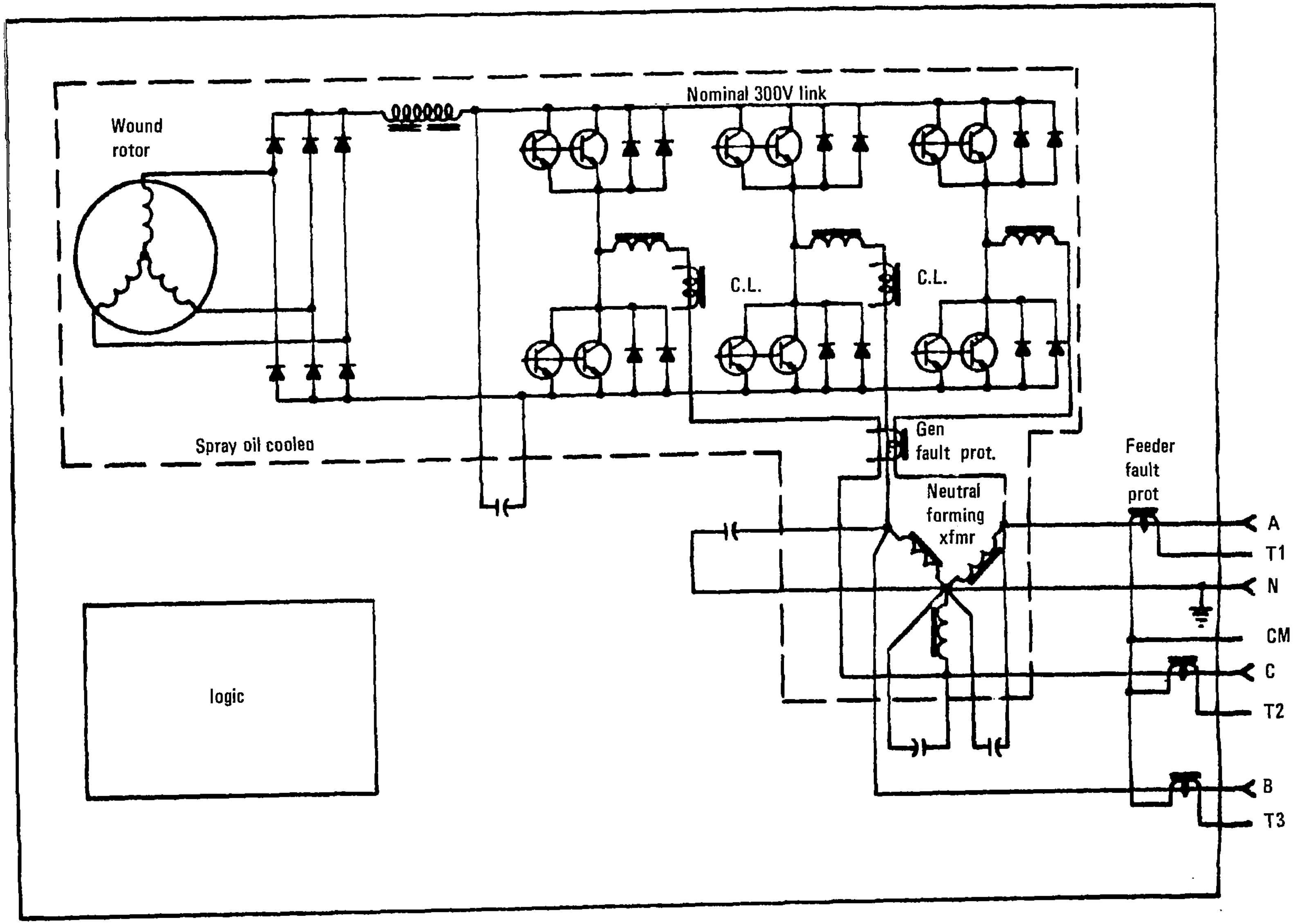


Figure 78. - VSCF dc link inverter circuit.

The primary difference between this type of system and the CSD/VSCF power systems is that the CSD/VSCF systems provide 100 percent constant power over the speed range of the engines, whereas the DDGS provides only that amount of constant power required to meet the needs of the avionics, flight-control computers, etc.

The DDGS frequency/voltage parameters and the power-system characteristics selected for the ATA are different from the conventional 3 phase 200 V 400 Hz, since the magnitude of the loads in the All-Electric Airplane demanded a higher system voltage. Also, the maximum speed of 2513 rad/s (24,000 rpm), possible with the 400 Hz system, was considered to be too low for large capacity compressors and motors. As a consequence, a 3-phase 400 V 800 Hz power system was selected so that the generator yields 800 Hz, at 92 percent HP spool-speed.

The hybrid approach, offered by the DDGS, is meritorious for the large power-capacity generator system since is takes advantage of dc link (or cycloconverter) VSCF technology which is presently being developed under USAF and NASA funding. DC link technology is limited, as mentioned, to 20 to 40 kVA power supplies, but such capacities are quite adequate to meet the 3-phase 200 V 400 Hz (and 270 Vdc) demands of even the very large ATA. Because of the work, (accomplished under the sponsorship of the NADC) 270 Vdc input/3-phase 200 V 400 Hz output inverters will be readily available in the marketplace and these can be readily-interfaced with generators of 200 kVA to 500 kVA capacity. Thus, it is possible to have a very high capacity electric power system without the efficiency loss, incident upon transmitting all this power through a full-capacity power-link system. Figure 79 is a schematic of the DDGS.

Summary of A, B, C, D candidates: All the above systems are candidates for the ATA but, the required system capacities (when engine bleed-air is eliminated) are such that system A, B and C are unfavorably impacted in terms of weight, volume and cost. The DDGS therefore trades more favorably not only in terms of these parameters but also in the areas of reliability, overall transmission efficiency and logistics support. This system was therefore selected.

6.1.2.1.2 Power system configuration: Two direct-driven permanent-magnet (SmCo type) generators are driven by each of the three engines: these generators are 3-phase 400 V 800 Hz generators of 200 kVA each, that develop their normal 800 Hz frequency at approximately 90 percent high-pressure spool-speed. On takeoff, the voltage and frequency of each generator will increase 444 V and 888 Hz respectively. The individual generator capacity is therefore effectively increased, during takeoff, to 222 kVA, and loads such as landing-gear/flaps/slats, etc. will operate at 111 percent of nominal (800 Hz) speed. This is a benefit in that drag is removed from the airplane as quickly as possible in the critical takeoff phase.

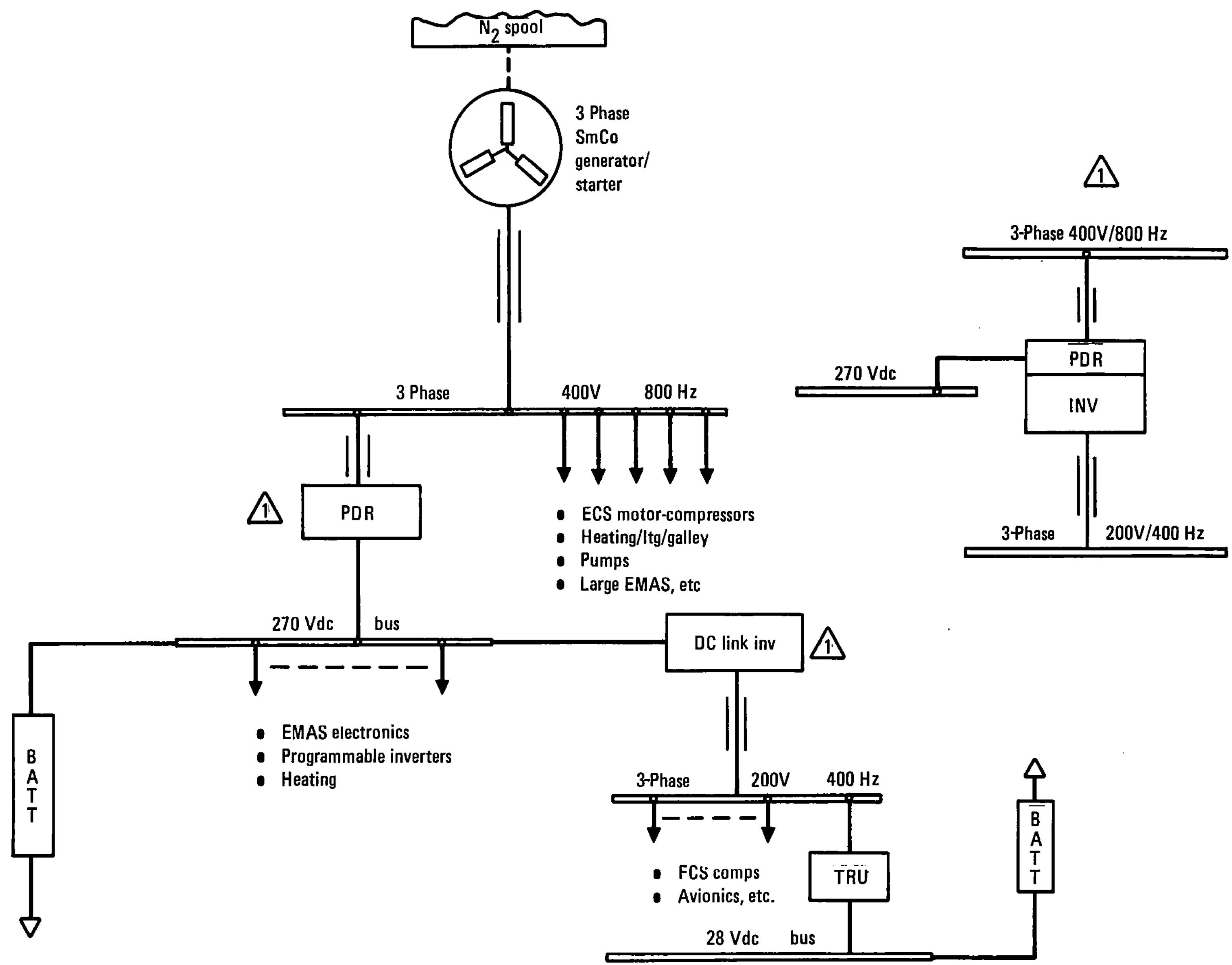


Figure 79. - Direct driven generator system (DDGS) schematic.

During normal cruise conditions the generators develop a nominal 400 V and 800 Hz frequency. This power is used to power directly many loads such as the galley, deicing/anti-icing systems, heating, lighting and large motor loads, such as the ECS compressor motors. Power for the FCS and other loads is derived from six phase delayed rectifier (PDR) units of 25 kW capacity each. These PDRs provide a constant level of 270 Vdc over the nominal 2:1 speed range of the engine-driven generators. Only four of the PDRs are in active use at any one time, so two of the PDRs serve as additional back-up for the important 270 Vdc power system, which supplies the 3-phase 200 V 400 Hz inverters and the power-electronics used with each EM actuator on the flight control surfaces.

The avionic loads and the FCS computers, which require constant voltage/constant-frequency (3-phase 200 V/400 Hz) ac power, are supplied by four 15 kW inverters connected to four PDRs. These inverters, along with the avonics suite and the FCS computers are located in the pressurized fuselage-area. The power electronic assemblies for the FCS actuators are, on the other hand, located outside of pressure in the wing/empennage areas. The objective here is to locate the power electronics in close proximity to the EMAs, so that RFI noise is reduced. Conductive cooling for the power-electronics is planned by locating the assemblies directly to the wing/empennage spar-beams. It is possible, however, that in the ongoing development, an active cooling-loop might become desirable for these assemblies.

Landing-lights using low voltage (high-power) filaments will be powered by step-down 200 V 400 Hz transformers (located as an integral part of each landing light assembly), but other external internal lights will be powered by a typical retified 28 Vdc system. This system will also power instruments, relays, magnetic indicators and other low voltage dc circuits. The 28 Vdc system will be powered by three 28 V 150 A transformer-rectifer units, or three 28 V 150 A high speed switching converters.

Generator system/feeder protection: - In the advanced system, the generators operate in a nonparalleled/isolated mode, with each generator supplying its own distributed bus-section. As generators and/or engines fail, appropriate bus-tie contactors will close to ensure continuity of power to the affected bus-sections. Protection of the system is planned to be simple, because overvoltages/overfrequencies, undervoltages/underfrequencies cannot be developed, unless there are overspeeds or underspeeds of the engines. Since the engines incorporate reliable and sensitive speed controls, there is little prospect of such anomalous-operation. It is also proposed that a high-impedance neutral-grounded generator system be used, thereby eliminating the prospects of very high fault-currents to structure (which occur with the more typical line-to-ground type faults). If such faults occur in this system, the ground-leakage current will be limited to some 50 milliamperes, and an indication will be provided of such ground-leakage in the flight station (and on the maintenance panel).

Generator power characteristics: - As the PM (permanent-magnet) generators are direct engine-driven, the voltage and frequency will be proportional to engine speed. Pursuant to this, the following generator power characteristics will prevail over the ground/flight operating conditions.

Condition	Line-to-line Voltage	Frequency
Ground Idle/Taxi	200 V	400 Hz
Takeoff/Climb	435 V	870 Hz
Cruise	400 V	800 Hz
Idle Descent Let-down	356 V	712 Hz

These voltage/frequency parameters change linearly with speed, but for the major part of the flight-envelope, the system operates like a constant voltage/constant frequency power system, without the complexity of CSDs or sophisticated power-converters.

Transmission/fuel-efficiency: The main feature of the advanced power system is that it provides high transmission efficiency (92 percent) which is necessary, when transmitting power levels of 200 kVA or more. Evidently, the interposition of a CSD, between an engine and the generator, results in a power-loss and a thermal- management problem. For this configuration transmission of 400 kVA of heat-resistant power, at say an overall efficiency of 72 percent, would result in a heat-rejection of 77.9 kW (4434 Btu/min) from each drive/generator unit (two units per engine). This would pose a significant thermal-management problem, and it would be very fuel-inefficient.

Power supply and load distribution: The SmCo generators directly-power the following:

- Large motor loads (such as the cabin-compressors/freon-compressor motors)
- Electric/avionic loads
- Primary/secondary flight controls
- Galley loads
- Motor drives for fuel/oil pumps, etc.
- Space/floor/wall/duct heating
- Internal/external lighting

- Main/nose landing gears

- Conditioned power-supplies

- Non FCS electromechanical actuators (landing gear/nose wheel steering, cargo doors)

- Brakes and miscellaneous functions

Powering these loads (over the speed range), is possible because of a somewhat natural-matching of the airplane's generator capacity with the load demands, incident on flight and ground operation. For example, the maximum load reflected by the ECS system occurs during climb/cruise-flight and, it is at this time that the generators develop their maximum power. On the ground, the generator-capacity is reduced but the power demands are also reduced, even though the cabin-cooling demand may be high, as on a hot day with a maximum passenger-complement. During idle descent let-down (when the high pressure spool-speed may drop to some 80 percent) the electric-driven cabin compressors, will operate as though they were driven directly by the engines. To meet this speed change, the ECS control system adjusts the ICVs, etc., to maintain adequate pressure-ratios across the EM driven compressors. The FCS, at the same time, requires constant-rate operation (and constant-power capabilty, regardless of engine speed) so the dedicated inverters provide this constant-power requirement.

As described in reference 7, a distributed bus system is proposed for the far-term electric power system, because of the increased number of loads in the wings and empennage. Figure 80 illustrates the configuration of the primary ac power system, which is laid out as a distributed 3-phase bus system: the 3-phase 200 V 400 Hz CFAC system is however planned as a conventional radial distribution system. Also shown in figure 80 are the interconnections of the APU/external power supply, the two starting inverters and the PDRs.

As indicated the two starting-inverters will be located in the fuselage, in an area close to the ECS power packs, from which the inverters may receive an active cooling fluid, via a transport-loop. The PDRs are located one on each front/rear spar beams (left and right wing) and two in the empennage. The output power from the PDRs (not shown in figure 80) will be connected into a distributed 270 Vdc system that will follow the redundancy criteria of the primary ac system: triple-redundancy in the wings; quad-redundancy in the fuselage and empennage. The APU, like the external ac power supply, will tie into two of the distributed buses in the fuselage.

Control and management of the power generation system and the bus distribution system will be controlled by a digital data management system that will be interfaced with the flight station command-control. Selection and individual control of the distributed bus contactors will be sophisticated and require discrete interlocking during the power generation, start, external power, APU and emergency modes of operation. Since a dedicated start-bus system is not used and the normal power supply (generator) feeders are used to conduct current to the generators in the start mode, a conventional power constant frequency, etc. must be maintained while the programmed electric power is applied to the different power plants during engine starting. Consequently, appropriate contactors must be opened to isolate bus sections during the start condition. Also, the power load/management system will isolate loads such as the FCS, EMAS, etc., that are not required during the start mode. As evident from figure 81, external power (for example) is tied into left and right fuselage buses, and the bus-section control can be such that start-power can be selectively applied to left wing, right wing and empennage.

Overall, the power, load and bus management system will require detailed consideration and layout, since there are a number of candidate approaches. It is this type of work that requires NASA's further attention, since the subject cannot be covered adequately in a brief/broad-study. It is likely also that in a large all-electric airplane that, as advanced technology APUs are reduced significantly in size and weight, two units might be justified in the airplane. As an example, one APU might be used for "powered-wheels" during taxi, while the other APU supplies conventional ac power to the other aircraft loads. There are also merits in the powering of two separate distributed bus-sections during emergency conditions, such as an "all-engine-out" condition. Such power-redundancy provisions will be far superior to that presently in use in any contemporary secondary power system.

Figure 81 shows the configuration of the 270 Vdc distributed bus system, which follows the basic lay-out of the primary ac system. Uniquely, it would be desirable to tap into the distributed-busses without making numerous breaks and terminations in the distributed-feeders. This again is a subject for further study and development, but it is necessary that as line-taps are made in the distributed-feeders, protection of any individual supply lines should be integrated within the tapping device. High rupturing fault currents are possible with the dc system, since it is difficult to achieve current limiting, as proposed for line-to-ground failure in the primary ac system. Typically, high rupturing capacity (HRC) filled-type fuses might offer a compact means for protecting the dc distributed feeders, from faults in sub-circuits tied to that feeder. An integral line-tap assembly that serves also as a multiple (HRC) fuse splitter would ensure that individual circuit protection is affected right at the distributed bus tap, thereby preserving the integrity of the bus from faults in the load circuits. (NOTE: A joint NASA-JSC/Calac disclosure of invention was filed on this technology). There is significant work to be accomplished on the distributed bus technology, as a whole, and such work should become an integral part of NASA's further investigations on the advanced power generation and distribution systems.

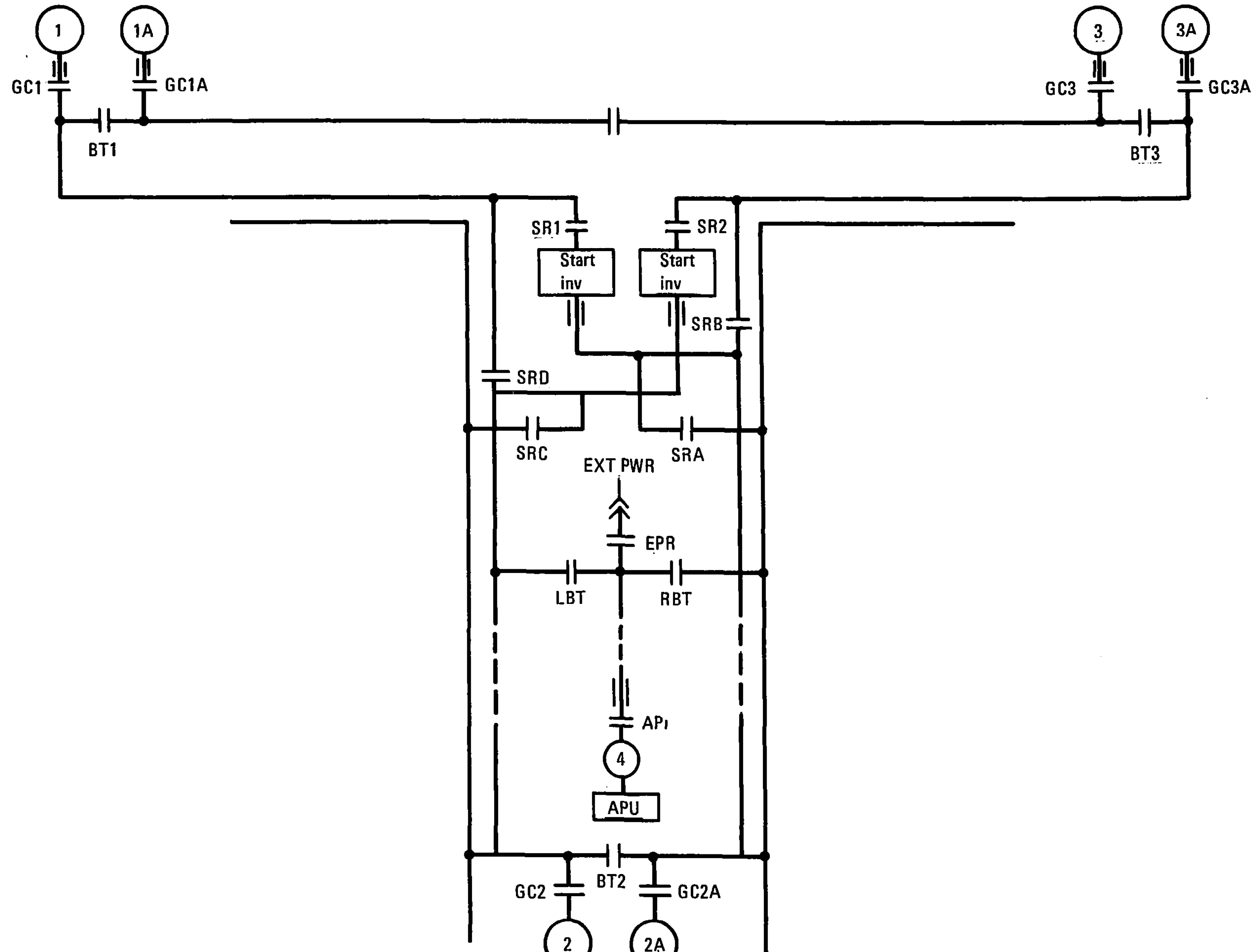


Figure 80. - 3-phase ac distributed buses.

6.1.2.1.3 Power/load management: It is to be noted that in the design of the electric, FCS, and other subsystems, a digital-data load-management system is used to monitor and control the operation of these systems, over all normal and abnormal operating conditions. This system is not described in this report, but its design will follow the traditional practice of assigning each load a priority-tag, which governs its position or level in the load hierarchical-structure. In operation, individual loads (and groups of loads) will be shed in accord with a software program that establishes the priorization schedule, vis a vis different levels of emergency.

6.1.2.1.4 Engine-starting: Engine starting is accomplished using the samarium-cobalt 150 kVA generators in the dual role of synchronous-motor engine-starters. The technology of using the generators as starters has been validated by substantive laboratory-testing by the General Electric Company. The greater part of the GE work has been directed towards the operation of the cycloconverter (in each channel) in a reverse-mode. This requires that each cycloconverter be of the same (or higher) rating than the generator.

One of the first production applications of such a system will be the procurement by AFWAL (Air Force Wright Aeronautical Laboratories) for the A10 aircraft. These starter-generator systems will be in the 60 kVA rating, but there is current interest in production versions of the 150 kVA starter-generator systems (that have also had extensive laboratory-testing). These latter size systems will be applicable to the larger engine in the 18 143 kg (40,000 lb) to 22 679 kg (50,000 lb) thrust class.

In the advanced systems configuration, there are no in-line inverters (of comparable capacity to the generators), so two static 270 Vdc (programmable-output) inverters are used to furnish the synthesized three-phase ac power necessary for the starter-generator. Figure 82 is a simplified schematic of the system. As shown, a rotor-position sensor feeds commutation-logic back to the power-electronics (via the starter-logic panel). Other logic sensors, along with control inputs from the flight station, govern the engine-acceleration rate (torque/inertia ratio), through the engine light-off and starter cut-off (SCO) speeds.

The inverters used for starting utilize dc link technology, but the design is different, and much less complex compared to inverters that provide MIL-STD-704 type (constant-frequency) power. As an objective, the inverters are designed to be operable, and compatible with the onboard 3-phase 400 V 800 Hz APU generator, the 3-phase 200 V 400 Hz external-power and 3-phase 200 V 60 Hz commercial power. As presently-proposed, the inverters are dedicated to the primary-role of engine-starting, but it is projected that in the future the inverters may be also adapted to powered-wheels and other multiple-roll functions.

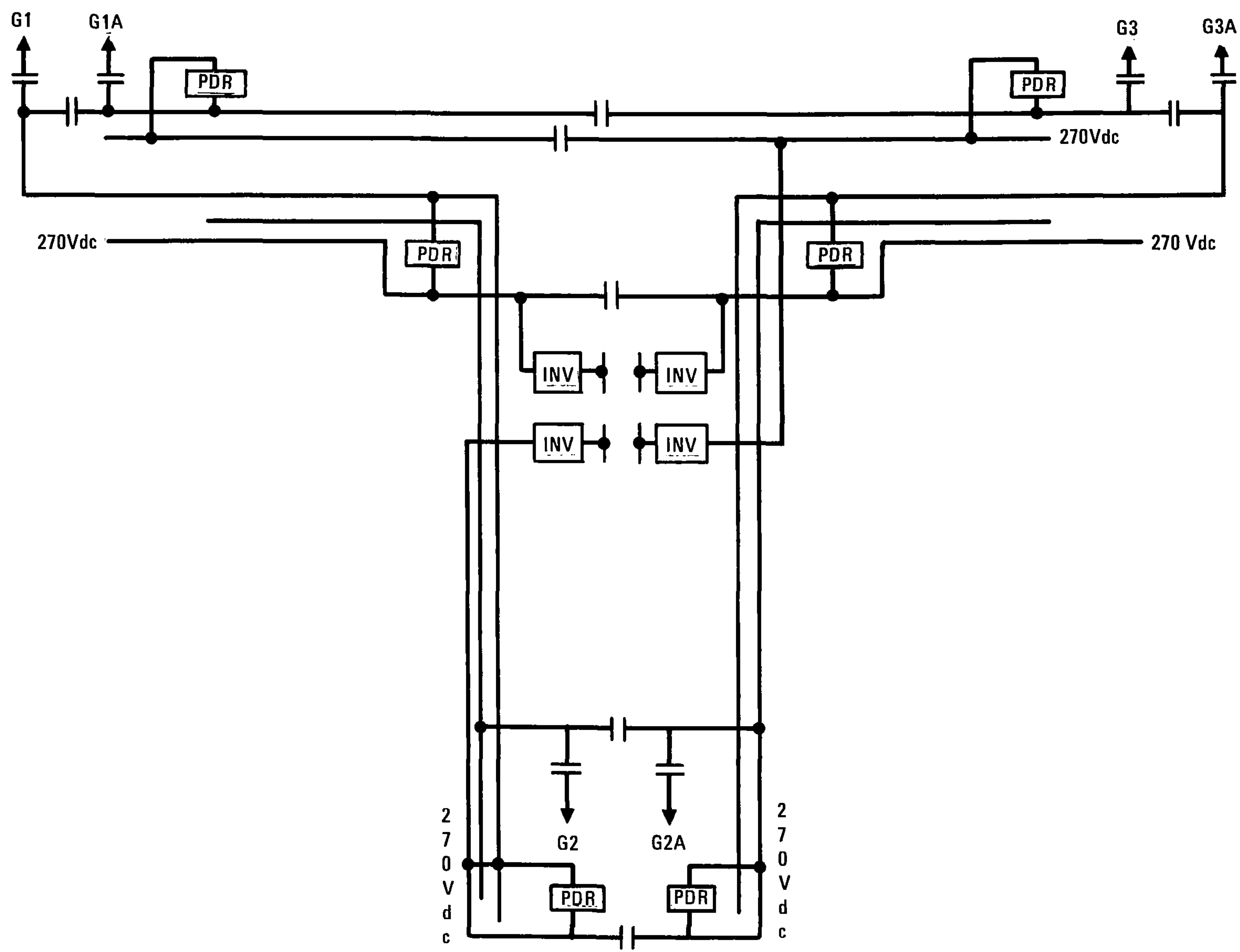


Figure 81. - 270 Vdc distributed bus.

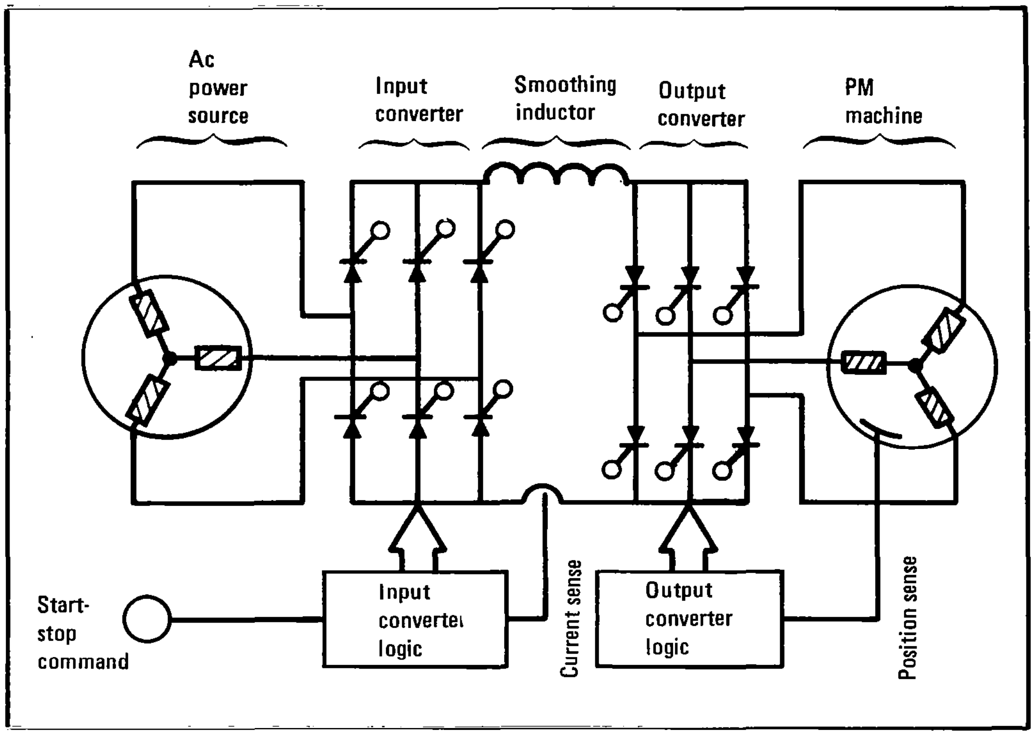


Figure 82. - SmCo starter-generator.

For the advanced configuration airplane, details of the engine polar-moments, engine drag-torque vs speed, etc. are not presently known. It is projected however that the high by-pass E^3 type engines will have high compression ratios, higher polar moments of inertia and, therefore, higher starter-power requirements. These requirements must be studied and evaluated fully, at a later date. Optimistically, it would offer better dispatch-capability to the airplane, if either of the two generators, in each power-plant, could be used as starters, but this might require a degree of over-sizing above the 150 kVA rating. Nonetheless such oversizing might be worth consideration and evaluation in continuing studies.

There is also the possibility that other alternative electric-start configurations might be considered that are different from the methodology being presently considered. Also, the technology of engine-starting and its interface with APUs and an external power system is highly important to the successful implementation of the all electric airplane, so its development and its reduction to production-hardware status is a key technology in ensuing development programs.

Integrated engine starter/generator (IES/G): More recently, as exemplified by the work accomplished under AFWAL funding (reference 8) the integration of the generator within the engine has also been investigated: figure 83, which is taken from the subject report, is an example of such an approach. The significance of the IES/G work to NASA is that the trend towards high capacity generators in the all-electric airplane could make the IES/G approach attractive. However, the design does place the generator in a fairly inaccessible position, for maintenance actions, and it is a higher temperature environment. Another disadvantage is that the generator rotor speed is constrained to that of the high pressure spool. Typically, advanced technology generators may run at speeds of 1676 rad/s (16,000 rpm), 1885 rad/s (18,000 rpm), or 2513 rad/s (24,000 rpm) and this would offer two main advantages:

- The volume/weight of the generator would be low
- The inertia of the engine-rotor, referred to generator-rotor, would be reduced.

A disadvantage of the non-IES/G approach is that the gearbox, on the engine, would be a more complex installation and it would require a lubrication system. The (generator-only) gearbox would be more simple and austere (than the conventional fancase/core-case mounted gearboxes), but the advantage of a gearless drive for the generator would still be lost. The subject of integrated versus gearbox driven generator is therefore in need of a further evaluation and analysis. In this analysis, it would be necessary to acknowledge the complexity added to the IES/G, by the incorporation of the fast-acting mechanical-disconnect clutch, as shown in figure 83. Such clutches are necessary for the SmCo generators, (whether they are mounted on the rotor or on a gearbox), but their inclusion in the IES/G system does detract from the basic simplicity of merely mounting the rotor over the high-pressure spool shaft.

6.1.2.1.5 Emergency power/APU power: The major dictate and consideration in the design of the emergency electric power system is the FCS. The baseline (conventional) airplane, using hydraulic power-operated controls, was supported by a ram air turbine (RAT) driving a hydraulic pump. This RAT could be dropped out at high speeds and could furnish power down to the approach and flare-out speed of the airplane. With the elimination of hydraulics in the all-electric airplane, the FCS will utilize EMAS for actuation of the primary and secondary flight control surface. These surfaces will be PBW/FBW, and will depend upon quad redundant electrical power/avionics and at least quad redundancy in the full FBW primary flight control system.

In this advanced configuration, the APU will be electrically dedicated: no engine driven compressor/hydraulic pumps, etc. In the extreme emergency of an all-engine-out condition, an APU will be utilized as the emergency power source, to provide power to the avionics and other essential loads, rather than a RAT hydraulic pump as in the baseline, or rather than a RAT electric generator.

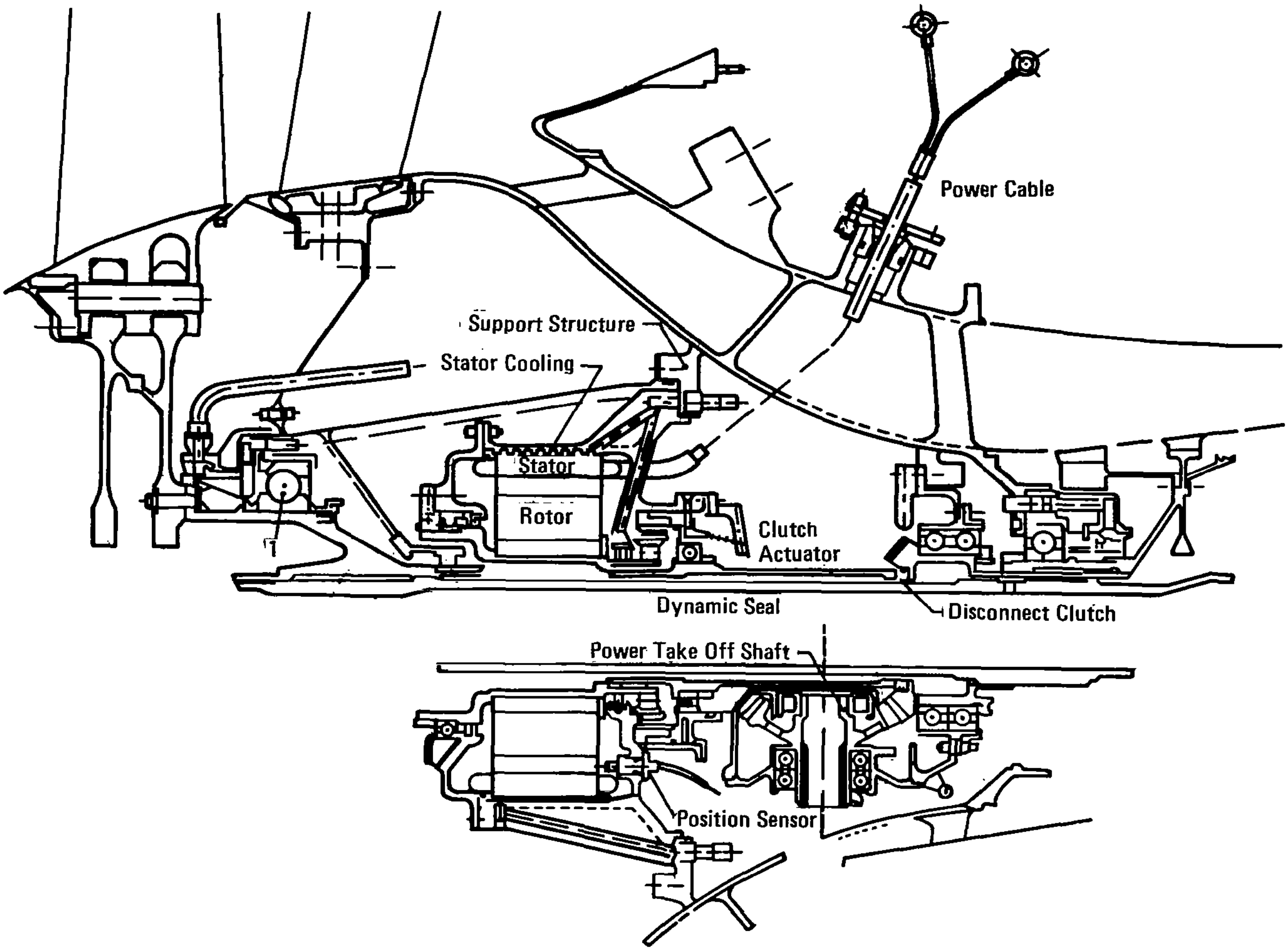


Figure 83. - Integrated engine starter/generator.

The advanced APU will be used to provide electric power for the ECS and the ground-start power-functions and furnish power to other electrical services in the airplane when the engines are not running. The sea-level rating of the APU will be in the area of 5.6×10^5 W (750 hp) to 7.5×10^5 W (1000 hp) but it will be capable of starting and operating at high altitudes. Under 7.62 to 12.19 km (25,000 to 40,000 ft) operational-conditions, the rating of the APU will be significantly reduced, but it will be more than able to supply start-power to the engines: it will also have the necessary power-capability to furnish electric power to the inverters for the FCS, avionics and other essential loads. Further, to cover the short-period of time, before the APU comes on line, two 270 Vdc 15 amp-hour batteries will provide noninterrupted power to the FCS computers (see figure 84).

Starting of the APU itself will be accomplished using a 28 Vdc battery and a conventional brush-type 28 Vdc starter-generator on the APU. Brushless-type 28 Vdc starter-generators will be available before 1986, so these will be traded off against the brush type. However, the additional weight, use and overall complexity of these brushless starter-generators may not be justified or be cost-effective in the APU-start role. Undoubtedly, such starter-generators used on small general-aviation aircraft will have significantly more application-merit since the machine will be operating continuously in the "generator-mode," when brush wear would be a problem.

Figure 84 is a simplified schematic of the emergency ac/dc power system. As shown with all generators G1 through G6 de-energized, power may be supplied on the ground by external-power or, during taxi (and in flight), by the on-board APU. The bus-tie contactors, BTCs, are a schematic-representation of the fact that all buses can be supplied by the APU or external power. In actuality, the distributed bus-sections are closed in a different manner from that illustrated. The arrangement nonetheless, shows a schematic-implementation of the actual working configuration of the electric power system.

From the diagram all ac buses (bus-sections) can be powered simultaneously with the consequence that all PDRs are also simultaneously energized. During this emergency-mode, all size generators are disconnected from the buses by the opening of the generator line contactors, GLCs. All bus sections and the power-elements connected to them can now be powered, avoiding the need for any selective-switching of individual-buses: the use of complex "go-around" emergency bus systems and "load-disconnect buses" are thus avoided. However, it is still necessary to prevent overloading of the APU-generator, so in this emergency (and in cases where there have been combination engine/generator-failures), the power/load management system automatically disconnects loads from all bus-sections, in accord with a prioritized system of load management. This management system works equally through the 3-phase 400 V 800 Hz, 3-phase 200 V 400 Hz, 270 Vdc and 28 Vdc system loads to

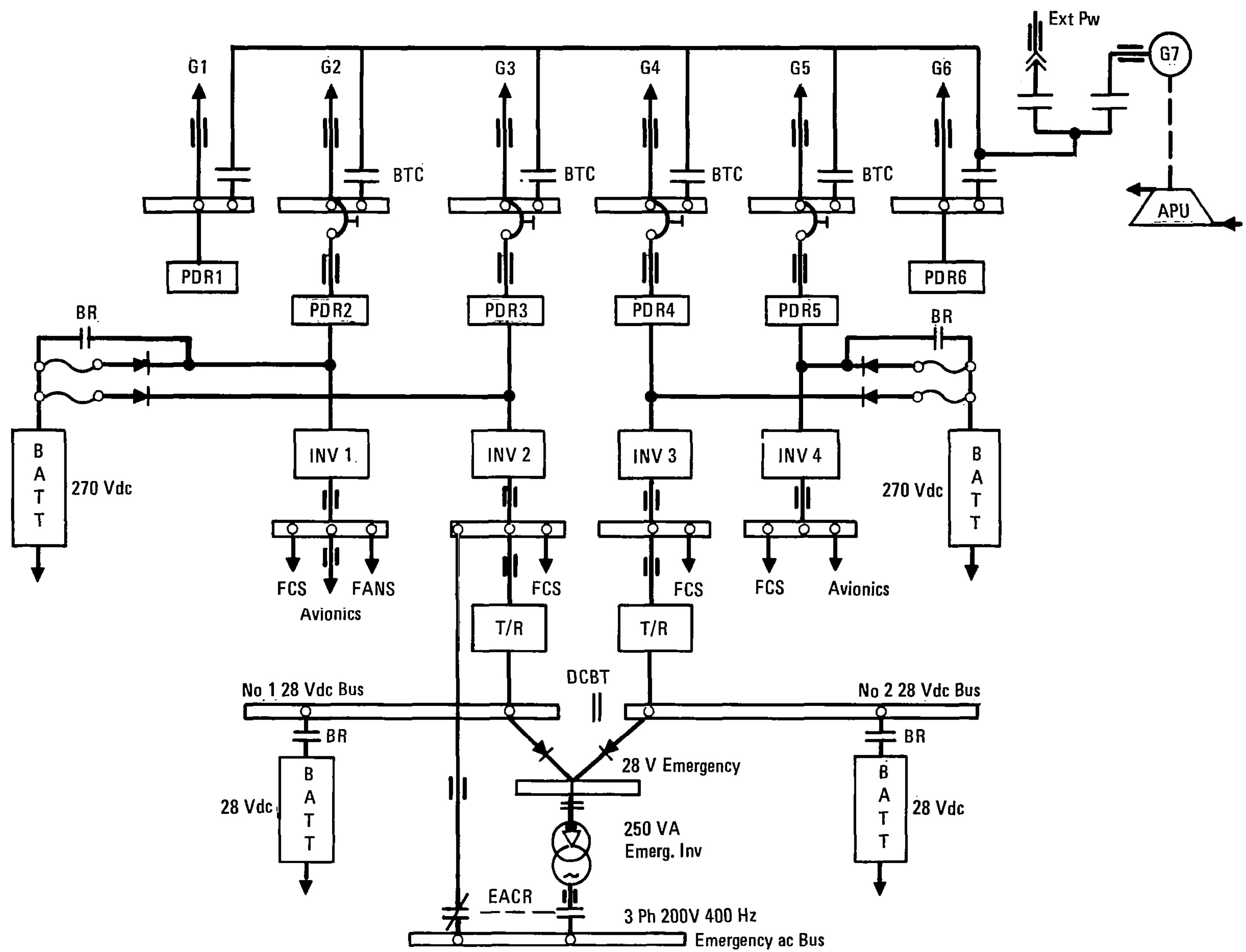


Figure 84. - Emergency electric system.

insure that none of the power elements is overloaded by the services connected to that power source. This is a superior form of load- management, compared to load-bus management and disconnect systems; it will, however, in the design phases, require detailed software planning and coordination.

As indicated in figure 84, a two 28 Vdc system is proposed, which is powered by two T/R (transformer-rectifier) units of 28 V 150 A rating. The two dc buses are normally isolated (DCBT open) but in the event of a power loss from either T/R, DCBT will close to parallel the buses. A 28 Vdc emergency bus is connected to both of the dc buses, via the isolation diodes, and this powers a few emergency dc loads, including a small 250 kVA inverter. The purpose of this inverter is to power engine instruments/fuel-gages and other small emergency loads, when primary ac power is lost. As shown, the emergency ac bus is normally powered from one of inverter outputs via the left set of EACR contacts. Logic will detect any loss of power from the inverter bus and initiate closure of the right set of EACR contacts. The contacts on the input side to the inverter will also be closed at this time. Under this condition, the emergency ac bus can be powered (through the inverter) by one or both dc buses, or one or both 28 Vdc batteries.

6.1.2.1.6 FCS/avionics power distribution: To achieve the reliability-statistics necessary for the FBW/PBW system, a minimum of four inverters are proposed for the important FCS and avionics loads. The level of redundancy provided in the airplane follows the philosophy of the baseline airplane, which provides triple-redundancy in each wing, and quad-redundancy in the fuselage and empennage. This basic wiring distribution was shown in figure 80. The inverters are supplied with 270 Vdc by four of the six PDRs (which are connected to the 3-phase 400 V 800 Hz primary ac power system) and they supply the 200 V 400 Hz constant-voltage/constant frequency requirements in the airplane. Typically, these loads will be the FCS computers, the basic utility avionic system, and certain special loads such as constant speed ac fans/motors, gyroscopic instruments, transducers, etc.

The wire-distribution system for the FCS follows the redundancy features shown in figure 68, which was used in reference 7; this related to the FBW system, and interfaced with the hydraulic actuator system in the near-term airplane. This figure shows that the FCS computers 1, 2, 3, 4, which are common to flight control surfaces, are cross-linked into the secondary-actuators to provide the following levels of redundancy for the flight control surfaces.

	Redundancy Level			
	4	3	2	1
Horizontal Stabilizer	X	-	-	-
Rudder	-	X	-	-
I/B Ailerons	-	X	-	-
O/B Ailerons	-	-	X	-
Spoilers	-	-	-	X

Evidently, as there are six spoilers per wing, the single actuator/ surface does not reflect the real redundancy-level of the spoiler system. Using the figure 68, type of cross-linking (and the downstream-redundancy at the actuator-level), it is estimated that a 10^9 reliability can be achieved for the whole FCS.

Figure 85 follows the same distribution philosophy for the all-electric FCS as the one followed for the FBW/HMAS shown in figure 68. The main differences in this schematic are that the secondary actuators are replaced with control-logic and power-electronic assemblies, as shown diagrammatically in figure 85. In figure 85, the same type FCS computers, output digital-command data over an avionics MUX (AMUX), link (not shown) to the supply three logic-units, controlling each of the three I/B aileron channels (left and right). These data in the digital bit-stream dictate the output requirement of each of the six power electric assemblies, which furnish a pseudo ac rotating-field for the SmCo (Samarium-cobalt) ac motors. These motors in turn drive through a power-hinge and reduction gear train onto each control surface. The speed of the rotating field, its direction and number of revolutions are dictated by pilot/FCS computer inputs. The surface-rate and deflections are in turn controlled by the position and stabilization feedback signals in the servo-loop.

Referring to figure 85, four insulated/isolated digital-data buses effect the same type of cross-linking as that shown in the FBW/HMAS diagram (figure 68) again, also, on the input side the FCS inverters, two emergency 270 Vdc batteries parallel onto two pairs of PDRs to provide additional power-source redundancy. The purpose for this is to cover the remote possibility of an all-engine-out (in the all electric airplane), where the utilization of RSS (relaxed static-stability) may make it essential to provide a non-interrupt type power system for the FCS.

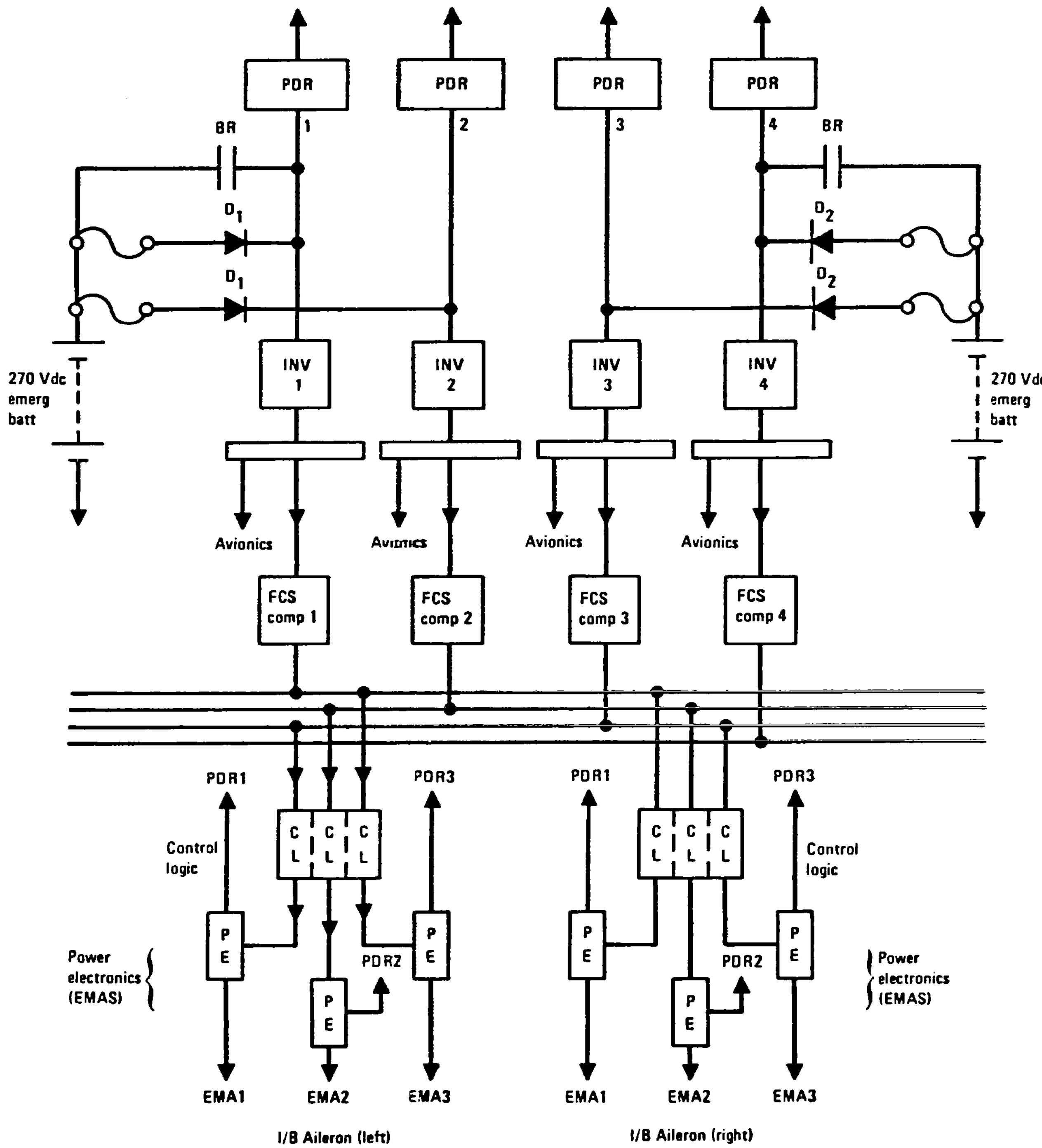


Figure 85. - FCS distribution system.

To meet the all-engine-out contingency, an advanced technology APU is installed in the empennage of the aircraft to provide emergency power in the event of multiple engine failures. Start-up and connection of the APU generator, into the power distribution system, will be effected via the digital power management system that monitors the status of the power generation system and its component elements. During the APU start-up time, the delay occasioned in tieing the APU into the power system, the two dc batteries will directly power the four inverters. Simultaneously with this, the load mangement control system will initiate an automatic-disconnection of all loads, other than those essential to flight and other essential/emergency functions. Since the delay-time, for the APU to come on line, will be a matter of only 15 to 35 seconds, the individual capacity of the two 270 Vdc batteries can be very small. However, as a conservative approach, the batteries are designed for an operational time of 15 minutes and an energy of approximately 2.0 kWh.

The 3-phase 200 V 400 hz inverters and the essential/emergency loads connected to their outputs can be provided for a period of approximately 15 minutes. When the APU comes on line, the batteries will be recharged from PDRs 1 and 4, via battery relays. These battery-relays are normally open and only closed during the recharge cycles; the batteries are otherwise continuously connected to the PDRs, through diodes D1 and D2. These diodes preserve the individual integrity of the PDRs and they protect them from any prospective short-circuit problems in the batteries themselves. Overall, this configuration of wire-distribution will provide a highly reliable quad-redundant power supply system for the FCS and avionics system.

6.1.2.2 Electric ECS: The advanced transport (configuration 6) will utilize an all-electric ECS. Two basic conditions size the capacity of the ECS: the hot day cooling requirement (with a full passenger complement), and the high-altitude pressurization requirement. Additionally, the ECS provides heating, cooling and humidity control. Figure 86 is a schematic of the system.

Cooling system: Cooling is derived from three ECS packs, which include three motor driven vapor-cycle cooling systems, which employ a reverse-Rankine cycle. A Freon R114 refrigerant is used and the freon-flow is modulated by an expansion-valve on the inlet side to each of the three evaporators.

As typical of commercial vapor-cycle cooling systems, the liquid R114 from the condenser is flashed to a low pressure, cold liquid/gas when it flows through the expansion valve. This cold liquid-gas is used for cooling the stators of the motors and, primarily, as the coolant for the evaporators (through which the cabin air supply passes). In trend with other fuel-efficient ECS configurations, a 50 percent air recirculation system is employed, so that conditioned-air from the cooling packs is mixed with filtered recirculated air from the cabin. The flow-capacity of the ECS is designed to refresh air every three to five minutes with a capability to pull-down the cabin-air temperature to approximately 24°C (75°F) on a standard 40°C (104°F) hot day in 15 to 20 minutes. An air moisture content of 0.018 (130 grains/lb) is taken as a typical value for estimating the latent heat. As planned, the motor-freon-compressor units will be high speed, hermetically sealed units and the motors will be designed for 3-phase 400 V/800 Hz and 3 phase 200 V/400 Hz ac power. Each unit will, however, provide rated cooling at the 400 Hz condition.

The trade of the alternative candidates, for the cooling system, involved a motor-driven bootstrap and the conventional vapor-cycle cooling system. The latter was chosen because of the higher coefficient-of-performance and the fact that such systems do not require a source of pressurized air. As discussed previously, there is no bleed capability on the APU compressor, and there is no APU driven compressor, so the cooling-system in the advanced configuration must be powered by the APU driven generator, or from external electric power. Motor-driven bootstrap cooling systems are viable alternatives for an all-electric ECS: the regenerative power of the expansion turbine can actually be used to reduce the horsepower capacity of the electric drive-motor. Such a system could also take advantage of new technologies, such as high-pressure water separators and air-foil bearings. The high-pressure water separator permits cooling of the air to subzero temperatures (without the problems of water freezing) and condensation can take place at a higher temperature. The air-bearing technology permits the use of high-speed turbomachinery and it offers the advantages of a bearing system that is free of lubrication. Elimination of conventional bearings and a lubrication system make it possible to put the turbomachinery on an on condition maintenance schedule.

Radiant heating of the fuselage and solar input through the windows of the stretched cabin is higher than for the comparable L-1011 airplane. With 61.265 m (201 ft) there will be some 80 windows on either side of the fuselage. Radiant heating is estimated at some 18.5 kW (63,000 Btu/hr), while the solar-heating through the windows, based on typical projected window areas will amount to some 5.6 kW (19,000 Btu/hr) (including the flight station). The sensible metabolic heat load (passengers and crew,) is estimated at some 26.4 kW (90,000 Btu/hr), while the latent-heat load is estimated at six tons. The average internal electric/electronic heat dissipation is estimated at some 16 kW (55 kBtu/h), bringing the total cooling-load estimate to approximately 87.86 kW (300 kBtu/hr). This is equivalent to a cooling capacity of 25 tons approximately which, typically, will require some 65 to 75 kW of APU external ground power capacity.

For a fully loaded 350 passenger cabin on a 10 668 m/0.8 M (35,000 ft/0.8 M) cruise flight/hot day, a cooling demand of some 11.71 kW (40 kBtu/h) is estimated; however, this small amount of cooling can be furnished by the conventional ram-air heat exchangers and will not require operation of the vapor cycle cooling system.

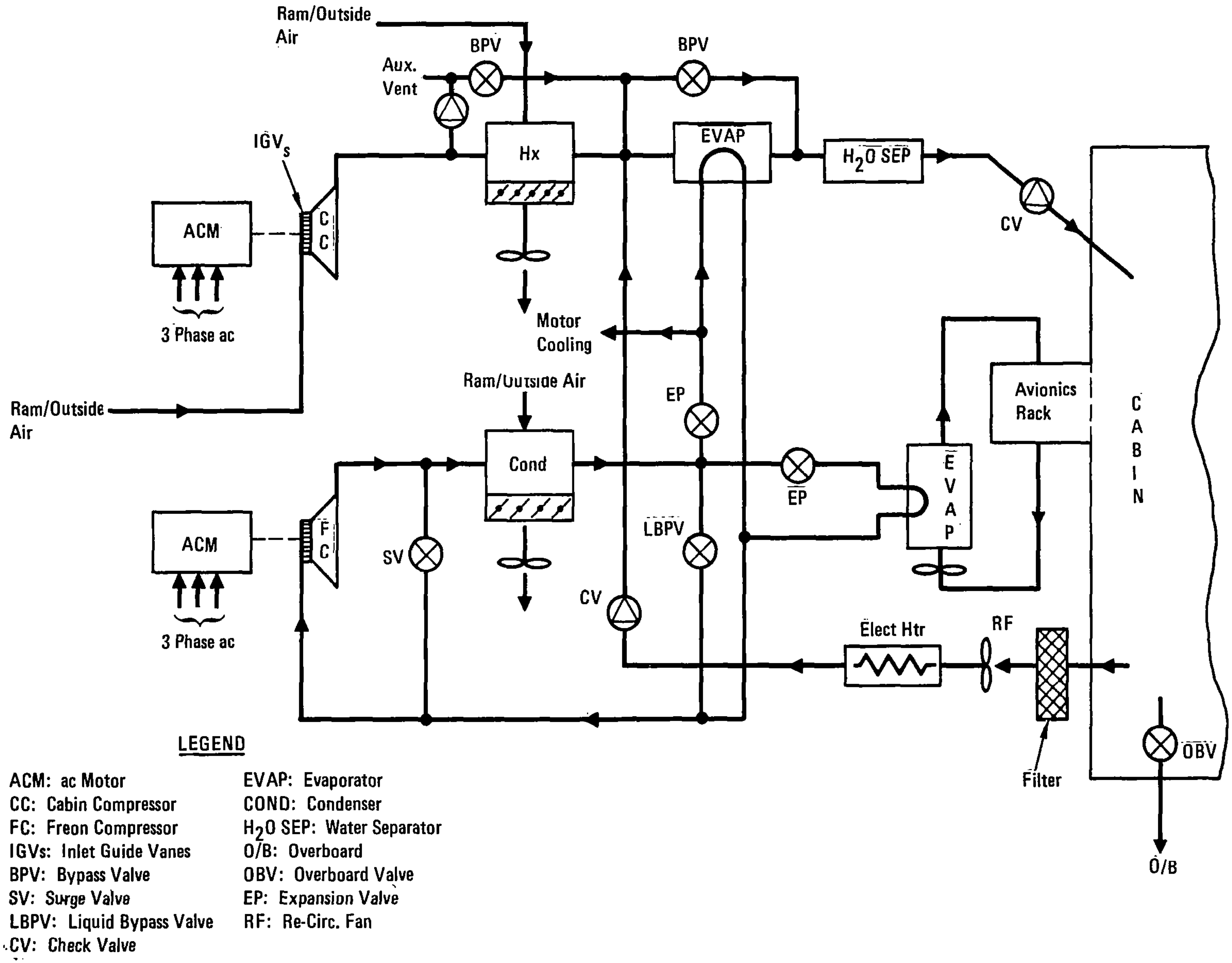


Figure 86. - Advanced electric ECS.

Cabin pressurization: The maximum pressurization load occurs at high altitude-cruise-flight. The system is designed to maintain a 1828 m (6000 ft) cabin up to 10 668 m (35,000 ft) approximately, and an 2438 m (8000 ft) cabin, up to 12 801 m (42,000 ft): the latter condition corresponds to a 75 318 Pa (10.924 psi) cabin and a (maximum) differential cabin pressure of 58 191 Pa (8.44 psi). Ventilation rate is premised on 9.1×10^{-3} kg/s/passenger and a fresh air rate (with 50 percent recirculation) of 4.5×10^{-3} kg/s/passenger (0.6 ppm/passenger). The total flow rates for the airplane are therefore 1.6 kg/s (210 ppm). With the three pack system proposed, the nominal flow capacity per electric-motor driven compressor would be 0.75 kg/s (1.66 pps), but to ensure an ability to maintain cabin pressurization, (and to provide an adequate a fresh air flow with one pack out of operation), a design compressor flow-rate of 0.79 kg/s (1.75 pps) is used. Thus, on the basis of 24821 Pa (3.6 psi) dynamic inlet pressure at 12 801 m/0.8 M (42,000 ft/0.8M) condition, a pressure ratio of 3.25:1 is required. This pressure ratio and flow-rate with two packs establishes the motor shaftpower at approximately 89.4 kW (120 hp) but, during three-pack operation, it will be about 59.6 kW (80 hp) only. The 12 801 m/two-pack (42,000 ft/two-pack) operation therefore represents an infrequent loading condition for the motor and compressor unit.

Refinements of the motor-compressor units used in the included variable inlet guide vanes and a pole-changing motor, which allows for two-speed operation. This speed changing capability and the facility for changing inlet guide vane angle, enable the compressor to maintain pressurization conditions under all flight conditions. For example, under conditions of high atmospheric pressure and high air density (as at low altitudes), the motor operates at say 3513 rad/s (24,000 rpm) (nominal) with the IGVs operating near these closed position. From 1828 m (6000 ft) to some higher altitude 4572 m (15,000 ft), the IGVs are modulated to maintain the 1828 m (6000 ft) cabin altitude condition until the IGVs reach a fully-open position. Any increase in altitude above the point will result in a drop in duct-pressure which (through the processor-control) will initiate a change in the motor speed up to 5027 rad/s (48,000 rpm) nominal (synchronous-speed minus slip). At this point the IGVs will revert to their near-closed position. Further altitude-increments will then modulate the IGVs to their open position, until at 12 800 m (42,000 ft) they will again be fully open.

Cabin heating: Heating of the cabin on cold high-altitude night-conditions, etc., will be by heat-of-compression. Typically, with a 3.2:1 pressure-ratio, the discharge-temperatures from the compressors will be of the order of 93.3°C (200°F) or more. A degree of cooling is therefore always required and, this can be obtained by means of conventional ram-air heat exchangers. During low altitude and on the ground operation (with maximum passenger-complement and standard-day temperatures) the cooling-capacity of the ram air heat exchangers may be supplemented by the vapor-cycle cooling system. Electric heaters are provided and may be used during conditions of low-altitude cold-night operation, when the pressure rise across the compressors, may not provide sufficient heating capacity. These heaters will be located in the air-recirculation ducting, and they will be modulated by phase-angle control of SCRs.

For further study, relative to the far-term advanced-technology airplane, there is significant room for new innovative concepts, that might be uniquely applicable to the all electric ECS. There is also need for further and more detailed studies of the configuration of the all electric ECS and indeed, the competitiveness (efficacy) of 50 percent recirculation systems. There is no doubt that the 50 percent reduction in fresh-air content is a compromise to the cleanliness of the air, and while such recirculation is used in commercial and residential applications, the passenger-to-aircraft volume density will require highly efficient filters. Practically, in a three-pack system, the three packs need only be used when there is a maximum passenger complement: all other times, when there is a typical load-factor of 65 percent, one pack could be switched off to effect a 33 percent (ECS) fuel-reduction on the engines.

It is also pertinent that the degree of circulation could be dependent upon the reliability of the recirculation fans. If there were three such fans in the installation, the impact of single or multiple-failures of these fans would have to be evaluated in relation to the reduction in the total cabin in-flow-rate. However, the acknowledgement of a failure of one ECS pack is more pertinent, because it would still be necessary to supply the design minimum of fresh air per passenger. Therefore, for a 350 passenger transport, the normal 3 pack fresh air flow would be 1.6 kg/s (3.5 pps) or 0.53 kg/s/pack (1.17 pps/pack), and this would be inadequate for 2 pack operation. The individual pack rating would therefore have to be increased to 0.80 kg/s (1.75 pps) (a 1.5:1 increase) to maintain the minimum fresh-air requirement. As an alternative, a 100 percent fresh-air system would required 1.057 kg/s/pack (2.33 pps/pack) and under 2 pack operation it would still provide 33 percent more fresh air than required: also it would save approximately 127 kg (280 lb) by deletion in the weight of the re-circulation hardware. The reliability of the system would also be improved by the elimination of the fan, etc. Therefore, while a 50 percent recirculation ECS is proposed for the advanced configuration, it is recommended that some further study and evaluation be made of 100 percent fresh air systems that by the use of innovative concepts and practical operating techniques, could offset the disadvantages that presently reside in the 50 percent recirculation system.

6.1.2.3 Icing protection: The present use of engine bleed air for wing/engine anti-icing, floor/wall heating, and other functions (such as thrust reversers) is another consideration that impacts on the all-electric airplane. To meet the objective of an all-electric SPS it is necessary that these and other functions be powered electrically.

Engine deicing, historically, has come under the provision of the engine supplier, who has usually selected hot bleed air to protect the engine lips and the compresser stages against ice build-up. Also, it is possible that, since a continuation of this policy would still keep the ducts within the confines of the power-plants, hot-air deicing of the engines might still be a tenable premise. Spraymat-type anti-icing, which utilizes resistance heating through sprayed on electrical conductive mats, could be considered since this appears more adaptive to the double curvature sections of the engine inlet system. Electric deicing approaches are not acceptable inside the engine.

Wing anti-icing/deicing is another matter. Here, a continuation of hot bleed air deicing would result in high temperature, high pressure ducting being brought outside of the power-plants into the wing area; this being undesirable, electric deicing is proposed in the advanced configuration.

Electroimpulse deicing: Electroimpulse deicing was selected because of its fuel saving advantage. Other benefits over the baseline pneumatic system include: reduced system weight, reduced acquisition cost, and improved applicability toward most fixed-wing aircraft. Electroimpulse deicing is a special form of deicing which provides an almost 10:1 reduction in power demands. Spanwise-spaced coils mounted in close proximity to the wing skin create a localized deformation of the skin when energized by large electric currents (in a sequential pattern) from a capacitor discharge system.

One of the reasons the electroimpulse system is power efficient is that its deicing capability is independent of outside air temperature and liquid water content conditions.

A significant disadvantage of the electroimpulse system is that the wiring structure must be designed especially to accommodate the installation and the skin must be capable of some elastic deformation. Fatigue stress or other metallurgical considerations have not been raised as a problem in this form of deicing system. Another problem, which will require preventative design control, is the consideration of the potential EMI problems.

Electrothermal deicing: Electrothermal deicing is an alternative system proposed for deicing of the slats and general wing area.

In this system, the leading edge slats are made up of an aluminum deice boot, which is actually the structural leading-edge panel of each slat panel. Stamped, or chemically etched, stainless-steel heater elements are sandwiched between an outer and inner layer of electrical insulation; the thickness of the outer insulation is thin enough to allow good heat-transfer to the outer skin surface. Primary ac power would be used for the deice boots and, this power could be introduced into each slat panel via a flat-cable deployed from a flat-cable cassette located in the fixed wing section behind each panel.

Electrothermal deicing has been used many times for small areas and can be used for wing deicing of large transports where an abundance of cheap (in terms of fuel) power is available. System capacity requirements would not be seriously affected by thermal deicing since galley power usage can be curtailed for periods of peak deicing.

6.1.2.4 Electromechanical actuator: Electromechanical actuation incorporates power-by-wire and fly-by-wire systems to provide the flexibility and efficiency inherent to both systems. EMA uses electrical power directly and avoids the electrical to hydraulic power conversion penalty. It carries the inherent capability to convert a digital command to an analog force output within the actuation unit.

Two major actuation features are: closed loop position servo circuits using analog and digital techniques, and permanent magnet 270 Vdc motors using brushless commutation and rare earth cobalt magnets in the rotor assembly to achieve high acceleration and torque in a minimum space and weight. Rare earth dc motors are efficient for the following reasons: There is little or no heat generated in the rotating parts, no commutator brushes to wear out, and high strength permanent magnets provide high holding torque with low stator current. This motor offers a 16 percent improvement in acceleration capability, a 17 percent weight savings, and twice the operating duty cycle compared to a conventional commutating dc motor.

The functions performed by the EMA unit are: respond to command signal inputs from the aircraft flight control system, provide electric current and voltage control to an EM drive unit, match and apply the rate and torque output of the drive unit to the aircraft control surface.

One of the advantages of EMAs compared to hydraulic actuators is low maintenance; no periodic maintenance is required whereas hydraulic actuators require periodic checks for filter replacement, repair of leaks and fluid level refills. There are reduced hazards with EMAs because there are no corrosive or flammable fluids involved.

While the electromechanical actuator, as a separate unit, is approximately the same weight as a hydraulic actuator, when the whole EMA system (including power source and distribution) is compared to the whole hydraulic system, the EMA's shows an advantageous weight savings.

Figure 87 is a representation of an AiResearch EMAS for application to the No. 1 spoiler panel of the baseline aircraft "power hinge" type gear reduction transmission to power the surface. This EMAS is used, in various motor/actuator combinations, to power the primary flight control surfaces for this airplane configuration.

6.2 Plans and Costs

6.2.1 Plans and costs - active controls. - Development plans have been defined for the following active controls technologies:

- RSS
- FBW
- CGM
- MUX for flight controls

Figure 88 is an active controls plan overview, to show relative lengths and validation dates of the major technology schedules.

6.2.1.1 Relaxed static stability: A plan and cost summary table is provided (figure 89) which lists the costs of major technologies and cost totals for active controls. The table has two parts: application of the active controls element to the conventional wing, and application to the advanced wing. Technology levels differ in places for the two applications, costs therefore differ as well.

Included in the development plan for RSS is an extensive plan (see figure 90) for development of a non flight-critical RSS technology (Phase I) and a flight-critical RSS plan (Phase II). In addition a development schedule was borrowed from the Small Tail Program (NASA Contract NAS1-15326). The man-year and cost accounting for RSS was obtained by summing the extensive small tail and RSS plans.

6.2.1.2 FBW/MUX (HMAS and EMAS programs):

Development cost: $92M, $142M
Readiness year: 1988, 1990
Refer to figure 93

The ultimate goal behind the FBW development plan presented in figure 93 is proving to the airlines, the FAA, and the public, that the FBW flight control system is as reliable as the airframe structure. Toward this goal, the FBW plan must take an evolutionary path which slowly wins acceptance, first by application to non-critical flight control surfaces and then to more critical ones.

FBW will at first be patterned toward the intermediate goal of validating a redundant digital FBW flight control system (FCS). To start, the spoiler mechanical FCS should be removed from the transport and modifications made to the existing spoiler servos for FBW. This will yield immediate payoffs for the customer airlines in weight savings and reduced maintenance costs, promoting their acceptance. The spoilers are not flight critical. Simplex redundancy is all that is required at each spoiler surface. Therefore development and certification should go quickly. Some major airframe manufacturers may choose to leapfrog this step by going to an EMAS spoiler system immediately.

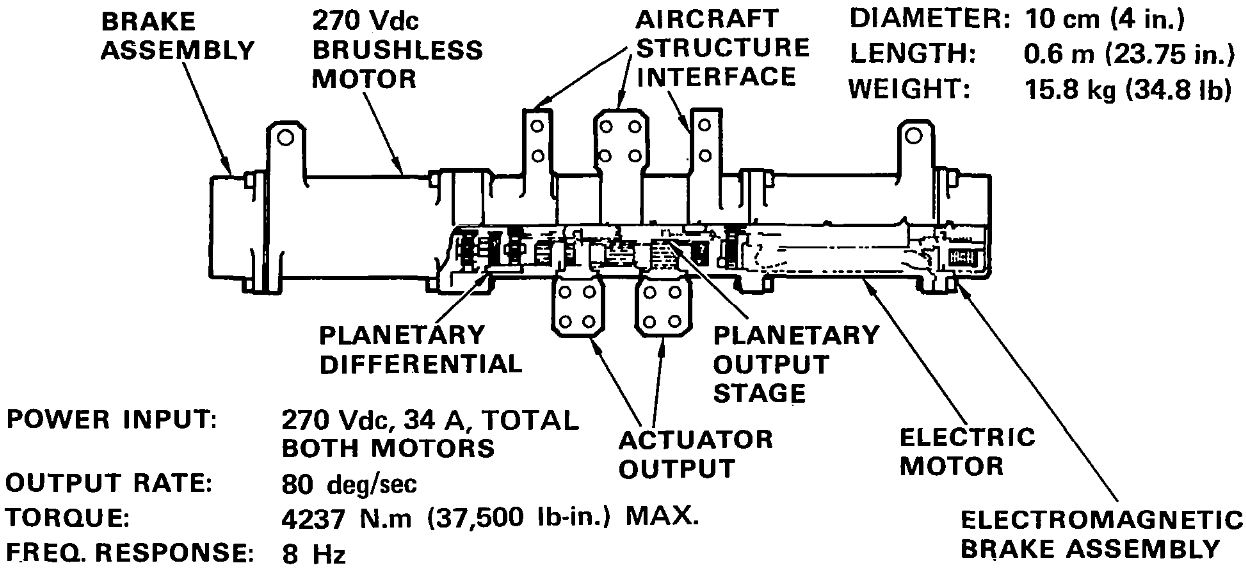


Figure 87. Electromechanical flight surface control actuator (AiResearch).

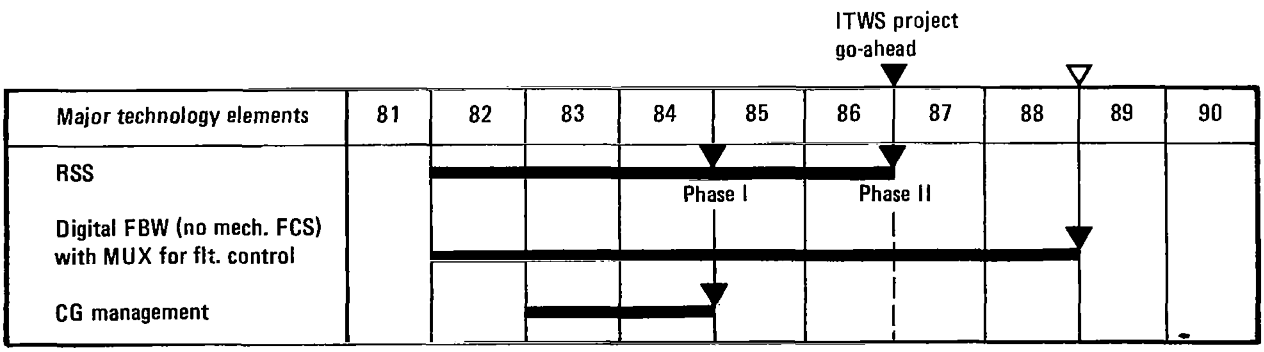


Figure 88. - Active controls plan overview.

Technology	Readiness year	Man-years (MY)	Cost(M$)	Risk (L,M,H)	
Conventional wing (config. no. 5)					
RSS phase I (figure 90)	84	40	4.6	L	
ACEE/EET (figure 91)	83	55	8	L	
FBW/MUX	88	1150	92	H	
	88	1245	105		TOTALS THIS CONFIG.
Advanced wing (config. no. 14, 15, 16)					
RSS phase I & II (figure 90)	86	110	11.6	H	
ACEE/EET (figure 91)	83	55	8	L	
FBW/MUX	88	1150	92	H	
CGM	84	20	1.5	L	
	88	1335	113		TOTALS THIS CONFIG.

Figure 89. - Active controls plan and cost summary.

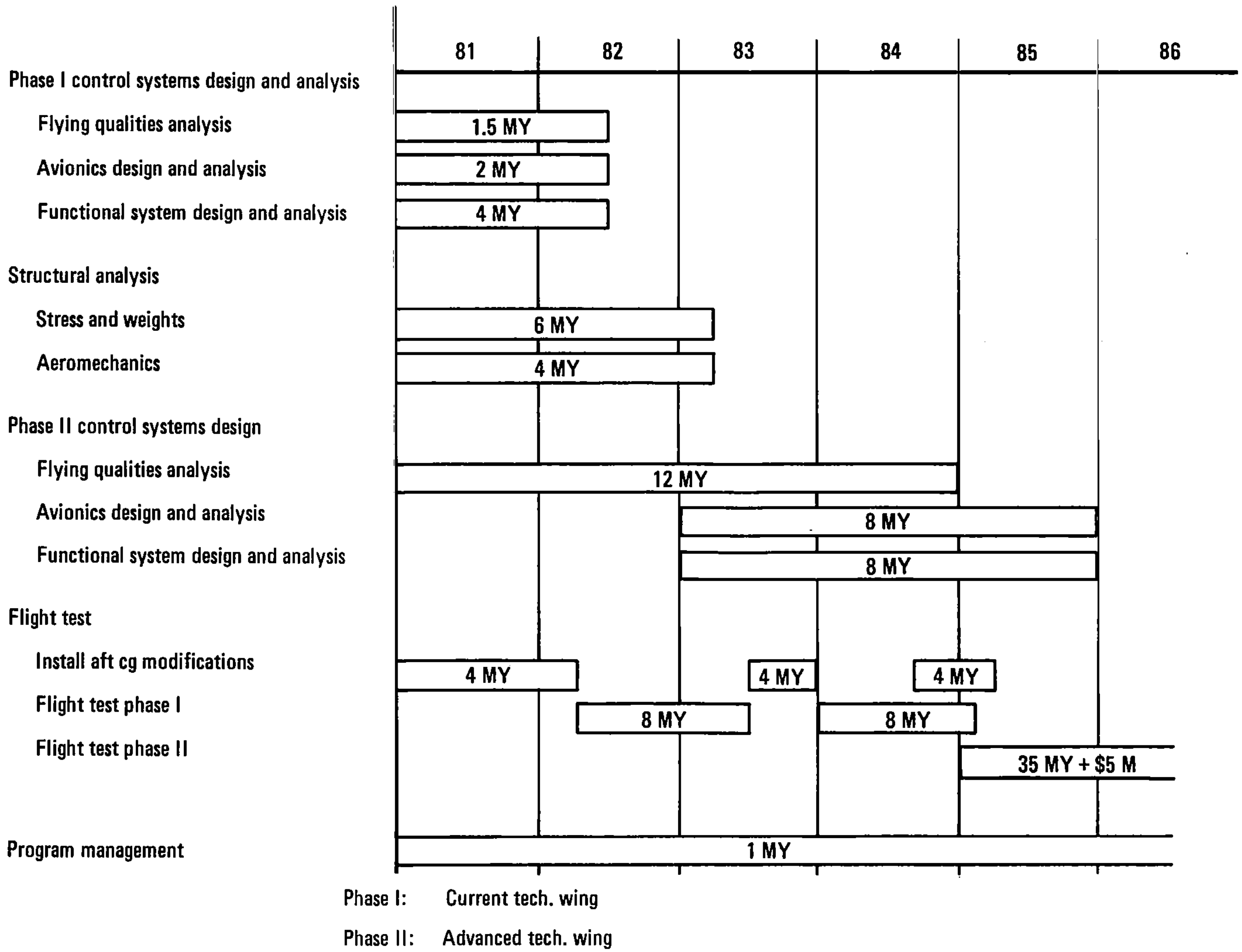


Figure 90. - Advanced RSS technology development.

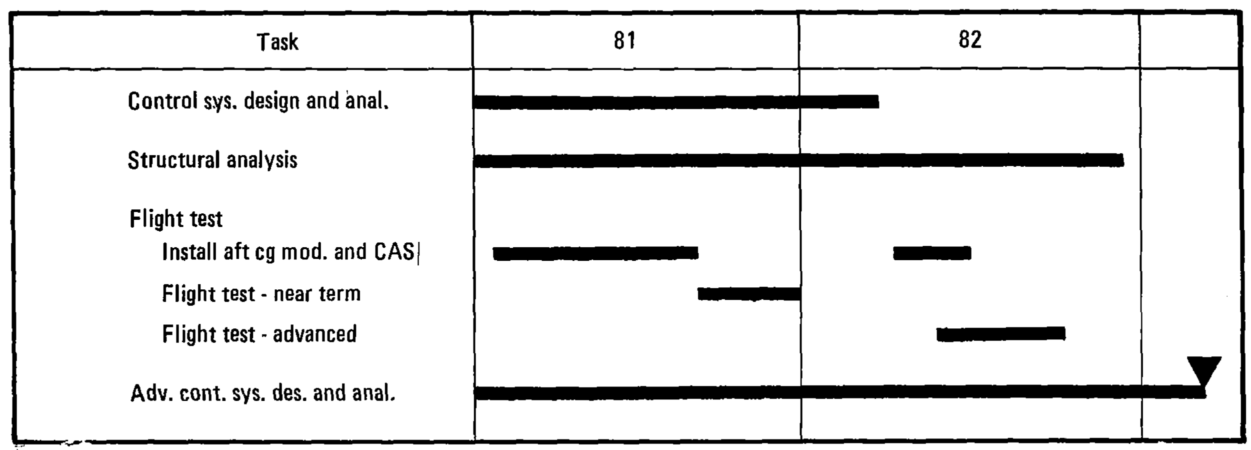


Figure 91. - RSS/pitch active control technology.

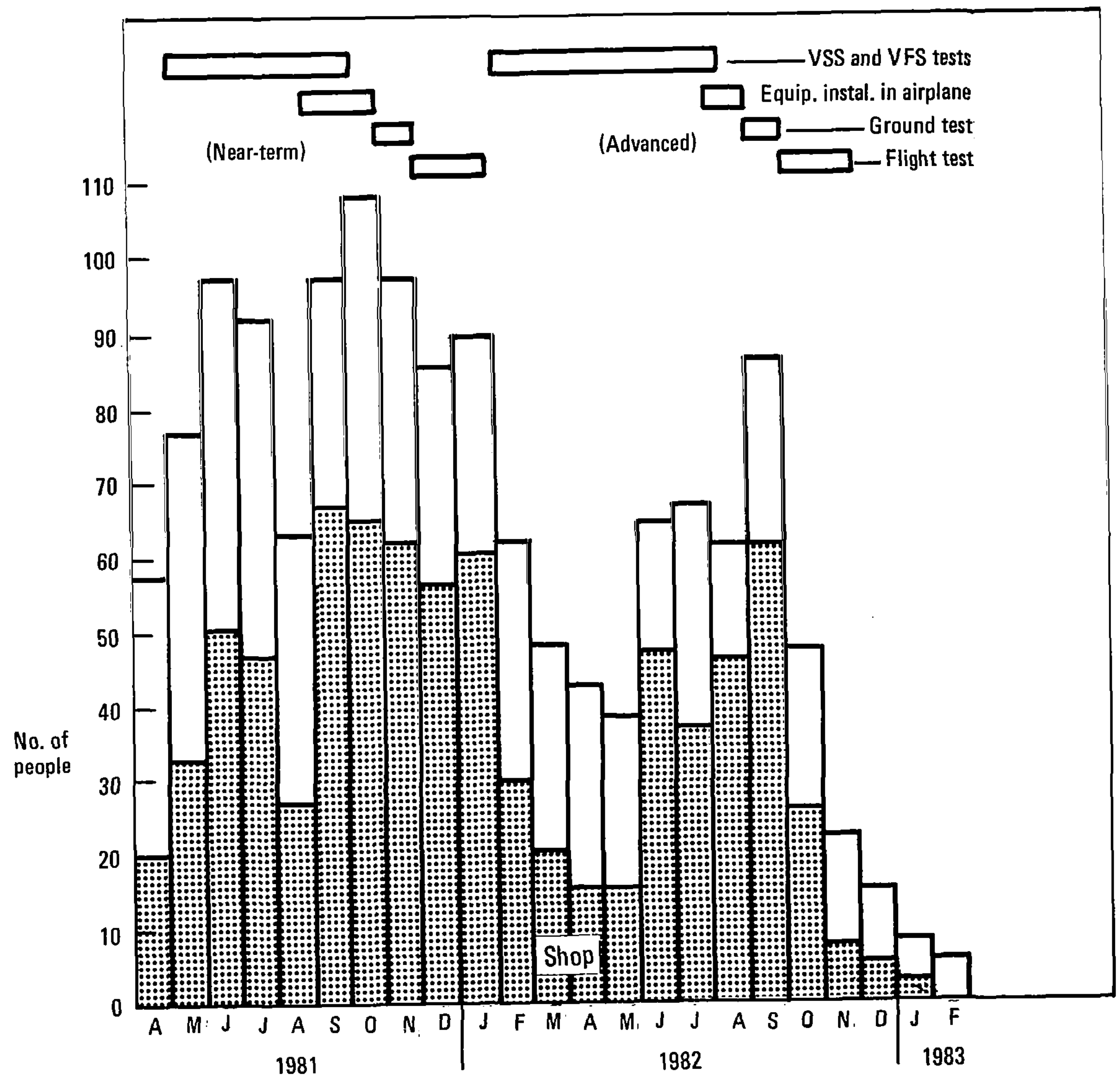


Figure 92. - RSS manpower requirements.

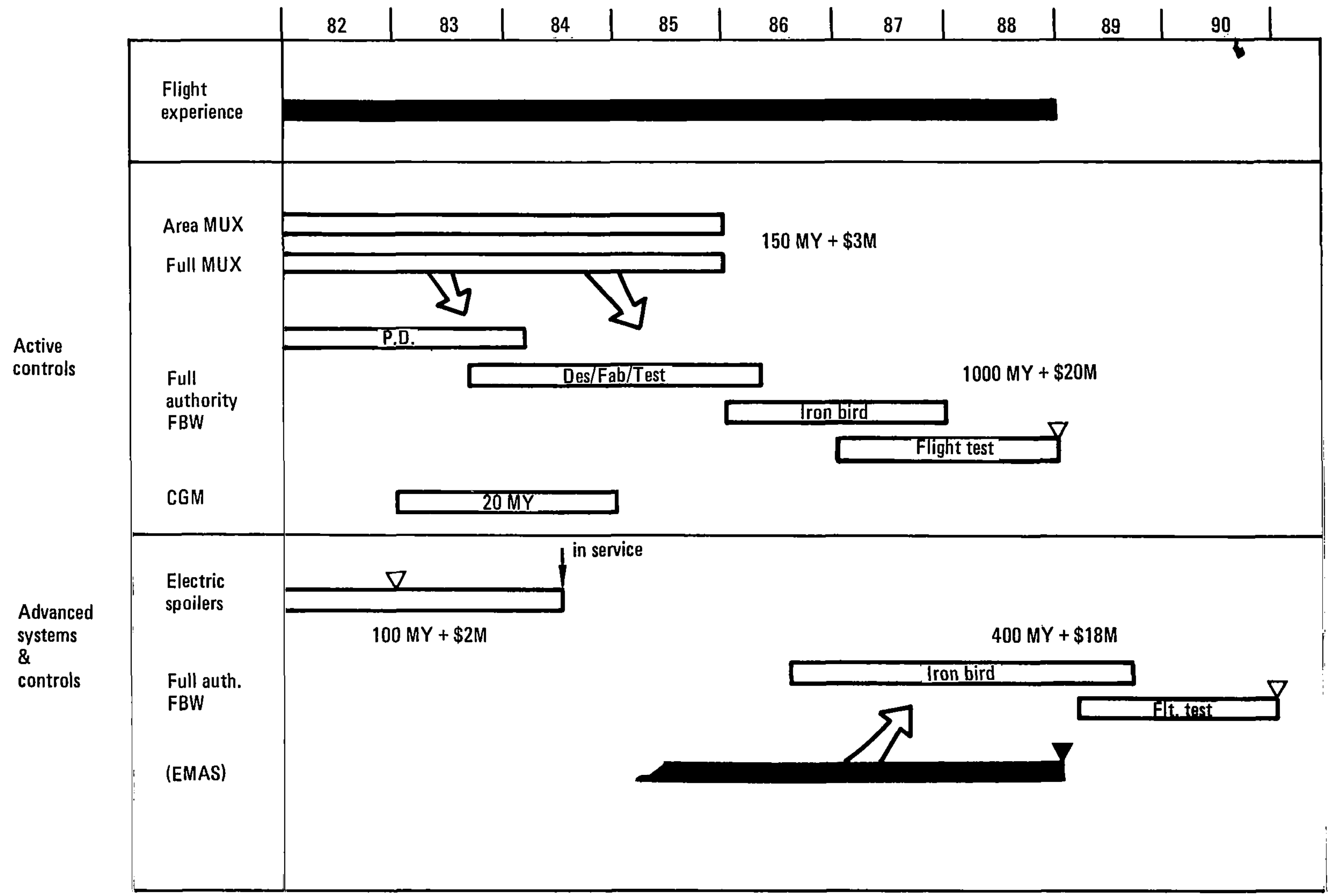


Figure 93. - FBW development, MUX.

The FBW spoiler system can be expected to be validated and in service by the end of 1983 for an electrohydraulic actuation system (EHAS), and by the middle of 1984 for an electromechanical actuation system (EMAS). Progressing in parallel to the spoilers development should be a separate all axis (yaw, roll, and pitch) development program for a FBW flight control system. The all-axis program will include research and development of FBW for all primary and secondary flight control surfaces.

At first this all-axis program will develop FBW with hydraulic servo-actuators to move the surfaces. Redundancy schemes, fault tolerant hardware/software and fault tolerant computer experiments will be conducted to develop a full FBW flight control system utilizing hydraulic secondary power (HMAS) and no mechanical backup.

Development for the FBW (HMAS) flight control system calls for iron-bird (systems simulator) testing and flight testing of a FBW airplane. This can be completed by 1988. Drawing on the flight experience of existing FBW and future FBW airplanes such as the Concorde, F-16, F-18, and the Jaguar, enough confidence should have been acquired by 1988 to win acceptance of the advanced FCS.

Development of FBW/PBW utilizing EMAS for the flight controls is dependant upon the progress and completion of EMAS actuator development by 1988. Most of the FBW validation work will have been done by the FBW/HMAS system development program, and an advanced electrical SPS (secondary power system) will also have been validated. Ironbird and flight testing of the new EMAS actuators integrated with MUX/FBW and advanced SPS will be necessary for validation by 1990.

The FBW/MUX plan (figure 93) includes a schedule for the development of digital FBW, and multiplexing for load management as well as for flight controls. Figure 93 also shows distribution of costs.

6.2.1.3 CG management (CGM):

Development cost: $1.5 M
Readiness year: 1984
Refer to figure 88

The development cost for CGM includes $1.2 M for 20 MY of labor and about $300K for materials to build a mock-up of the system. The labor should include the general tasks: definition of criteria, preliminary design and structural analysis, construction of integral tanks in a vertical tail and simulated horizontal tail section, and testing of the complete fuel pumping system (microprocessor, check-valves, gravity-feed feature, etc.). Testing should include iron bird simulation testing; where the system (especially the fuel tanks) can be subjected to different structural loadings and vibrations.

One precedent development of a CGM system exists that is similar to the one proposed; the Concorde SST fuel pumping system. The Concorde system is designed to shift the cg aft for trim drag fuel savings also. But its trim tank is in the aft fuselage section, and not integral with the tail planes as the proposed one is. It is because the proposed system has never been attempted before, for an advanced transport, that an integration development/ testing is necessary before an aircraft development go-ahead.

6.2.2 Advanced systems and controls. - Plans have been defined for the technologies shown in figure 94. This is the plan overview for this airplane configuration. Three of these technologies, power distribution, EMAS, and fly-by-wire, finish their development beyond the 1986 readiness date, but are considered important for this configuration as they are crucial to the overall development of the all-electric airplane.

A cost summary for these technologies is presented in figure 95. Total development cost for this configuration is $216M.

6.2.2.1 Starter-generator system (S-GS):

Development cost: $7.0M

Readiness year: 1985

Refer to figure 96

The plan shown in figure 96 includes the development of the advanced power generation-starting system. Advanced power generation (APG) development and engine starting system development will at first be conducted separately. A cross-flow of information between the two developments will follow through to integration design where both functions of the starter/generator will be addressed.

The APG system development plan also includes the developments of power distribution and load management, and will lead to iron bird testing of a total APG system. During testing, this system will be subjected to abnormal electrical loading (as occurs with surges, voltage spikes, subsystem failures), as well as the electrical loading which would occur for an all-electric airplane during a typical flight.

Engine starting hardware will be lab tested by starting an inertial load under various conditions. This will lead to eventual start-testing of a engine on a test stand. Total cost of the program will be about $7.0M.

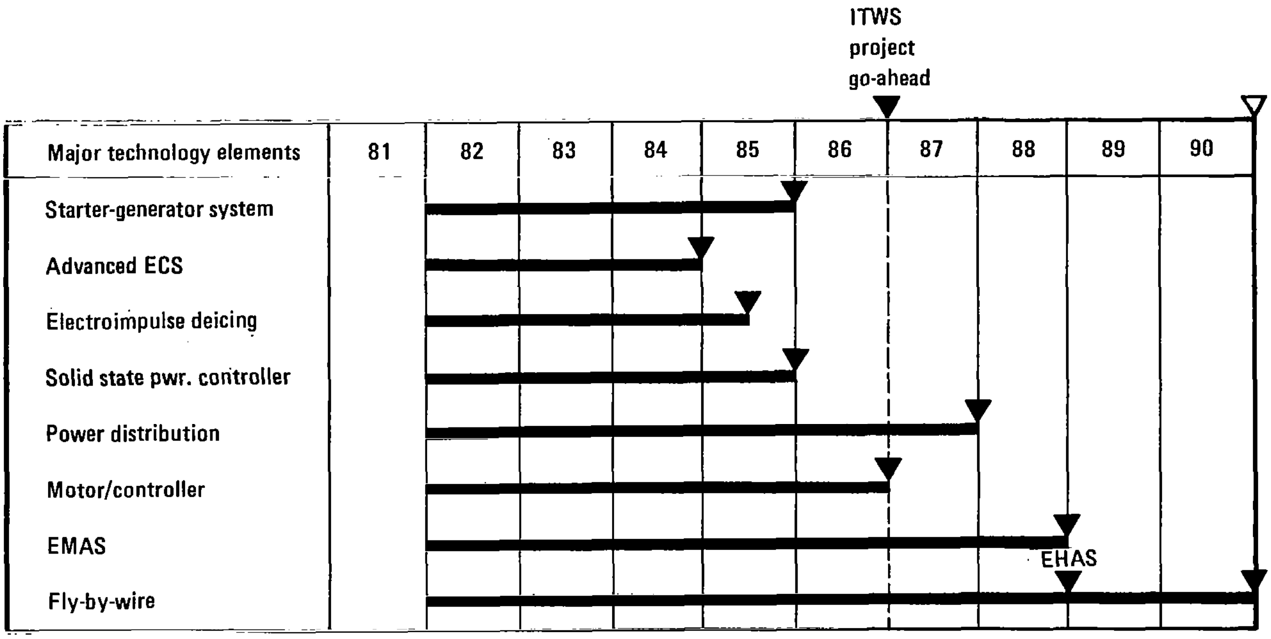


Figure 94. - Advanced systems and controls.

Technology	Readiness year	Manyears	Cost (M$)	Risk (low, med, high)
Starter-generator system	85	116	7.0	L
Electric ECS	84	74	5.0	L
Electroimpulse deicing	84	24	1.7	M
Solid state power controllers	85	147	6.0	M
Power distribution	87		10.0	
Motor/controller technology	86	*	*	H
EM actuator systems (EMAS)	88	790	39.0	H
Multiplexing-load management	87	50	5.0	H
Fly-by-wire	90	1650	142.0	H
TOTAL	90	2851	216	

* Accounted for in EMAS cost (next line down)

Figure 95. - Advanced systems and controls, plan and cost summary.

6.2.2.2 Solid state power controllers:

Development cost: $6M

Readiness date: 1985

Refer to figure 97

SSPC technology development will have to include research/testing directed toward resolving the following questions.

1. Can they be designed/packaged to perform well in a hostile environment?

   - vacuum
   - high altitude
   - moisture

2. Can they be designed to meet precise performance requirements?

3. A SSPC will have to be able to carry a certain rating amperage under normal conditions and be able to open or close during spike/surge conditions when the current may be as much as ten times the rated current.

   - what is the optimum size for continuous rating?
   - how large a current can be interrupted?
   - how many interruptions is a SSPC capable of?

4. What is the optimum design for minimum heat dissipation? It may be that a mechanical switch wired in parallel with a SSPC (for long-term loads once SSPC has switched on) may be the best way to keep from losing power through heat dissipation. Perhaps SSPC efficiencies can be improved.

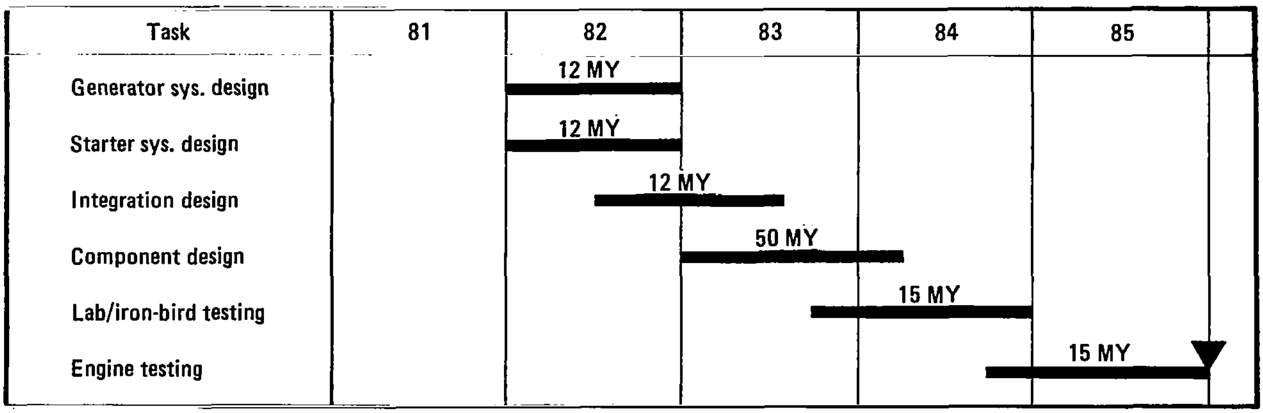
   The Army, Navy, and Air Force all have programs for SSPC technology development.

6.2.2.3 Electric ECS

Development cost: $5.0M

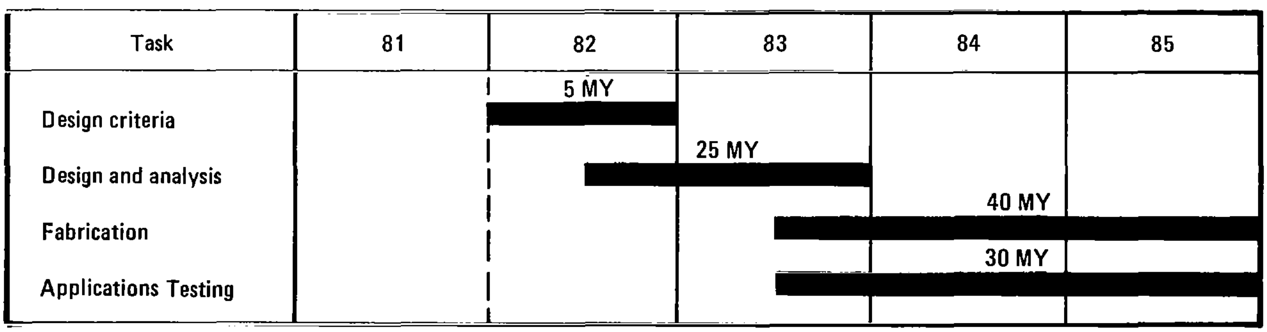
Readiness year: 1984

Refer to figure 98



116 MY
M$ 6.96 labor
M$ .28 material

Figure 96. - Starter-generator system.



147 MY

$6.0M labor
$ .3M material

Figure 97. - Solid state power controllers.

Development of an advanced all-electric environmental control system (ECS) will first begin with an examination of alternative energy-efficient candidate approaches: electrically driven bootstrap, vapor cycle, regenerative, etc., followed by preliminary design of one or more selected candidates. Component hardware design and fabrication for the final candidate will follow, and a prototype system developed to be eventually coupled with the prototype advanced power generation system on an iron bird for testing in a simulated all-electric aircraft environment. Work will be planned from the start with cooperation from suppliers such as AiResearch, and with the major airframe manufacturer as the prime contractor.

Referring to figure 98, the plan calls for a total expenditure of $4.88 million: $4.44 million for 74 man-years of labor and $440,000 for material costs.

6.2.2.4 Electromechanical actuator systems:

Development cost: $39M

Readiness year: 1988

Refer to figures 99, 100, and 101

A plan for EMAS development was outlined with the assistance of AiResearch Co., one of several controls/actuation manufacturers doing research with 270 Vdc SmCo motor/actuators for powering primary flight control surfaces (figure 99). As shown in the figure, the plan is organized into the task sections of motor, controller electronics, controller inverter thermal management, mechanical components, and controls.

Technology needs includes technologies whose development is thought necessary for readiness of a flight worthy EMAS for all flight control surfaces of the advanced transport. Also included, but not accounted for in cost and manning predictions of figure 100, are technology pursuits considered desirable, but unnecessary. Desirable technical needs are developments which would simplify or allow greater flexibility in design procedures.

- Motors: The availability of rare-earth material (such as SmCo) for permanent magnets at reduced cost and increased production volume will be necessary for future EMAS. Magnets with large energy products (20 to 30 x 10^6 gauss-oersted) in large commercial quantities will allow the development of smaller, lighter motors, with higher specific power and power-rate capabilities. Increasing motor speeds allows reduced motor size and weight for a particular power requirement. Motor and gear-train reliability may vary with motor speed. Optimum speeds for reliability need to be investigated.

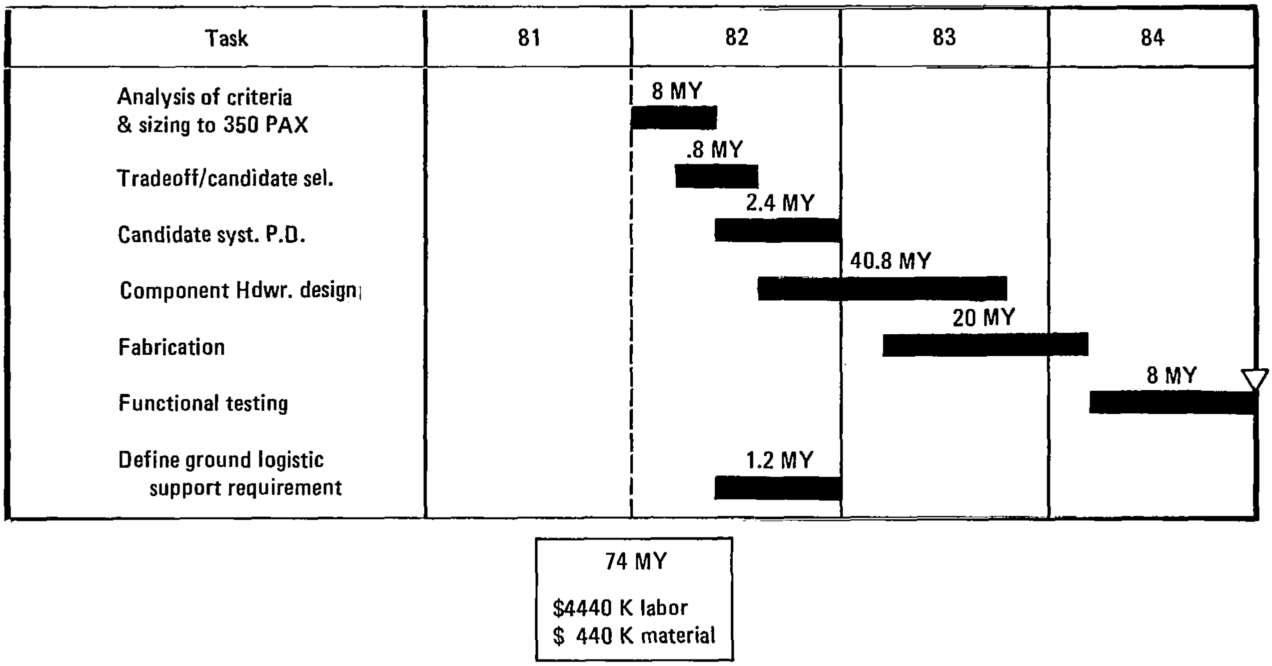


Figure 98. - Electric ECS.

Selection is the desirable technology need which concerns development of criteria for motor selection for various applictions. Improved motor selection methods would allow faster preliminary design, and avoid motor overdesign. Development under the heading of manufacture concerns improving methods permitting favorable motor geometry (large length-to-diameter ratio).

- Electronics: High current, high power metal oxide semiconductor field effect transistors (MOSFETs) will ameliorate thermal management problems. These criteria would be established for the flight control applications of aircraft similar to the baseline. Inverter design problems which need to be addressed include a) inductive energy dissipation requirements and b) overvoltage conditions due to motor overspeed (from an aiding load on the flight control surface).

- Inverter Thermal Management: Work needs to be done in the areas of inverter design analysis and optimization, inverter coolant performance over long durations, and evaluation of heat sink performance in various inverter applications.

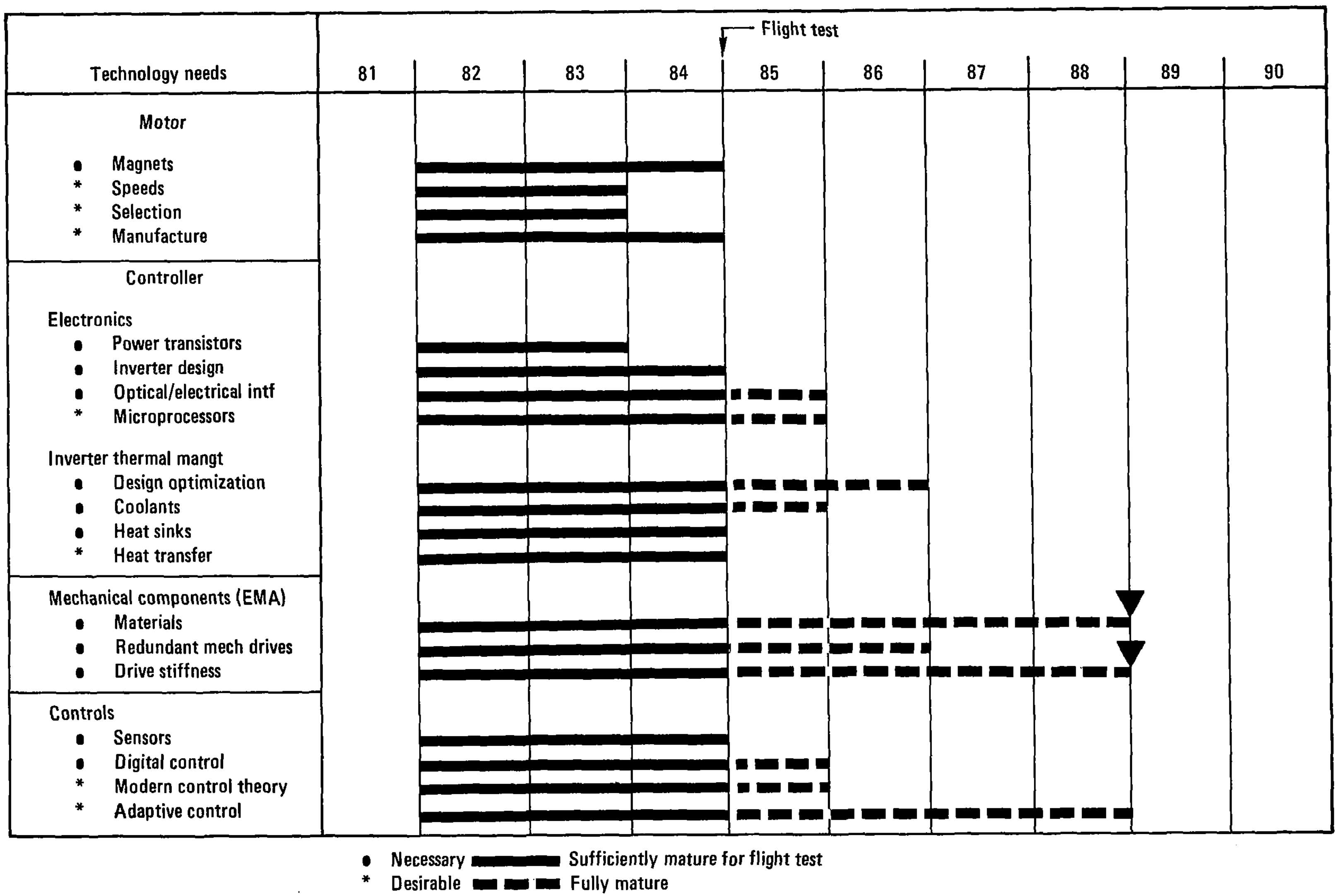


Figure 99. - EMA and motor/controller

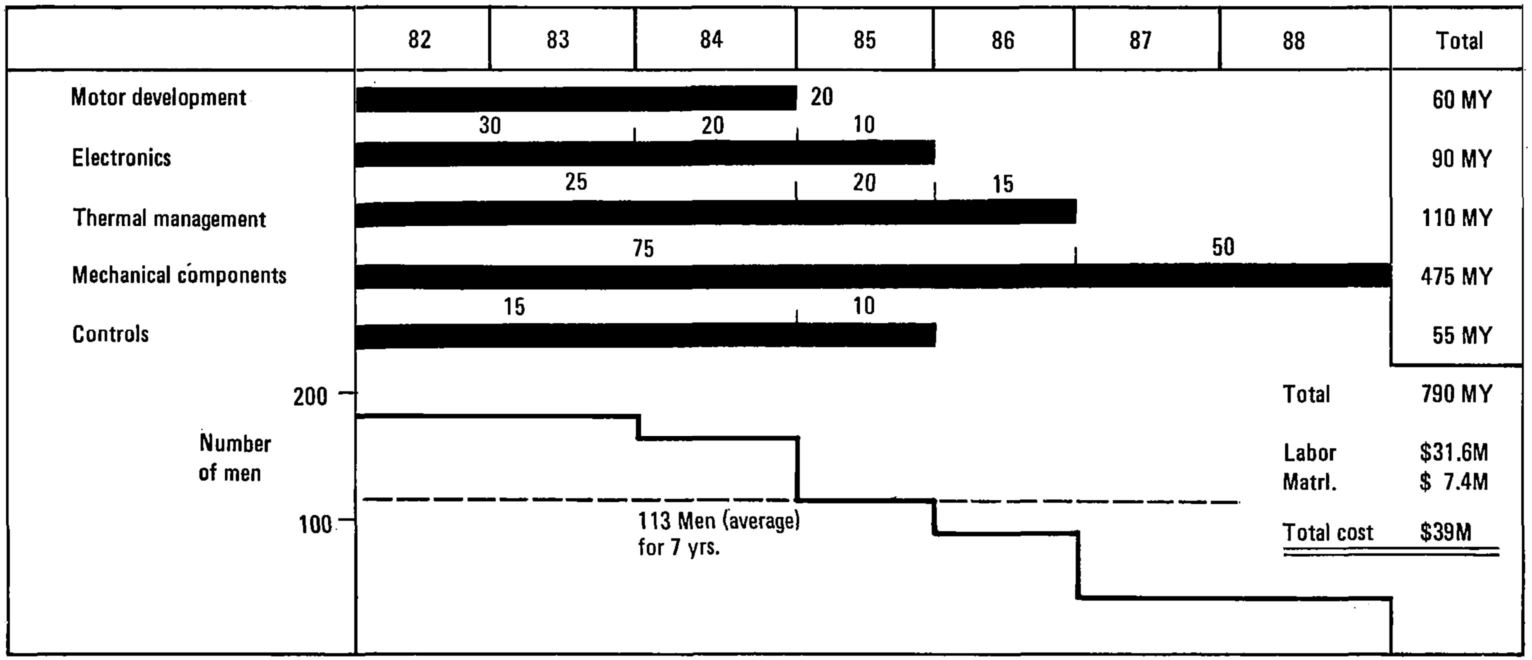


Figure 100. - EMAS - labor, materials and costs.

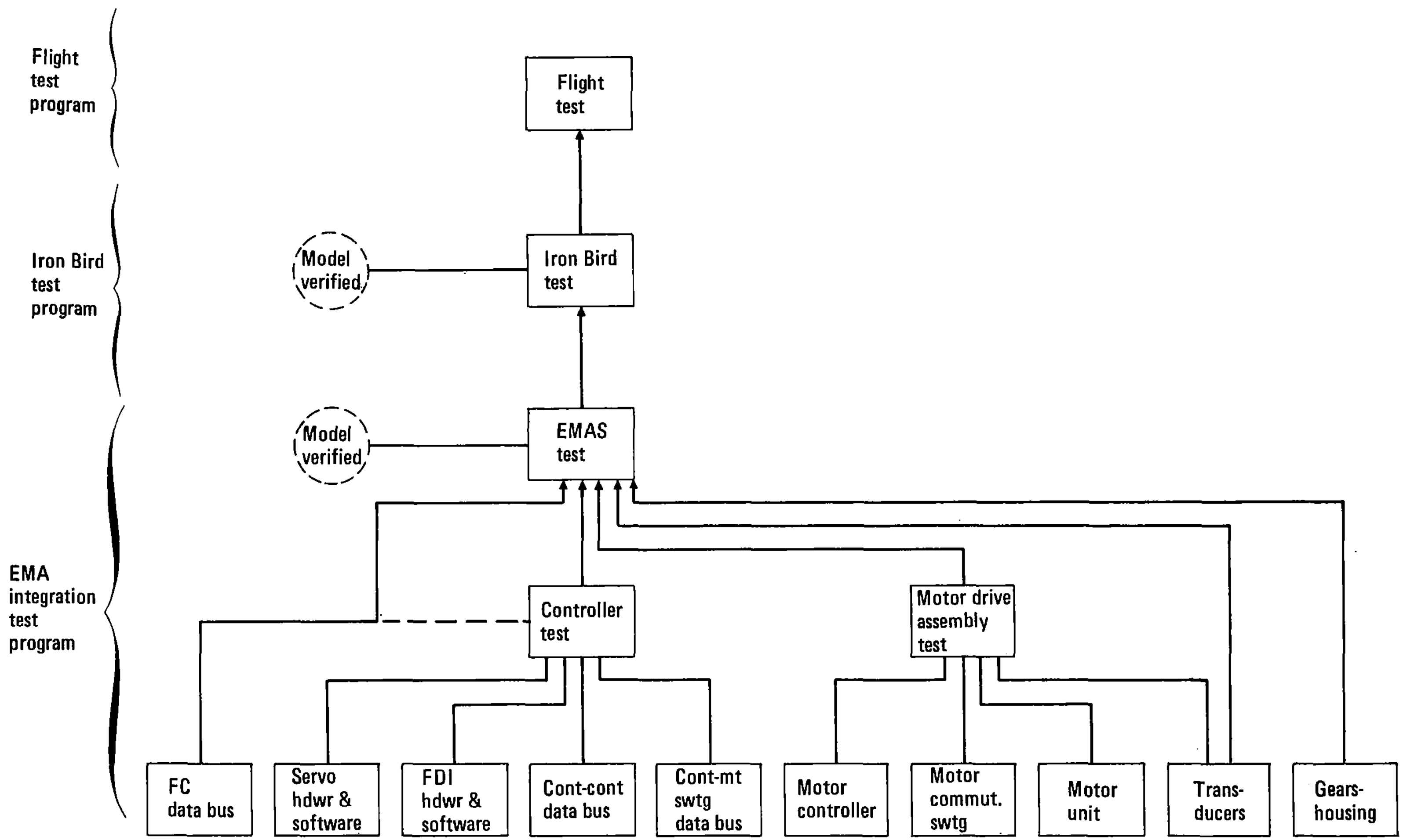


Figure 101. - EMAS development scenario.

- Mechanical Components: Advances in material fatigue characteristics will be required. Studies are needed to define optimum lubrication methods at various gear-train speeds and the resulting impact on sealing and maintainability. Also, techniques need to be developed for measuring the drive stiffness value.

- Control: Improved sensors for motor rotor position and rate, and actuator position and rate are necessary. sensors providing a direct digital input to the controller would be the most desirable. In the area of digital control, design and performance specifications should be updated to a level comparable to analog control systems specifications.

  Modern control theory should be reviewed and utilized more by controls engineers instead of relying on classical theory. The reason for this is that modern control theory is better equipped to deal with non-linear control systems, such as EMAS, than classical theory. "Adaptive Control" refers to development of schemes which deal with actuation systems failures. An example of a "failure-adaptive" scheme would be the disconnection of a failed motor in a multi-motor EMAS.

Figure 101 is a development program scenario, taken from a previous study (Reference 7), of how a major airframe manufacturer and actuator vendor might jointly develop an EMAS for flight control applications. The scenario shows that the controller and the motor/drive units would each be developed separately to design specifications and then tested as a total system for verification of the mathematical model. Ironbird and flight testing would follow. All flight control surface applications on the aircraft would be individually addressed.

6.2.2.5 Electroimpulse deicing plans:

Development cost: $1.7M

Readiness year: 1985

Plans all for costs of $1440K for labor (24 MY) and $280K for material, with development completed by 1984 and flight testing completed by 1985.

6.2.2.6 Fly-by-wire plans: (Refer to section 6.2.1.2)

6.3 Risk

6.3.1 Active controls airplanes. - There is no doubt that an active controls airplane can be built which will have significant benefits in reducing trim drag. The risk is in two areas (1) the benefits might not reach expectations and (2) the required reliability might cost more in effort, cost and weight than anticipated. The amount of benefit is in question because it is aircraft dependant and has unexplored aerodynamic areas. The amount of trim drag available for elimination, and thus savings, is a function of horizontal stabilizer lever arm. A long slim aircraft such as the DC9-80 benefits less than a short stubby airplane such as the S-3A. The unexplored aerodynamic area is the amount that the tail volume coefficient can be reduced because of relaxed pitch stability.

The question of reliability for safety evolves into how much the required safety costs in terms of research, manufacturing cost and aircraft weight. There is much research in this area at present and it seems the problems will be solved and standardized approaches developed for fault tolerant software and hardware for a variety of aircraft. This quest for electronics reliability is also characteristic of fly-by-wire technology.

6.3.2 Advanced secondary power. - Advanced secondary power has two major areas; bleed elimination and hydraulics elimination. Bleed elimination has very little risk, as it takes little new technology. The only question is, will it provide the benefits. On small aircraft such as fighters where little bleed is required, the benefits will be small; whereas in large aircraft with large cabins to pressurize and many people to keep comfortable, the benefits will be large. In both cases the benefits will be worthwhile. The most difficult technical problem is the starter generator, which we feel is just a matter of design and testing, there is little risk.

In the removal of hydraulics the risk is in electromechanical actuators (EMAS) which is discussed in another section.

6.3.3 Environmental control system (ECS). - There is little risk in the electrical ECS. Freon refrigeration systems have been used successfully before. The use of samarium cobalt motors for drive requires careful design and testing but no breakthrough. The rotary centrifugal compressor for cabin pressurization involves the same technology as is already used in the air cycle system. Again careful design and testing is required.

6.3.4 Solid state power controller (SSPC). - The design concepts of solid state power controllers is not well established. It is certain that significant improvements can be made over present electromagnetic controllers, however if the maximum benefits hypothesized in this study are not realized, the all-electric airplane will not be at risk. Alternate methods are available including improved electromechanical controllers and hybrid controllers.

6.3.5 Electric Deicing. - Development of electroimpulse deicing is risky. Not much has been done in this area (some wind tunnel testing of a wing mockup). Unknowns needing to be researched include possible adverse effects the impulse power surges may have on local avionics, and the durability of the slat material with repeated impulse deformations. Because of the risk, electrothermal deicing technology should be kept current as an alternative, if electroimpulse should prove unfeasible.

Some form of electric deicing is essential to the realization of an advanced transport with an all-electric secondary power system, and because electrothermal is already here, it serves as a low risk back-up technology for electroimpulse development.

6.3.6 Electromechanical actuators (EMAS). - The concepts for adequate and complete failure mode protection have not been established. Therefore there is risk in that more research than anticipated may be required, and also that once adequate protection is devised for jammed mechanisms, the actuator system may weigh and cost more than anticipated. The same is also true of the solid state motor controllers hypothesized. The cooling systems and redundancy required might increase cost and weight.

6.3.7 Fly by wire (FBW). - Fly by wire presents complex and substantial problems in providing adequate reliability for safety. However much research and development is presently underway. The F-16 and F-18 are flying, and other systems are in development. It is not felt that in the time frame under consideration there is much risk. The military will have established the concepts.

7. ADVANCED PROPULSION SYSTEM

7.1 Introduction

Benefits obtainable from advances in propulsion system technology fall basically into two areas; those associated with gas turbine and nacelle installation improvements and those related to propulsion system/airframe integration as shown in figure 102. The benefits available from both of these technologies are evaluated in this study and combined to define the total benefit achievable from advanced propulsion system technology.

The General Electric Energy Efficient Engine (E^3) study results were used to define the advanced technology engine benefits, program plan and related technology risks. The data used were taken from references (9) through (12). The technology benefits associated with propulsion/airframe integration were developed primarily from the NASA EET Propulsion/Airframe Integration Test Program while the technology program, cost and technology risk were defined by Lockheed.

The purpose of the NASA Energy Efficient Engine Project is to develop engine technology so that future engines will provide significant improvements in cruise specific fuel consumption (SFC), direct operating cost and conform to stringent environmental standards. These goals are presented in figure 103. The goals will be achieved through advancements in propulsion system technology and by emphasizing environmental requirements in the basic engine design.

A summary of the results show that the conventional aircraft with an advanced engine and related propulsion system/aircraft integration will reduce block fuel by 13.4 percent relative to the same aircraft powered by a conventional propulsion system. For the supercritical wing aircraft the advanced technology propulsion system with integration will achieve a 16.9 percent reduction in block fuel relative to the reference, conventional aircraft. These results are discussed in more detail in Section 7.2.

7.1.1 <u>E^3 flight propulsion system (FPS) description</u>. - The FPS defined in reference (9) incorporates a long-duct nacelle composed primarily of advanced composite construction with extensive use of acoustic absorbers on the inner surface. The wide-chord, titanium, 32-blade fan features a lowered midspan shroud and low tip speed to enhance efficiency and reduce noise. A quarter-stage booster provides additional core supercharging and centrifuges foreign objects from the core air to help prevent foreign object damage (FOD). A moderately loaded, five-stage, low pressure turbine drives the fan and booster. Selective aerodynamic loading and stage blade number are used to reduce low pressure turbine noise. A mixer is used to mix the hot core ex-

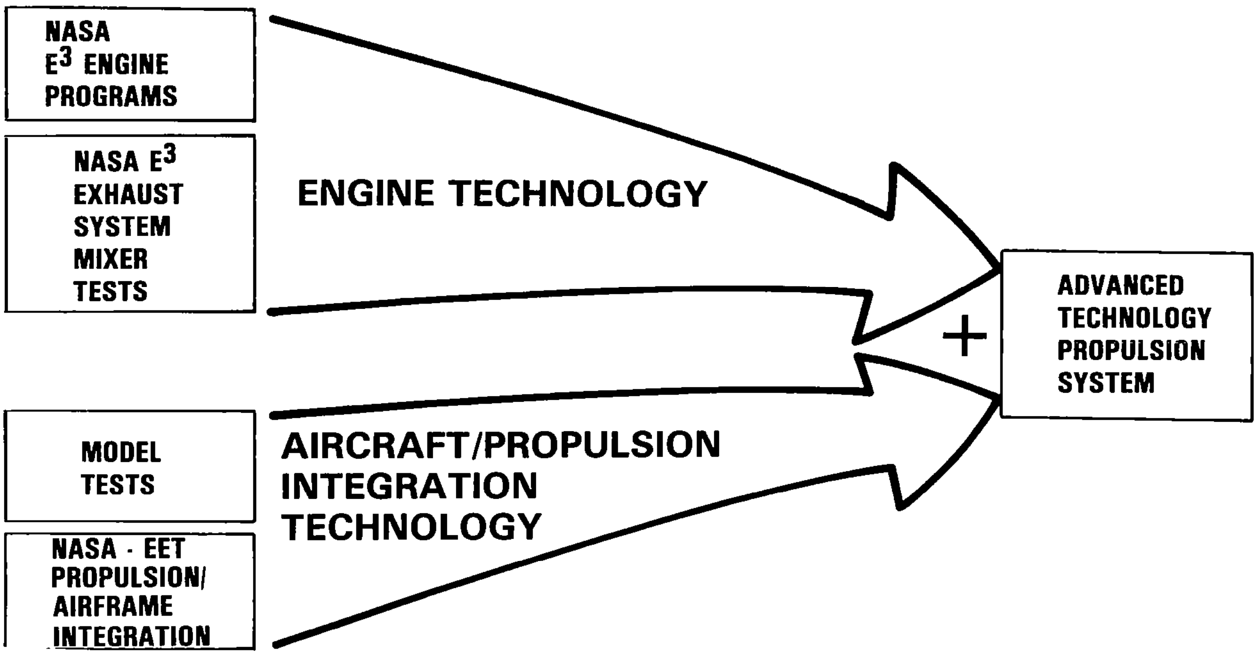


Figure 102. - Technology data base.

- 12% REDUCTION IN INSTALLED SPECIFIC FUEL CONSUMPTION (SFC)
- 5% REDUCTION IN DIRECT OPERATING COST (DOC)
- 50% REDUCTION IN SFC DETERIORATION IN SERVICE
- MEET FAR 36 (MARCH 1978) ACOUSTIC STANDARDS WITH PROVISIONS FOR GROWTH
- MEET PROPOSED EPA (1981) EMISSIONS STANDARDS FOR NEW ENGINES

Figure 103. - E^3 program goals.

haust gas with the cooler fan air to improve the SFC of the engine and reduce exhaust noise. The mixer also spoils core thrust in the reverse mode - allowing the weight and cost of a core reverser to be eliminated from the installed FPS.

An active clearance control system is employed on the aft portion of the high pressure compressor (HPC), the high pressure turbine (HPT), and the low pressure turbine (LPT). Active clearance control enables minimim clearances to be maintained during steady state engine operations and permits larger clearances during transients when current engines would ordinarily experience performance deteriorating tip wear.

A 10-stage, highly loaded, high pressure compressor is driven by a two stage turbine. The compressor produces a 23:1 pressure ratio at the maximum climb power design point. The combustor is a double annular design with two combustion zones to reduce emissions for all power settings. A shingled liner design is utilized in the combustor for longer life and reduced maintenance cost. Accessories are driven by a core mounted accessory gearbox. Core mounting reduces nacelle frontal area and consequent aerodynamic drag. Two main frames with special mounting designs are utilized to minimize engine casing distortion and consequent blade tip and seal wear.

A cross-sectional view of the E^3 Flight Propulsion System is shown in figure 104 and some salient characteristics of the System are given in figure 105. The physical and cycle characteristics of the E^3 FPS are compared to the reference CF6-50C engine in figure 106 for a common thrust size of 242.8kN (54,600 lbf). The E^3 engine weight, dimensions and performance are scaled in this study according to the relationships defined by General Electric in an unpublished report.

The E^3 Flight Propulsion System was resized (optimized) for each configuration studied. A weight buildup is shown in figure 107 for the thrust size of 166.2 kN (37,370 lbf) required for the preliminary advanced configuration (Configuration P16), described in section 9.1.

7.1.2 Propulsion system installation. - The nacelle configurations for the E^3 mixed and separate flow exhaust engines are presented in figure 108. For these designs, provided by General Electric, the maximum nacelle diameter and forebody sections are identical for either engine. During this study the engines/nacelles have been scaled to various sizes, consistent with identifying the aircraft performance benefits associated with selected advanced technologies. Figure 109 shows the E^3 mixed flow engine/nacelle installation for an engine thrust of 166.2 kN (37,370 lbf). This thrust size is required for the preliminary design incorporating all advanced technologies considered in this study. The nacelle has a maximum diameter of 251.5 cm (99.0 in.) and an overall length of 612.1 cm (241.0 in.). The nacelle alignment corresponds to a toe-in angle of 1.93 degrees and a pitch up attitude of 2 degrees.

7.2 Technology Benefits

This section summarizes the benefits used in this study for propulsion system technology improvements and propulsion system/airframe integration improvements. The benefits attributable to engine technology are those associated with the E^3 Flight Propulsion System (FPS) which includes a mixed flow exhaust system. A matrix of configurations was examined to establish the propulsion technology benefits from various propulsion system configurations. This matrix is shown in figure 110. While this study assumed the exhaust mixing benefit to be part of the E^3 Flight Propulsion System definition, an evaluation of separate vs mixed flow exhaust systems was conducted in the propulsion system matrix evaluation.

7.2.1 E^3 flight propulsion system. - The technology benefits used in this study were based on differences between the E^3 Flight Propulsion System performance and the CF6-50C installed performance. The cruise SFC difference between these two engines is presented in figure 111 and is approximately 14.6 percent. The breakdown in E^3 FPS SFC improvement relative to the CF6-50C engine is presented in Figure 112. SFC improvements attributable to technology benefits in the various areas of the propulsion system are identified. Large contributors to the performance improvement are component efficiences, mixed flow exhaust and cycle definition.

7.2.2 Mixed versus separate flow exhaust system. - The SFC benefit attributable to exhaust mixing for the E^3 FPS is presented in figure 113 as a function of rated power and flight Mach number. As shown, the maximum benefit of 3.1 percent is achieved at the 100 percent rated thrust condition at 0.8 Mach number. This benefit is reduced as the rating is decreased, therefore, during cruise the SFC benefit of exhaust mixing will vary from approximately 3 percent at start of cruise to 2 percent at the end of cruise.

Mixing the exhaust flow also results in an installed weight increase. This is a result of two factors. First, the mixed flow nacelle weight buildup is slightly heavier than the separate flow configuration for the same rated thrust, approximately 1 percent. A detailed weight breakdown for a mixed and separate flow nacelle configuration is presented in figure 114. Second, addition of a full length exhaust mixer relative to a separate flow exhaust system changes the spacing relationships of the propulsion system relative to the wing; and results in an unfavorable h/x_2 location and a subsequent high interference drag (assuming the engine is placed in the same cg location). To avoid any unnecessary interference drag the mixed flow configuration is mounted on a pylon such that the nacelle to wing spacing relationship (h/x_2) remains 0.8. While this minimizes the interference drag it results in a substantial pylon weight increase. These differences are discussed in more detail in Subsection 7.2.3.

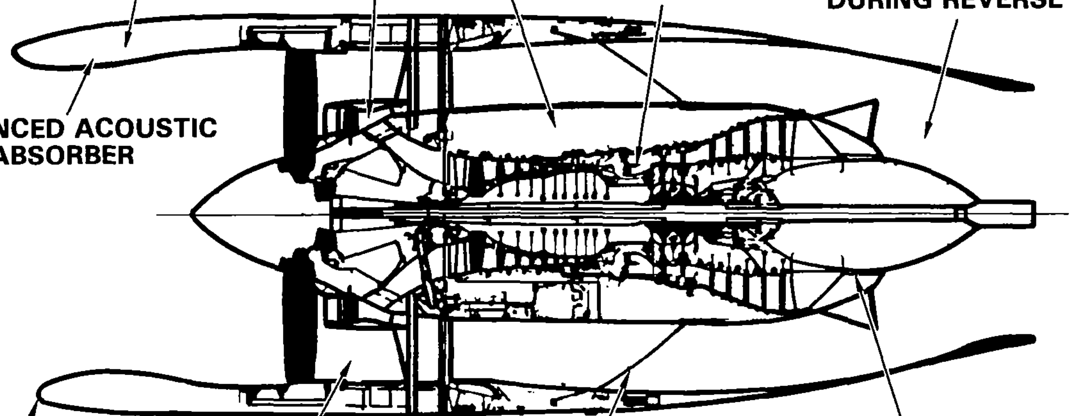


Figure 104. - Installed E^3 FPS features.

GENERAL ELECTRIC E^3 FLIGHT PROPULSION SYSTEM

• TAKEOFF THRUST ~ kN (lbf)	166.2	(37,370)
• TAKEOFF FLAT RATED TEMP, ISA+ Δ TEMP. ~ °C (°F)	15	(27)
• BYPASS RATIO	6.8	
• FAN DIAMETER ~ cm (in)	213.2	(83.9)
• ENGINE LENGTH ~ cm (in)	295.2	(116.2)
• BARE ENGINE WEIGHT ~ kg (lbm)	3484	(7682)
• ENGINE CERTIFICATION DATE	1990	

Figure 105. - Advanced propulsion system.

	CF6-50C	E^3
• TAKEOFF THRUST ~ KN (lbf)	242.8 (54.600)	242.8 (54.600)
• FAN DIAMETER ~ cm (in)	228.8 (90.0)	257.6 (101.4)
• ENGINE LENGTH ~ cm (in)	452.2 (178.0)	353.2 (139.0)
• BARE ENGINE WEIGHT ~ kg (lbm)	4321 (9524)	5348 (11791)
• CYCLE COMPARISON		
– BYPASS RATIO	4.2	6.8
– FAN PRESSURE RATIO	1.76	1.65
– OVERALL PRESSURE RATIO	32	38
– TURBINE ROTOR INLET TEMP (°C) SLS, 30°C, TAKEOFF RATING	1341	1343
– INSTALLED CRUISE SFC, M = 0.8, 10.7 km (35,000 ft) STD DAY	BASE	-14.6%

Figure 106. - Comparison of E^3 cycle to CF6-50C.

BARE ENGINE ~ kg (lbm)	3484	(7682)
INLET ~ kg (lbm)	165	(364)
FAN REVERSER ~ kg (lbm)	514	(1134)
CORE COWLS ~ kg (lbm)	108	(238)
PRIMARY NOZZLE ~ kg (lbm)	54	(119)
EXHAUST NOZZLE ~ kg (lbm)	108	(237)
ENGINE BUILD UP ~ kg (lbm)	202	(445)
	4635	(10,219)

Figure 107. - Advanced technology propulsion system weight E^3 reference thrust = 166.2 kN (37,370 lbf).

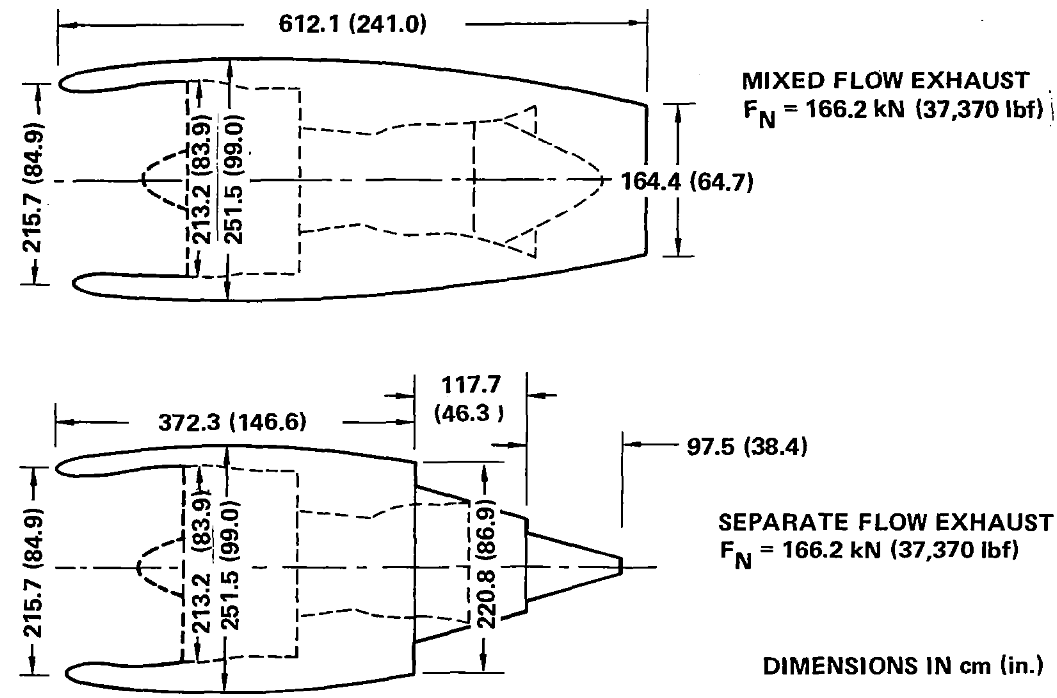
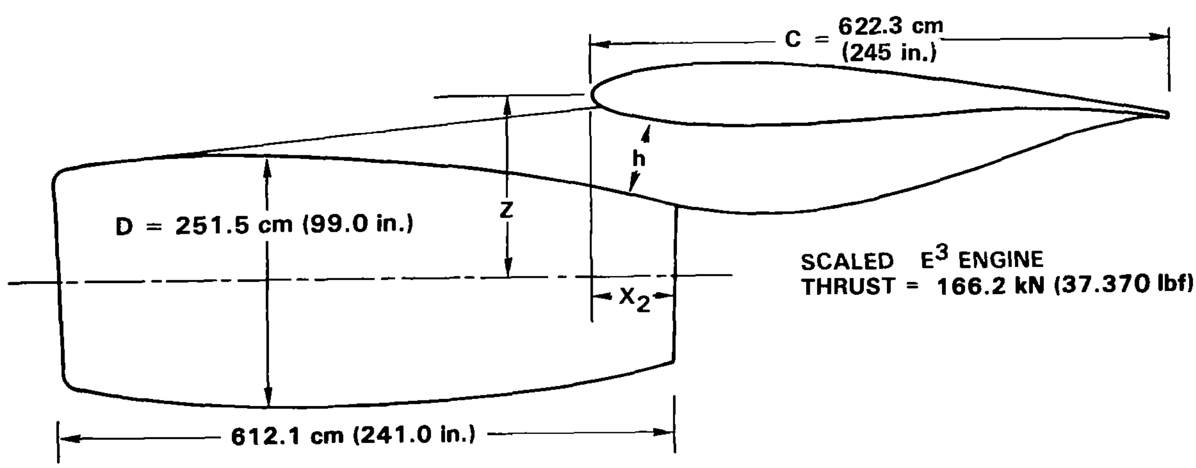


Figure 108. - Baseline E^3 mixed and separate flow engine nacelle configurations.



- NACELLE TYPE — MIXED FLOW
- PYLON SHAPE — CAMBER, AREA RULE
- PYLON CANT — 1.93° INBOARD
- NACELLE CANT — 1.93° INBOARD
- NACELLE PITCH — 2° UP
- INLET DROOP — 4°

NACELLE INSTALLATION PARAMETERS

h/x_2	= 0.80
X_2/C	= 0.156
Z/D	= 0.760
D/C	= 0.404
X_{cg}/C	= 0.389

Figure 109. - Mixed flow exhaust engine/nacelle installed on advanced aircraft.

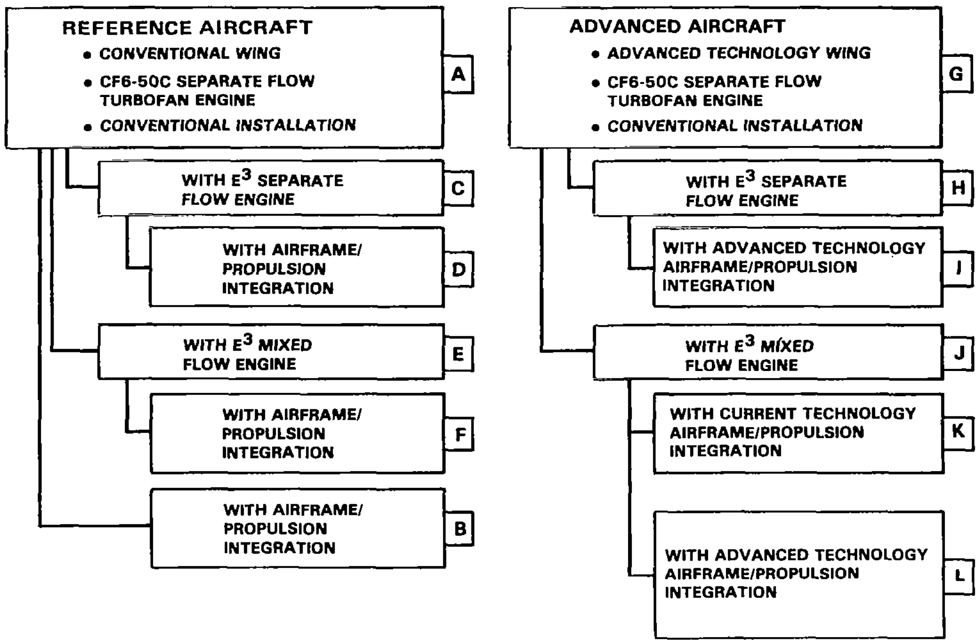


Figure 110. - Propulsion system configuration matrix.

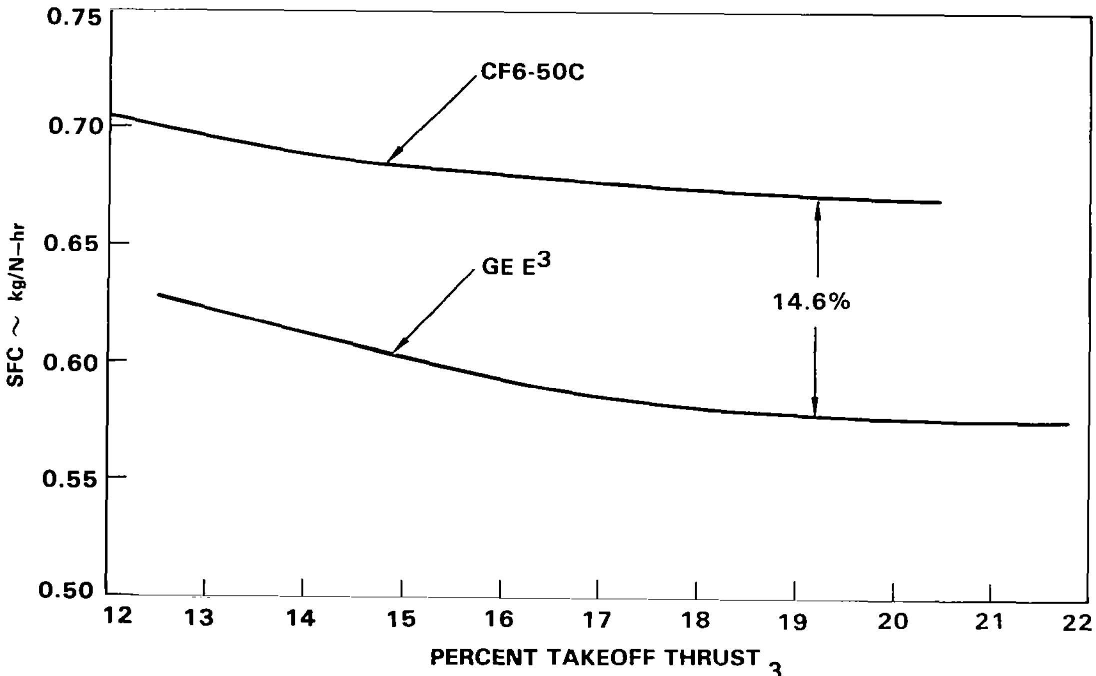


Figure 111. - SFC comparison CF6-50C and GE E^3 engines 10.7 km (35,000 ft) 0.80 Mach standard day.

	% Δ SFC	
• COMPONENT ADIABATIC EFFICIENCIES	−4.1	
• MIXED FLOW EXHAUST	−3.1	
• INCREASED CYCLE PRESSURE RATIO (20%)	−1.0	
• PROPULSIVE EFFICIENCY (FPR-BPR)	−2.5	
• INCREASED TURBINE INLET TEMPERATURE (~170°F) (94°C)	−1.5	
• COOLING AND PARASITIC FLOWS	−1.0	
• FLOWPATH PRESSURE LOSSES	−0.1	
UNINSTALLED Δ SFC		−13.3
• REDUCED ISOLATED NACELLE DRAG	−0.6	
• INTEGRATED AIRCRAFT GENERATOR COOLING	−0.3	
INSTALLED Δ SFC IMPROVEMENTS		−14.2
• CUSTOMER BLEED AND POWER EFFECTS	+04	
• REGENERATIVE E^3 FUEL HEATER	−0.8	
FULLY INSTALLED (CUST. BLEED AND HP)		−14.6

Figure 112. - E^3 SFC improvement vs. CF6-50C.

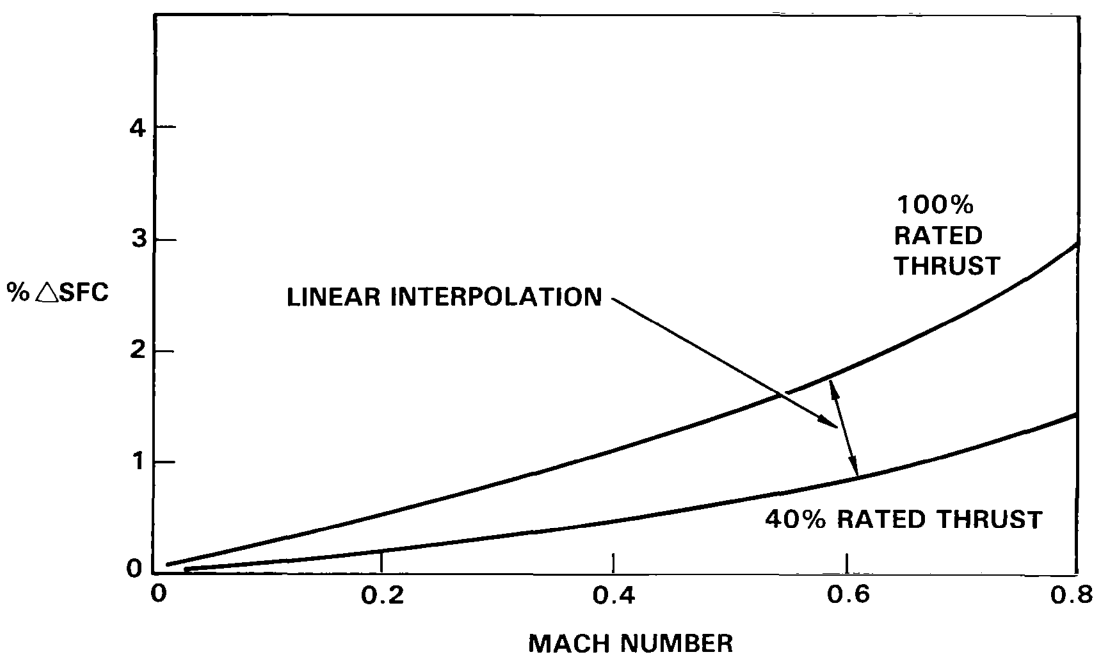


Figure 113. - E^3 separate flow exhaust % SFC relative to mixed exhaust.

	MIXED FLOW		SEPARATE FLOW	
BARE ENGINE ~ kg (lbm)	3484	(7682)	3484	(7682)
INLET ~ kg (lbm)	165	(364)	165	(364)
FAN REVERSER ~ kg (lbm)	514	(1134)	620	(1368)
CORE COWLS ~ kg (lbm)	108	(238)	76	(167)
PRIMARY NOZZLE ~ kg (lbm)	54	(119)	48	(106)
EXHAUST NOZZLE ~ kg (lbm)	108	(237)	—	—
ENGINE BUILD UP ~ kg (lbm)	202	(445)	202	(445)
TOTAL ~ kg (lbm)	4635	(10,219)	4595	(10,132)

Figure 114. - Mixed vs separate flow exhaust system weight reference thrust = 166.2 kN (37,370 lbf).

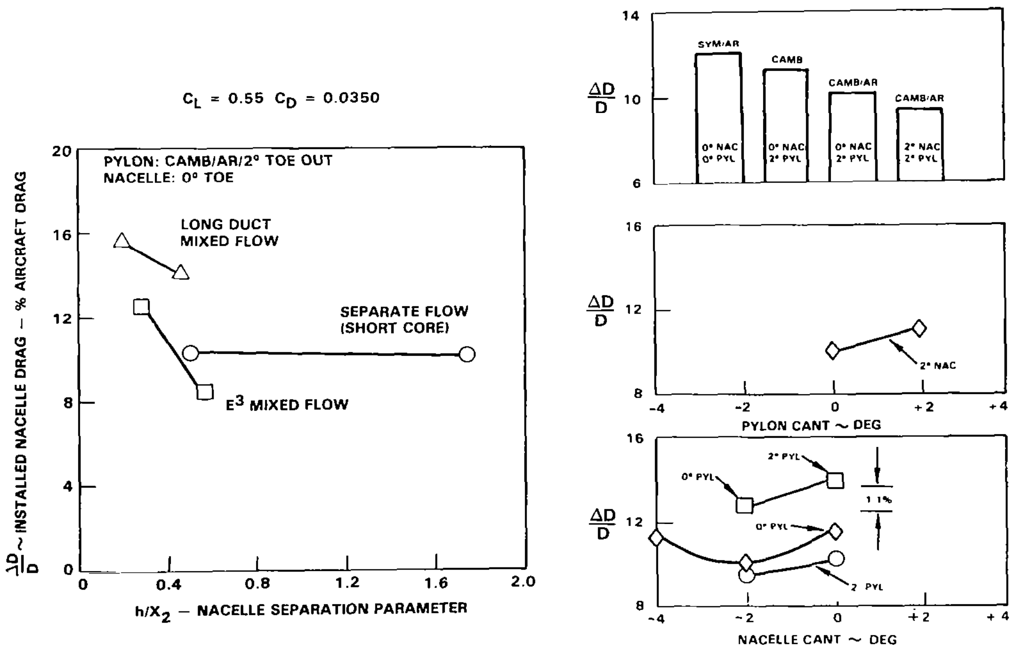


Figure 115. - Installed nacelle drag measured during NASA LaRC EET propulsion/airframe integration model tests.

7.2.3 Propulsion/airframe integration.

7.2.3.1 Technology base: For the advanced aircraft, installation of an underwing engine/nacelle on a highly loaded wing can result in significant installed interference drag penalties since the underwing velocities are high relative to those for a conventional wing. A comprehensive test program was conducted by NASA LaRC/General Electric during 1979 (Phase I) whereby installed drag levels were established for various nacelle types installed on a half span advanced wing model utilizing a turbine powered simulator. Configuration variables included nacelle location, pylon shape and nacelle/pylon alignment. The results from these tests have been used as the technology base for this study.

Figure 115 presents a summary of the NASA LaRC test data for the nacelle configurations of interest for this study. The total installed drag is plotted against the nacelle spacing parameter and shows the drag levels to be from 8 to 10 percent of the aircraft drag. Also shown on the figure are the effects on drag resulting from pylon shape (symmetrical, camber and area ruling) and nacelle/pylon alignment (pitch and toe). These data have been subsequently used to derive the drag levels associated with current nacelle installation technology for an advanced wing aircraft. The derivation procedures are illustrated in figure 116 for the E^3 mixed flow engine, and include, (1) correction to the reference symmetrical pylon cross section and nacelle/pylon alignment of 2 degrees pitch up and 1.93 degrees toe-in, based on NASA LaRC test results, (2) removal of the calculated nacelle/pylon friction drag associated with the model test conditions to obtain interference drag (as described previously) and (3) basing the interference drag coefficient on nacelle maximum cross sectional area rather than wing area, for use in the ASSET program.

The interference drag levels resulting from the above procedures, and subsequently used to evaluate aircraft performance benefits in this study, are shown in figure 117. Figure 117a defines the drag levels that would currently exist with no propulsion/airframe integration efforts. In figure 117b two levels of installed interference drag associated with propulsion/airframe integration efforts are identified. The higher interference drag is based on benefits resulting from pylon camber and area ruling as demonstrated in the NASA LaRC tests. Attainment of this level requires a minimal technology development effort and is considered a low risk. The second level of drag indicated on the figure represents the propulsion/airframe technology goal for this program, i.e., installation of the nacelle on the advanced wing with no interference drag penalty. Further reductions in interference drag below zero (favorable interference) are theoretically possible but have not been considered in defining technology benefits for this study.

7.2.4 Propulsion/aircraft configuration matrix evaluation. - The matrix of engine/aircraft configurations identified in figure 110 was systematically examined to establish the aircraft performance benefits resulting from advanced engine and aircraft configurations and from propulsion/airframe integration efforts. For this latter item the nacelle interference drag curves presented in figure 41 and 117 for the conventional and advanced aircraft, respectively, were used. In establishing the nacelle location for each of the configurations, consideration was given to the performance tradeoff between interference drag and pylon weight. This tradeoff results from the fact that as the nacelle is moved aft relative to the wing the interference drag increases for h/x_2 values less than 0.8, but the pylon structural weight required for flutter criteria reduces due to the reduced engine/nacelle overhang. To determine the performance tradeoff between these parameters an analysis was conducted using the effects of nacelle location on incremental pylon weight shown in figure 118, the interference drag curves previously presented, and sensitivity factors relating changes in weight and drag to aircraft block fuel. The results of the analysis are presented in figure 119 for the E^3 mixed flow engine/advanced wing configuration and indicate that penalties resulting from increased interference drag are much more significant than benefits realized from reductions in pylon weight. Based on the above
aircraft block fuel. The results of the analysis are presented in figure 119 for the E^3 mixed flow engine/advanced wing configuration and indicate that penalties resulting from increased interference drag are much more significant than benefits realized from reductions in pylon weight. Based on the above
analysis, each of the configurations evaluated was located to obtain a nacelle spacing parameter, h/x_2, of 0.80. The resulting interference drag levels for each of the configurations are summarized in figure 120.

Based on the improvements in engine specific fuel consumption and installed nacelle interference drag specified in the previous sections, the engine aircraft configurations were evaluated to determine the aircraft performance benefits. To obtain a valid performance comparison resulting from propulsion system changes only, no advanced technologies other than the advanced wing were included in the evaluations.

The results of the analysis are presented in figure 121 and show the change in aircraft block fuel for each of the configurations from that of the reference aircraft. For the conventional aircraft with no propulsion/airframe integration benefits, installation of the E^3 separate and mixed flow engines reduce the block fuel by 10.8 and 12.6 percent, respectively. With reductions in drag resulting from pylon camber and area rule these improvements are increased slightly to 11.5 and 13.4 percent.

For the reference aircraft modified to an advanced wing configuration the block fuel increases by 1.2 percent. This results from increased nacelle interference drag incurred when installing the CF6-50C on the advanced wing. With installation of the E^3 separate and mixed flow engines, and considering no propulsion/airframe integration benefits, the improved engine SFC results

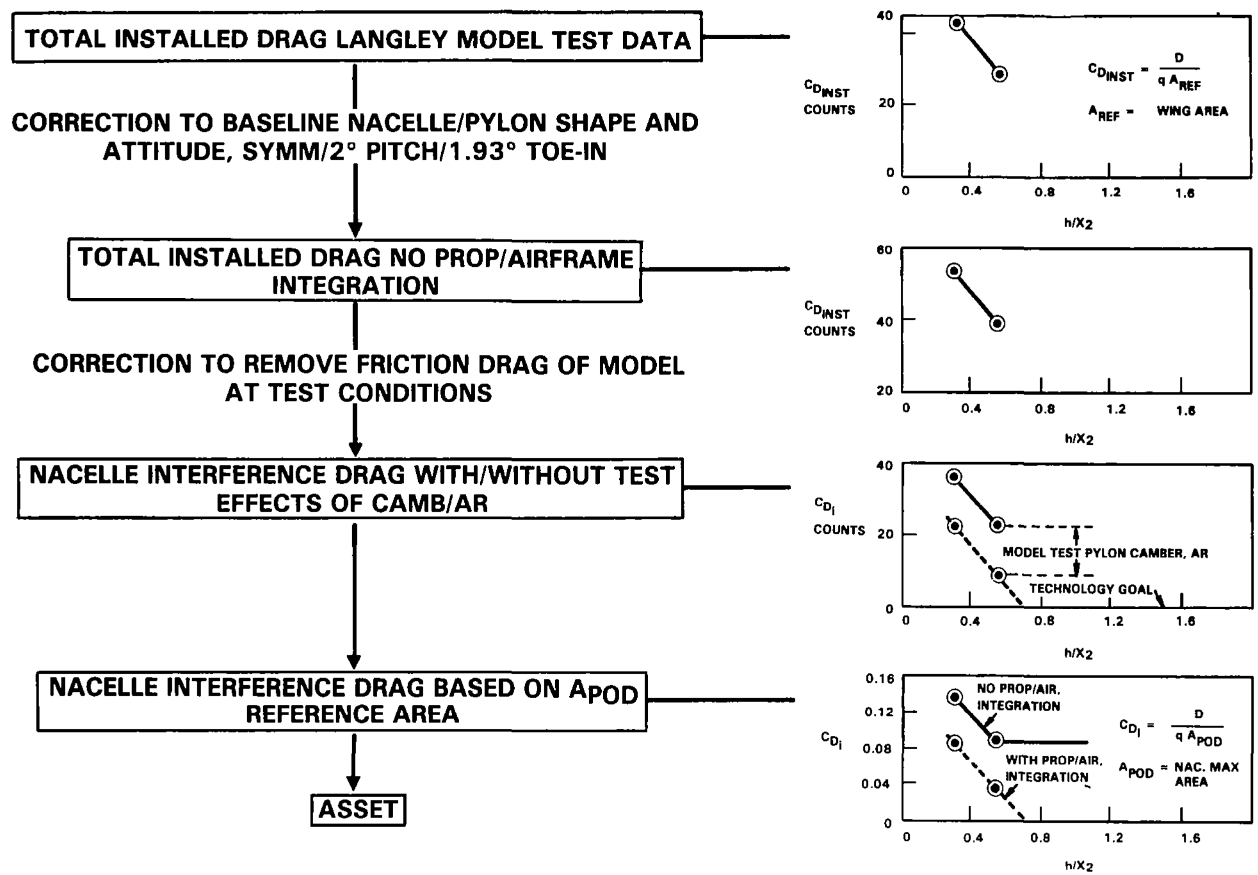


Figure 116. - Derivation of installed nacelle interference drag for E^3 mixed flow-advanced wing.

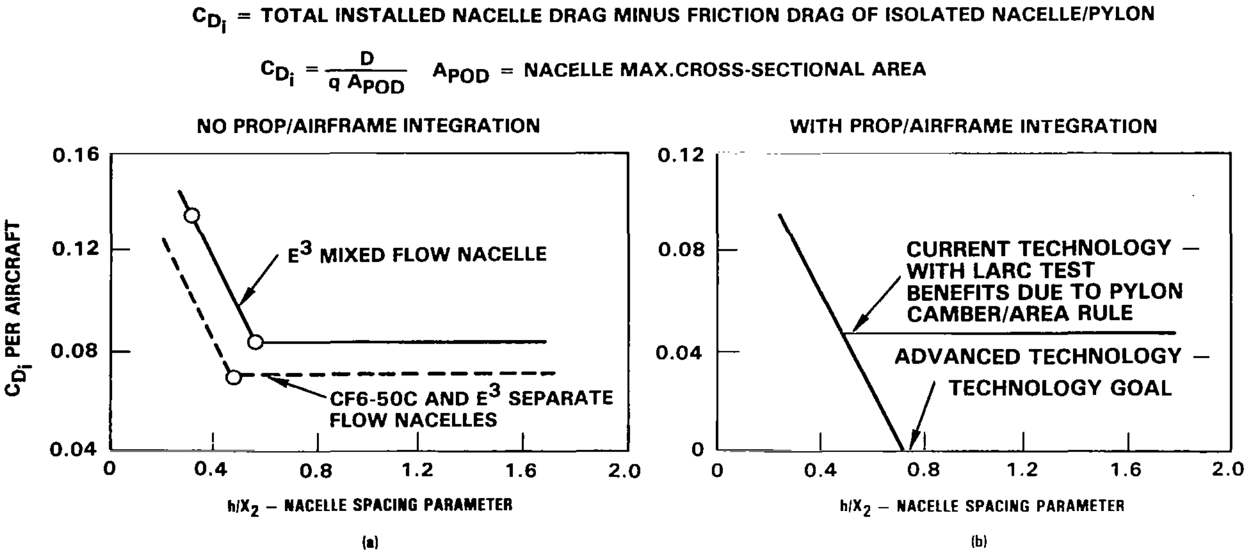


Figure 117. - Installed nacelle interference drag for the advanced aircraft.

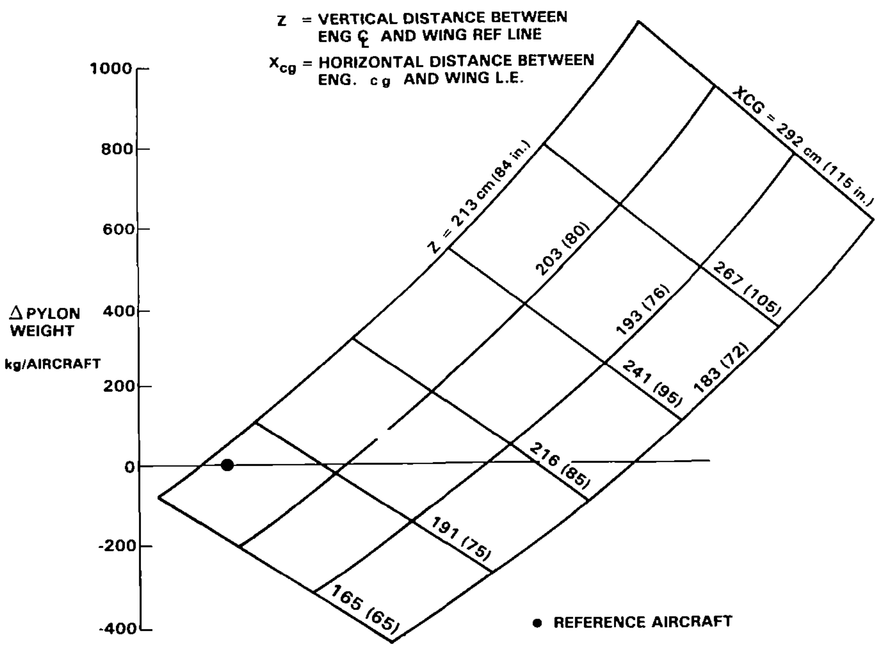


Figure 118. - Effect of engine location on pylon weight.

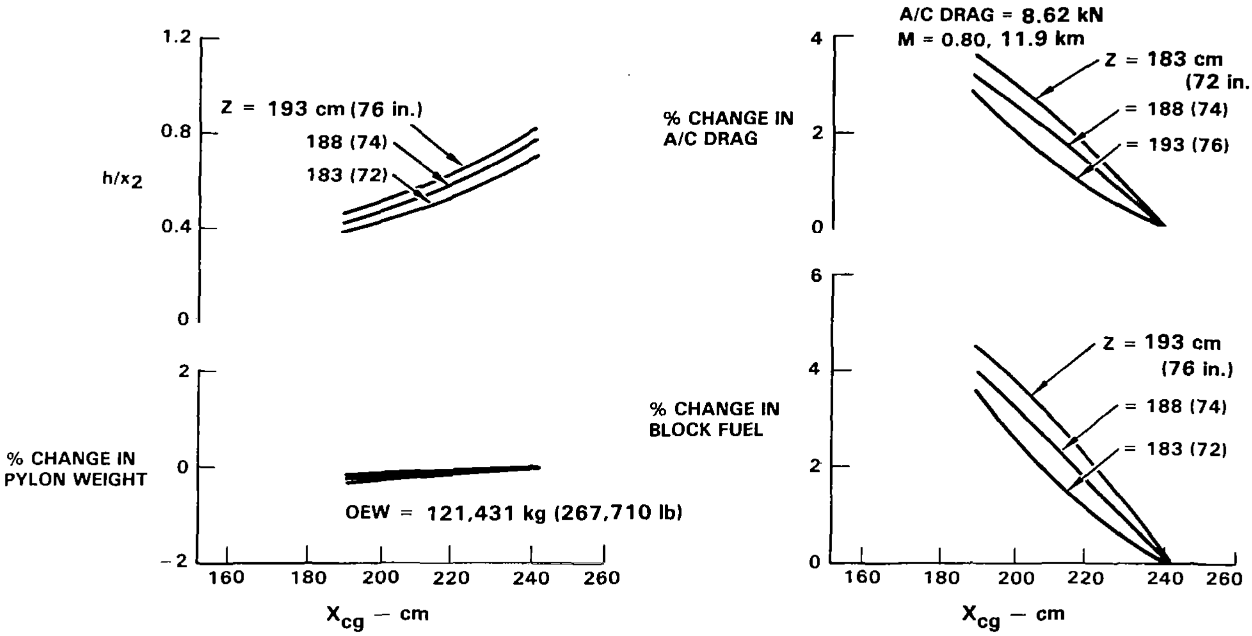


Figure 119. - Effect of nacelle location on block fuel advanced aircraft/E^3 mixed flow nacelle.

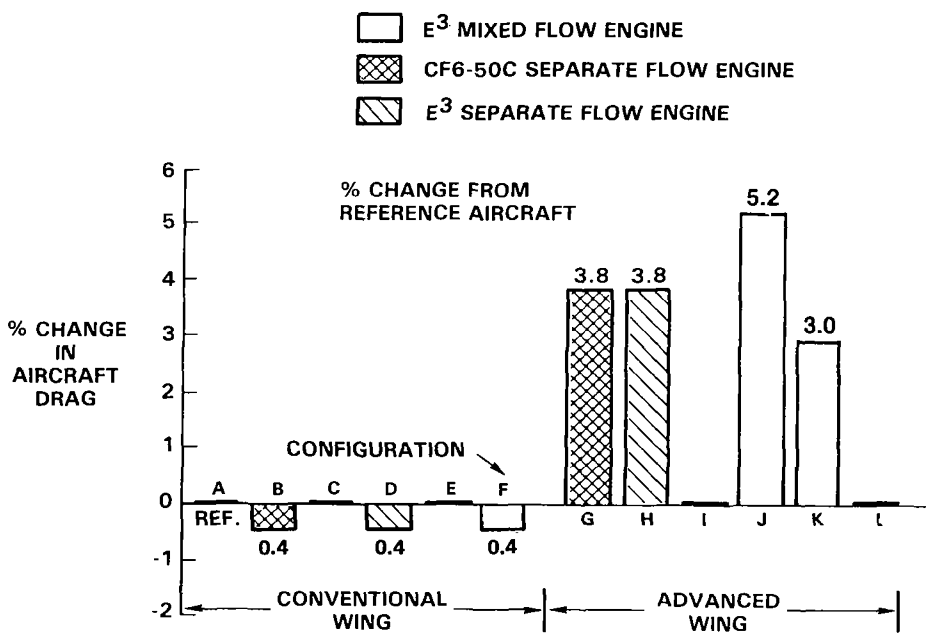


Figure 120. - Effect of engine/nacelle installation on aircraft drag.

in a 9.8 and 10.6 percent improvement in block fuel, respectively. Although the SFC of the E^3 mixed flow engine is almost 2 percent lower than for the separate flow engine the interference drag for this engine/nacelle is higher, resulting in approximately equal improvements in block fuel.

For the E^3 mixed flow engine installation on the advanced wing, reducing the nacelle interference drag through propulsion/airframe integration efforts provides further reductions in block fuel from the levels quoted above. For the low risk technology improvements associated with pylon camber and area ruling the reduction in block fuel is 13.3 percent or 3.5 percent additional reduction when compared to the same configuration with no propulsion/airframe integration. With elimination of nacelle interference drag, the technology goal identified in this study, the block fuel is reduced 16.9 percent from that required for the reference aircraft and 6.3 percent compared to the E^3 mixed flow engine/advanced wing configuration with no propulsion/airframe integration.

Installing the E^3 mixed flow exhaust engine on an advanced wing aircraft with current technology results in an estimated interference drag penalty equal to approximately 5 percent of the aircraft drag. Propulsion/airframe integration tests conducted at the NASA LaRC wind tunnel facility have demonstrated that this penalty can be reduced to approximately 3.0 percent through cambering and area ruling of the pylon. To eliminate this penalty requires a concentrated propulsion/airframe technology development program that combines theoretical analyses and wind tunnel research test programs. Such a program is described in the following section.

7.2.5 Engine performance variation with bleed and mechanical power extraction. The implementation of all-electric secondary power permits the elimination of engine bleed, as described in Section 6.1.2. The impact of engine bleed elimination on SFC is described in this Section.

Four engine power-extraction configurations are utilized for the twenty aircraft designs. Table VI gives a listing of the engine bleed and mechanical power extraction (MPE) for the aircraft.

The effects of bleed elimination can be seen in table VII for representative aircraft at cruise condition.

With a bleed to MPE conversion ratio of 81.3 kW for each kg/s (49.5 hp for each lb/sec) bleed for the CF6-50C engine, cruise SFC improves by 1.1 percent. The E^3 engine, with a 161.6 kW per kg/s (98.5 hp per lb/sec) bleed conversion, gives a 1.6 percent improvement.

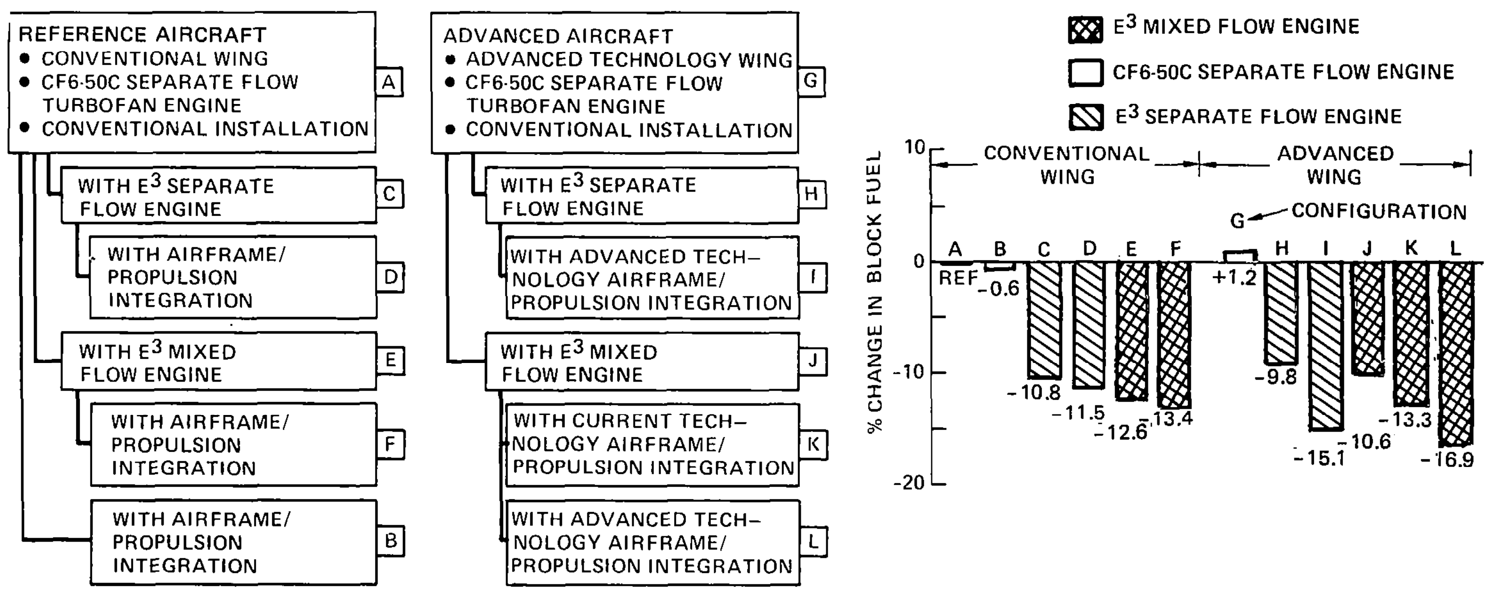

REFERENCE AIRCRAFT
• CONVENTIONAL WING
• CF6-50C SEPARATE FLOW TURBOFAN ENGINE
• CONVENTIONAL INSTALLATION
A
WITH E3 SEPARATE FLOW ENGINE
C
WITH AIRFRAME/ PROPULSION INTEGRATION
D
WITH E3 MIXED FLOW ENGINE
E
WITH AIRFRAME/ PROPULSION INTEGRATION
F
WITH AIRFRAME/ PROPULSION INTEGRATION
B
ADVANCED AIRCRAFT
• ADVANCED TECHNOLOGY WING
• CF6-50C SEPARATE FLOW TURBOFAN ENGINE
• CONVENTIONAL INSTALLATION
G
WITH E3 SEPARATE FLOW ENGINE
H
WITH ADVANCED TECH– NOLOGY AIRFRAME/ PROPULSION INTEGRATION
I
WITH E3 MIXED FLOW ENGINE
J
WITH CURRENT TECH– NOLOGY AIRFRAME/ PROPULSION INTEGRATION
K
WITH ADVANCED TECH– NOLOGY AIRFRAME/ PROPULSION INTEGRATION
L
E3 MIXED FLOW ENGINE
CF6-50C SEPARATE FLOW ENGINE
E3 SEPARATE FLOW ENGINE
CONVENTIONAL WING
ADVANCED WING
G CONFIGURATION
% CHANGE IN BLOCK FUEL
10
0
-10
-20
A B C D E F H I J K L
REF
-0.6
-10.8
-11.5
-12.6
-13.4
+1.2
-9.8
-15.1
-10.6
-13.3
-16.9

TABLE VI. - DESIGN ENGINE BLEED AND POWER EXTRACTION REQUIREMENTS

Engine	Bleed/engine		MPE/ENG		Configurations
	~kg/s	lb/sec)	~kw	(hp)	
CF6-50C with bleed	1.06	(2.33)	82	(110)	1,2A,3,4,5,7A,7B,9,10,11,12,13A
CF6-50C no bleed	0	0	167.8	(225)	6,14A
E^3 with bleed	0.53	(1.17)	82	(110)	7F,7J,7K,7L
E^3 no bleed	0	0	167.8	(225)	15,16

TABLE VII. - REPRESENTATIVE CRUISE PERFORMANCE FOR CF6 AND E^3 ENGINES AT 11.9 km (39,000 ft), M = 0.8

Configuration	Engine	Engine Scale	SFC ~daN/kg/s(lb/lb/sec)
1	CF6-50C with bleed	1.086	0.66 (0.647)
14A	CF6-50C no bleed	.803	0.65 (0.64)
7L	E^3 with bleed	1.129	0.569 (0.558)
16	E^3 no bleed	.797	0.558 (0.547)

7.3 Technology Plans and Cost

This section describes the technology development plan required to achieve the level of propulsion technology readiness defined in this study. The E^3 Flight Propulsion System data, including program development schedules and costs were taken directly from the GE E^3 Project. The propulsion system/integration program description and cost were developed by Lockheed. This technology program relied in part, on the results obtained from the NASA EET Propulsion System/Airframe Interference Test Program conducted at NASA Langley.

7.3.1 E^3 program description and cost. - A summary chart of the E^3 technology development program is presented in figure 122 and a program milestone chart in figure 123. As shown in figure 123 all of the design and hardware test activities are nearly complete. The technology development plan calls for the testing of the high pressure core engine and an Integrated Core Low spool (ICLS) engine. The ICLS is projected to demonstrate the 12 percent improvement in cruise specific fuel consumption. The technology level evaluated in this study, however, is that of the E^3 Flight Propulsion System which has an installed cruise SFC improvement relative to the CF6-50C engine of 14.6 percent. To achieve this performance will require additional component performance improvements relative to the E^3 ICLS technology level. These milestones are also included in figure 123.

The component technology improvement task and core engine testing for the E^3 FPS will take approximately two years and be complete in the third quarter of 1985. In addition, another six months will be required to complete the testing of the E^3 Flight Propulsion System in the ICLS configuration. This milestone is set at approximately the second quarter of 1986.

The cost to achieve the level of technology readiness in the current E^3 engine program is 204.8 million dollars. This amount is shared equally between GE and P&W. The GE exhaust mixer work is approximately 1.5 million dollars of the total 102.4 million allotted to GE. To achieve a comparable technology readiness level for the E^3 Flight Propulsion System used in this study will require an additional 24 million dollars for component improvement work and another 8-10 million dollars, as shown in figure 124, for an E^3 FPS ICLS demonstration.

7.3.2 Propulsion/airframe integration technology Plan and costs. - The propulsion/airframe integration technology plan consists of conducting wind tunnel model tests and developing and applying theoretical flow methods, as illustrated in figure 125. Parallel efforts in these two areas will enable updating of the theoretical flow codes based on model test results and improved model test configurations based on the application of the improved codes. The overall objective of the technology plan is to identify wing/pylon/nacelle configurations for which no interference drag exists (i.e., the

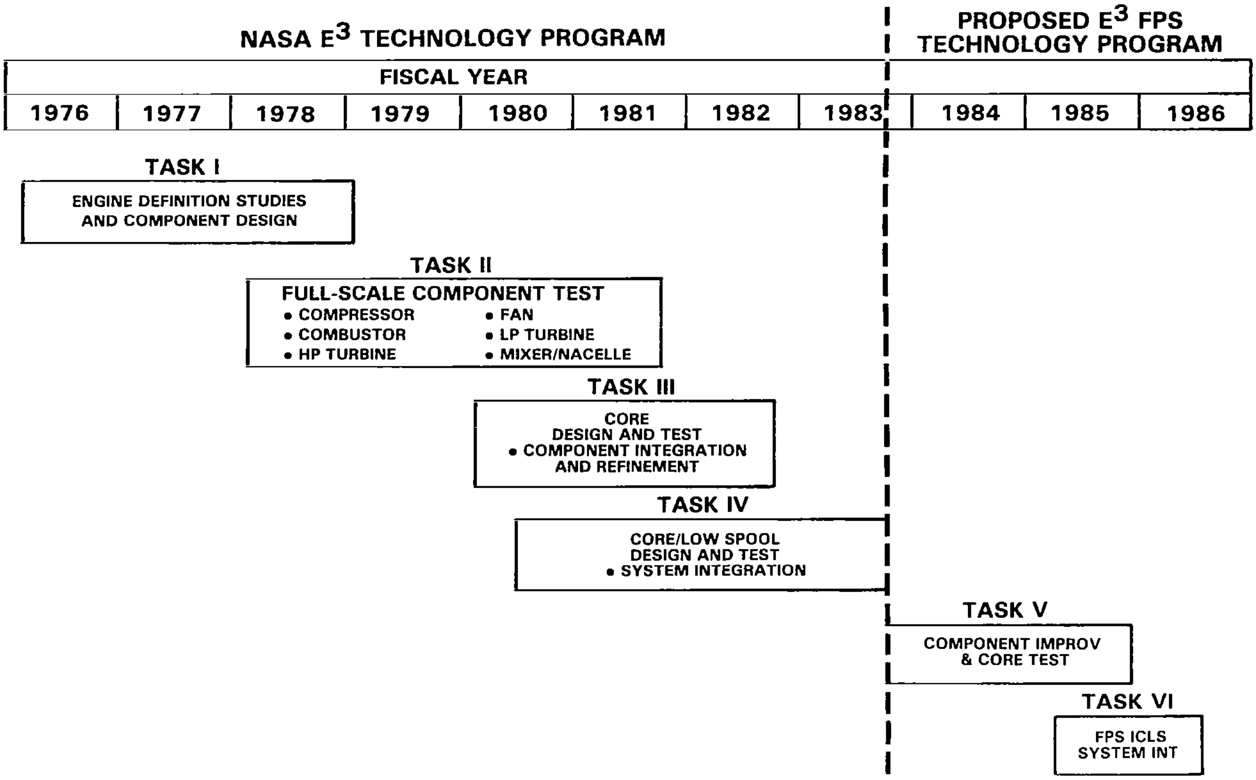


Figure 122. - Energy efficient engine program.

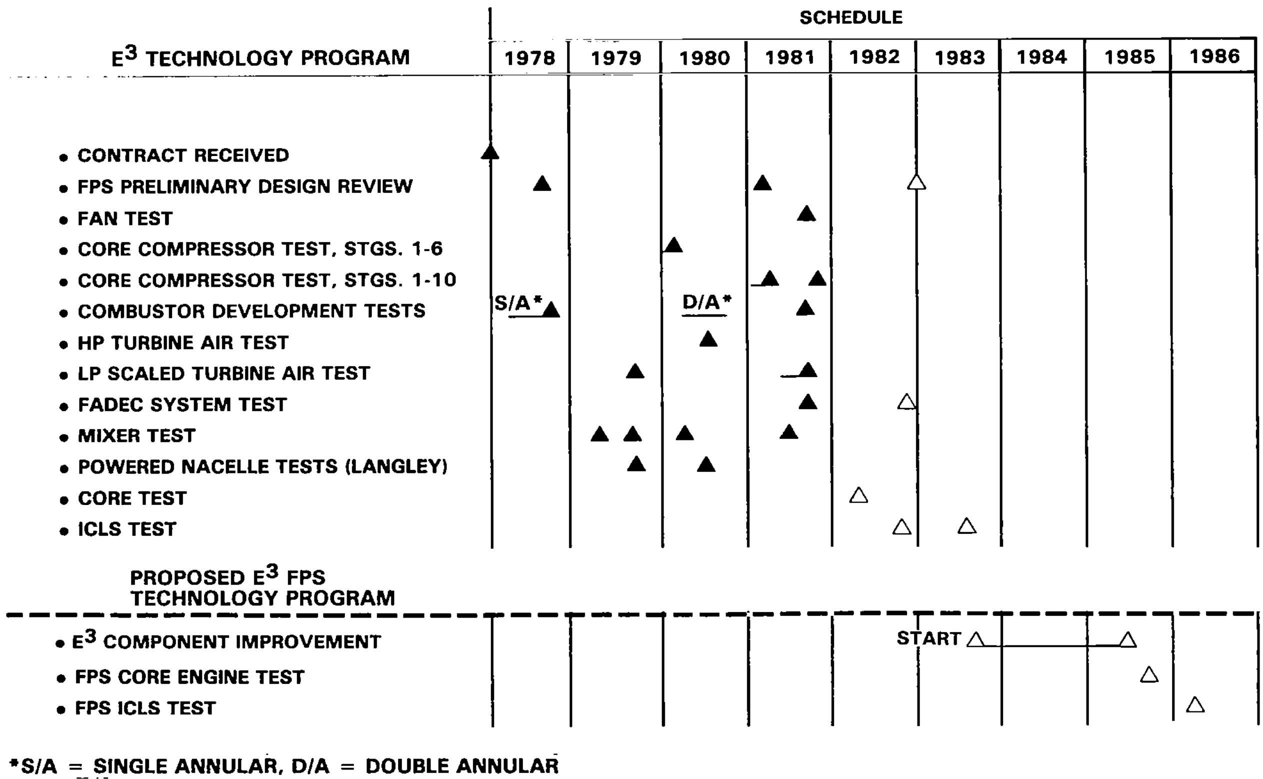


Figure 123. - E^3 program milestones.

drag increase due to the installation of the pylon and nacelle, relative to the clean wing, is equivalent to only the friction drag of the pylon and nacelle). These configurations should reduce the aircraft drag by approximately three percent over those developed using current technology methods. The estimated cost of this experimental/theoretical technology development program is approximately $5.5M.

7.3.2.1 Proposed test programs: As shown in figure 126, the proposed technology development test program will be a multiyear effort involving three phases of wind tunnel testing: (1) investigation of wing/pylon/nacelle interaction effects, (2) investigation of nacelle contouring and wing sculpturing techniques, and (3) optimization of the wing/pylon/nacelle combination. All tests will employ a turbine powered simulator (TPS) to duplicate as closely as possible, the engine inlet and exhaust conditions. Existing model hardware will be used where it is appropriate. Details of the configurations to be tested will be based on theoretical code results and test data obtained from previous phases of this test program as well as relevant tests conducted by other investigators.

Overall cost of the propulsion/airframe integration test programs is estimated to be $4.5M. Approximately 40 percent of the cost is for the wind tunnel test facility, and the other 60 percent is for model design, model fabrication, test support, calibrations, analyses, administration, and reporting.

7.3.2.1.1 Phase 1 - wing/pylon/nacelle interaction test: Wing/pylon/nacelle interaction testing, planned for 1982, will determine the drag effects of mixed flow nacelles due to their position relative to an advanced technology wing. In addition to overall aircraft drag effects, the effects of the pylon and nacelle on the wing drag and the effects of the wing on the pylon and nacelle drag will be identified. This comprehensive study of nacelle position relative to the wing will establish the optimum locations of the relatively long mixed flow nacelle when coupled with a relatively short advanced technology wing.

The model will employ the existing E^3 mixed flow nacelle and half span advanced wing previously tested by NASA LaRC. The model arrangement that is currently anticipated will utilize two force balances, one for the wing and one for the pylon and nacelle. A metric to metric gap or seal arrangement between the pylon and wing will separate the hardware so that forces on the pylon/nacelle can be measured independently from forces on the wing. The TPS supply air pipe and balance will be located in a support structure from the floor or wall of the tunnel to the bottom or side of the nacelle. This test setup has not been employed previously; however, the advantages of this test technique make it attractive to develop. This model arrangement allows testing of many nacelle positions at low cost relative to conventional model arrangements because the pylon for each nacelle location merely needs to be an aerodynamic fairing rather than a TPS support structure equipped with air

- E^3 ENGINE PROGRAM — $204.8M TO ICLS
  - $102.4M FOR GE
  - $102.4M FOR P&W
  - EXHAUST MIXER WORK — $1.25M (PART OF THE $102.4M)
- E^3 FLIGHT PROPULSION SYSTEM — $32 - 34M
  - $24M FOR COMPONENT TECHNOLOGY READINESS
  - $8-10M FOR FPS ICLS DEMONSTRATION
- PROPULSION SYSTEM/AIRFRAME INTEGRATION — $5.5M

Figure 124. - Integrated technology wing study propulsion system technology readiness.

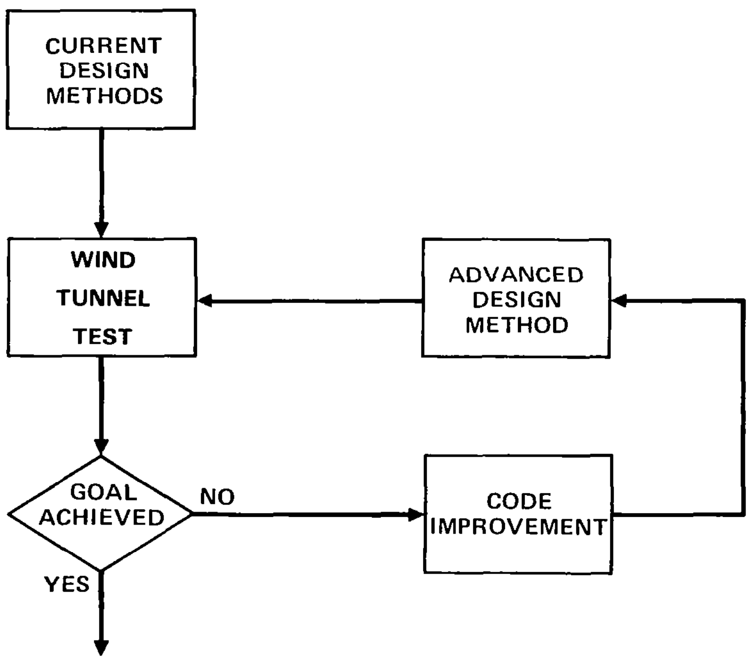


Figure 125. - Propulsion/airframe integration technology development program approach.

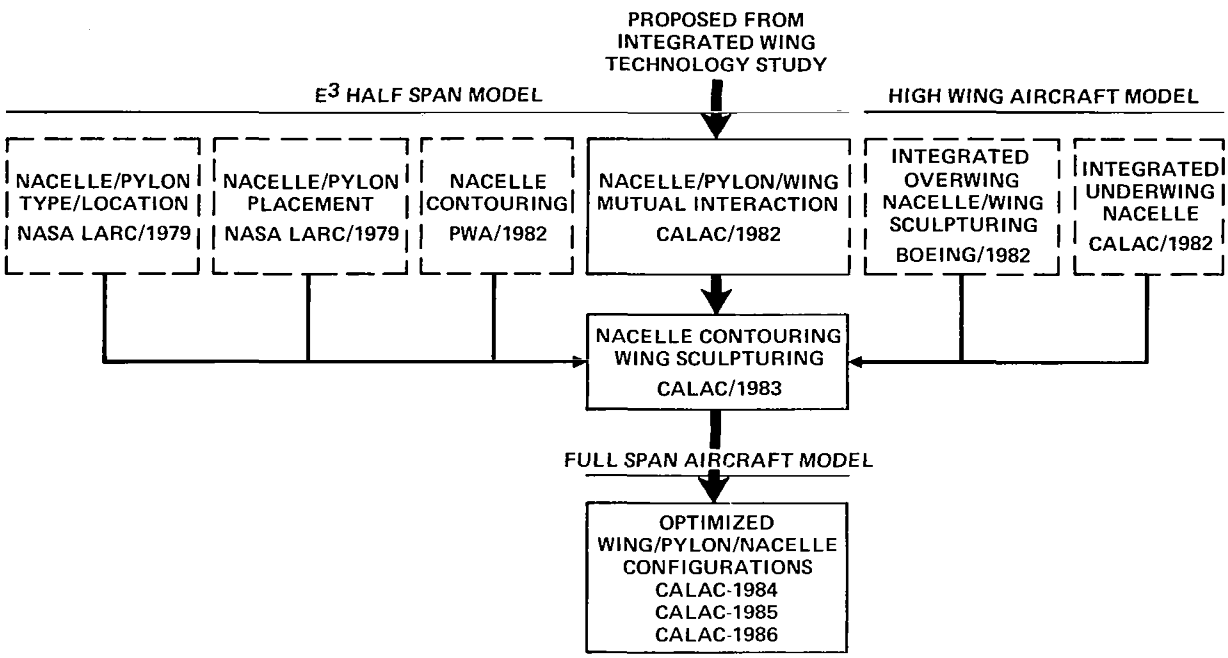


Figure 126. - Technology development test programs.

supply and instrumentation lines. Time required for model hardware changes is significantly reduced since the TPS instrumentation is not disturbed when a different pylon is installed. Testing would be done in the NASA-LaRC 7 by 10 foot wind tunnel.

Drag and lift effects, as well as detailed pressure distributions, will be obtained for a comprehensive number of nacelle positions. Other configuration variables, such as nacelle diameter to wing chord ratio, pylon shape, nacelle pitch angle, and pylon/nacelle yaw (toe) angle will be investigated at various nacelle positions to examine their influence on optimum nacelle location.

Estimated cost for this first phase of model testing is $2.2M. The wind tunnel facility costs are approximately $1.2M.

7.3.2.1.2 Phase 2 - nacelle contouring/wing sculpturing test: The second phase of the model test plan, scheduled for 1983, will be an investigation aimed at determining the drag effects of contouring the nacelle and locally sculpturing the wing. The configurations that will be tested will be the best attempt to improve performance at the optimum nacelle location selected from the first phase of testing.

The E^3 mixed flow TPS model on an advanced technology half span wing will again be used, as for the first phase. However, a typical installation is anticipated, wherein the supply air and instrumentation lines are brought through the wing and pylon to the TPS. A single force balance will be used to measure wing, pylon and nacelle total thrust minus drag. The NASA-LaRC 7 by 10 foot wind tunnel will be used for this phase of testing.

The configuration variables that will be investigated are three dimensional contouring effects of the nacelle, local sculpturing of the wing, and cambering of the pylon. These configurations will be developed by utilizing theoretical methods which will have been improved by using the results of the first phase of testing. In addition, results from other test programs identified in figure 126, which are related but not a part of this test plan, will be utilized.

Cost of the second phase of testing is approximately $900K, with about $400K being required for the wind tunnel facility.

7.3.2.1.3 Phase 3 optimized wing/pylon/nacelle configuration test: The purpose of the third phase of the test program is to evaluate the effects of advanced technology wing configurations, using optimized nacelles, on installed drag levels. An attempt will be made to reduce the aircraft drag by possibly installing a less-than-optimum clean wing configuration which, when coupled with a nacelle and pylon, may provide the lowest overall aircraft drag. Multiple entries may be required for this third phase of testing and these are currently planned for the 1984 through 1986 time period.

Estimated cost of this phase of the test program is $1.4M. Wind tunnel testing costs are approximately $300K. The model will be a full span aircraft model employing two nacelle TPS units. The aircraft will be mounted on a sting supported force balance, and the air supply and instrumentation lines to the TPS units will be routed through the wing and pylon. Testing will be done in the NASA LaRC 16 ft wind tunnel.

7.3.2.2 Theoretical methods/studies: No work is currently available for accurate analytical study of integrated propulsion and airframe systems. A recently published method due to Boppe (AIAA Paper 80-01300, January 1980, reference 13), which is based on an extended small disturbance theory, provides a capability to analytically study the first order effects of propulsion system/airframe interations at subsonic/transonic flight speeds. Specifically, it can be used to compute flowfields around fuselage-wing combinations with as many as four pylons, four pods/powered nacelles, and wing-tip-mounted winglets. Predicted results have been shown to be in good agreement with experimental data for several transport configurations. A copy of the computer program was obtained under special arrangements with NASA and made operational on the Lockheed-California Company computer system. The method lacks an accurate representation of the complex inlet flowfield and does not take into account the exhaust flow jet entrainment and displacement effects on the external flow. In addition, currently it can handle only rectangular pylons and axisymmetric nacelles. The computing time is also excessive, about 45 minutes per run on the IBM 370/3033 computer. The code, must be extended to handle swept pylons and 3-D nacelles, and its solution time must be considerably reduced.

The Boppe code will be evaluated in detail using primarily the L-1011 flight test data. In addition, data obtained from various wind tunnel tests of aircraft models with flow-through and powered nacelles will be analyzed to gain an understanding of the flowfields and then the results will be compared with the Boppe code predictions for further code evaluation as well as to guide future testing. All available wind tunnel and flight test data on the propulsion system/airframe integration problem will be collected and correlated to supplement the Boppe code in developing design methods. The resultant design methods will be used to define new wing-pylon-nacelle configurations to be tested under various programs.

7.3.2.2.1 Nacelle program: Several accurate computer programs, each with certain advantages and limitations, are currently available for the design and performance analysis of isolated subsonic/transonic nacelles. These will be further improved, adding additional capabilities therein as needed. Because of relative merits, some of these programs will have to be used in conjunction with the Boppe code in designing nacelles. The nacelle programs are briefly described and discussed below.

- Lockheed Transonic Flow Program. This program obtains compressible, full potential equation solutions to flows about 2-D and axisymmetric inlets without centerbodies at zero angle of attack. It can handle mixed subsonic/supersonic flowfields as well as shocks. Predicted results are in very good agreement with experimental data. The code will be extended to take into account the surface boundary layer, boundary layer separation, and small angles of attack.

- Lockheed Potential Flow Program. This program obtains incompressible solutions to flows about axisymmetric inlets with or without centerbodies and can handle inlet angles of attack. Compressibility corrections are then added to the solutions to obtain fairly accurate results even at high subsonic Mach numbers. However, the program cannot handle shocks or mixed subsonic/supersonic flowfields that are generally encountered in transonic flows.

- Stockman-Farrell Program (NASA TM-73728). This program obtains incompressible solutions to flows about axisymmetric inlets with or without centerbodies and can handle inlet angles of attack. Compressibility corrections are then added to the solutions to obtain fairly accurate results even at high subsonic Mach numbers in the absence of shocks and mixed subsonic/supersonic flowfields. The program, which has been obtained by Lockheed has several input options which allow more accurate results to be obtained for the same number of inlet coordinate points used in the Lockheed Potential Flow Program.

- Hess-Mack-Stockman Program (NASA CR-259578). This program obtains incompressible solutions to flows about arbitrary three-dimensional inlets with or without centerbodies and can handle inlet angles of attack and angles of yaw. The Leiblein-Stockman compressibility correction is then added to the solutions to obtain fairly accurate results even at high subsonic Mach numbers in the absence of shocks and strong embedded supersonic regions. This program will be obtained in the near future and evaluated in detail.

7.3.2.2.2 Exhaust flow program: Among several computer programs currently available for exhaust flow calculations, two stand out prominently because of their accuracy, possible applications, and computational speed. These are briefly described and discussed below.

- Lockheed Exhaust Flow Program. This program accurately computes mixed flow nacelle exhaust properties within the main external flow at subsonic, transonic, and supersonic flight speeds in the absence of shocks. It will be extended to take into account the nozzle boattail afterbody.

- Wilmoth Program (NASA TP-11626) This program takes into account the nozzle boattail/afterbody and computes the exhaust flow properties within the main external flow at subsonic flight speeds. Predicted results have been shown to be in fairly good agreement with experimental data. This program will be obtained and evaluated in detail. It will then be extended to transonic speeds and made much more accurate by incorporating into it the Lockheed exhaust flow program.

7.3.2.2.3 Application of theoretical methods: The Boppe code, with the incorporated improvements, will be used to study/analyze the nacelle-pylonwing mutual interaction effects during the first series of E^3 half-span model tests. The code will be used to guide the nacelle-wing sculpturing for the second series of tests. These test results will continuously be used to further evaluate and improve the Boppe code. For the third and final series of tests, various nacelles and wings will be designed separately using appropriate computer codes and then the Boppe code will be used to select the optimum nacelle-wing configurations/combinations to be tested.

7.4 Propulsion System Technology Risk

The undertaking of any advanced technology project includes a certain degree of risk that the full goal may not be achieved. Evaluating the risk in a technology program requires estimating the probability of problem areas and unknowns which could develop within the program time and budget constraints.

The technology risk database for the E^3 Flight Propulsion System was taken from the GE E^3 project as defined in reference (4). The technology risk involved in propulsion system integration was established by Lockheed based on experience in developing large subsonic transport aircraft and includes the background of model test information from both NASA and industry.

7.4.1 E^3 flight propulsion system. - The probability of achieving the target weight of the E^3 Flight Propulsion System is presented in figure 127. As shown on the figure there is less than a 50 percent probability that the target weight will be achieved. The probability of achieving the cruise SFC reduction for the E^3 Engine and the E^3 Flight Propulsion System is presented in figure 128. These data indicate an 85 to 90 percent probability of achieving the SFC goal specified for both engine programs. The probabilities of attaining the propulsion system price, maintenance, and direct operating cost (DOC) goals are presented in figures 129 through 131.

7.4.2 Propulsion/airframe integration.- A subjective statistical analysis was conducted to estimate the probability of achieving the goal of zero interference drag. Analysis results, in the form of probability distribution curves, are presented in figure 132 for application of current and advanced technology. The distribution curve for application of current technology was based on recent NASA LaRC experience on integrating a nacelle/pylon with a supercritical wing. Specifically, NASA test results for a configuration with pylon camber and area ruling indicated an interference drag of 3.0 percent of aircraft drag. The probability of achieving the same drag level for a new advanced technology wing was estimated to be 80 percent, as indicated by the point labeled "reference" in the figure.

The probability of achieving the interference drag goal by application of advanced technology is estimated to be 60 percent. By contrast, achievement of the goal by application of current technology is considered to be highly improbable. The distribution curve for advanced technology was estimated assuming the availability of advanced three-dimensional numerical methods and an expanded experimental data base for nacelle/wing interaction effects.

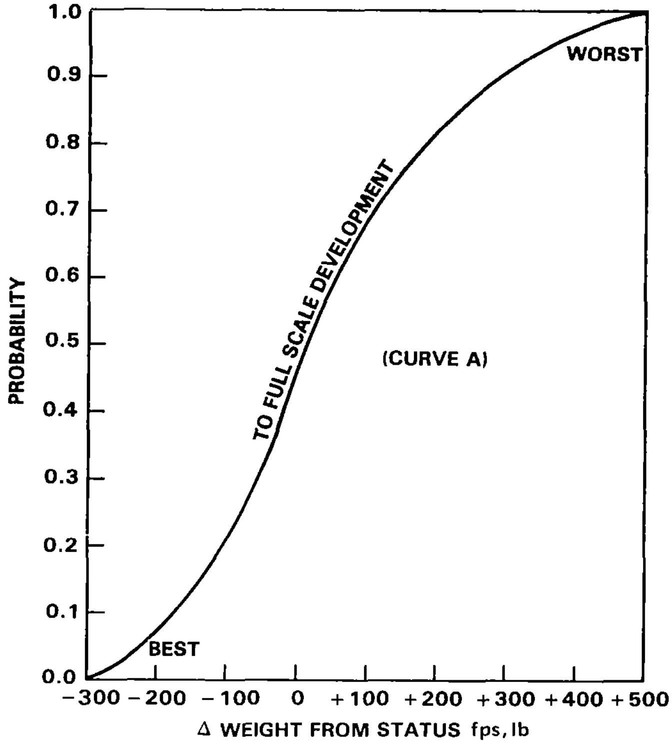


Figure 127. - Probability of achieving fps weight projection.

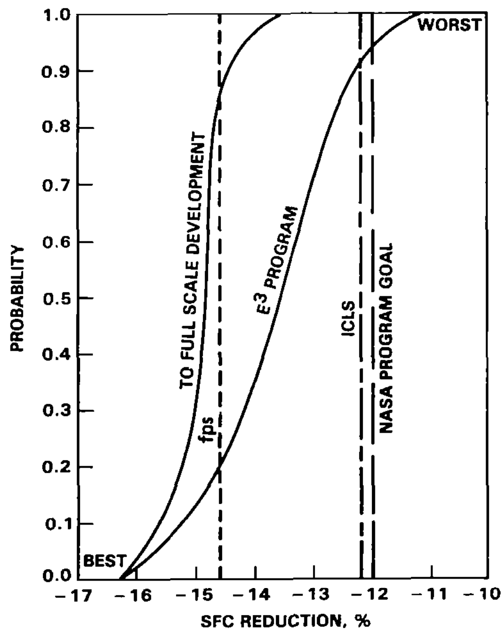


Figure 128. - Probability of achieving SFC goals.

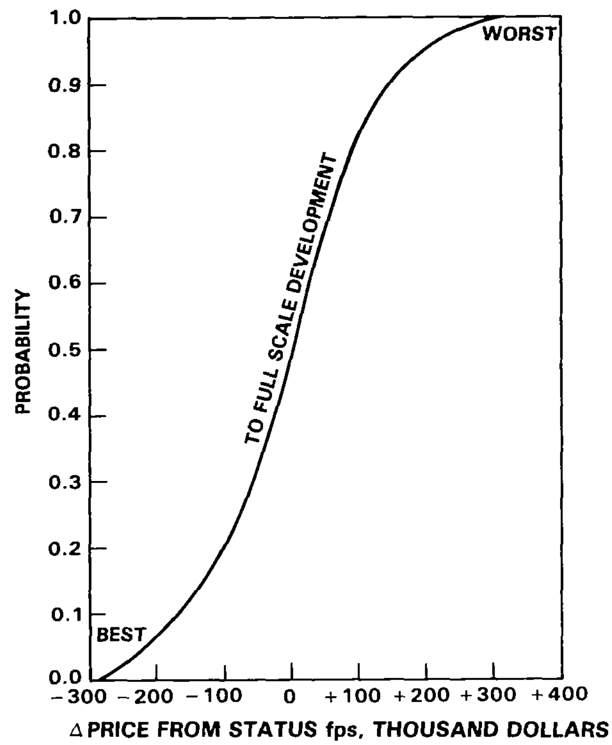


Figure 129. - Probability of achieving FPS price projections.

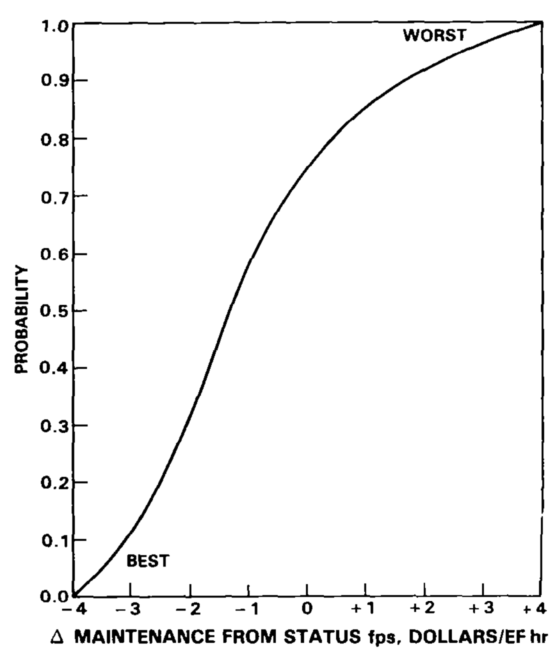


Figure 130. - Probability of achieving FPS maintenance cost projections.

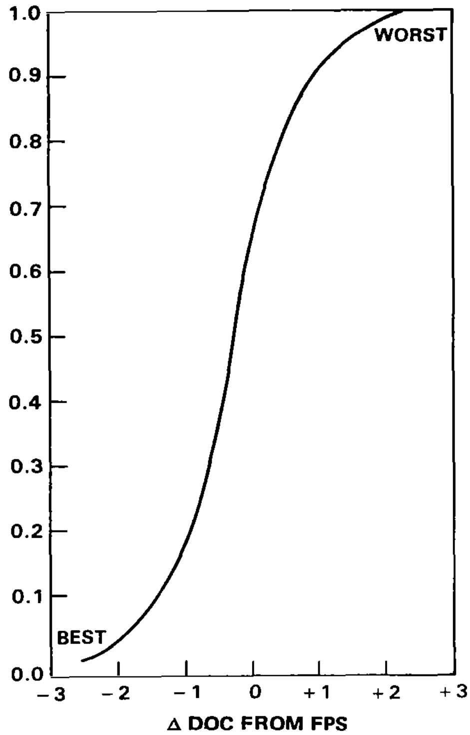


Figure 131. - Probability of meeting projected DOC.

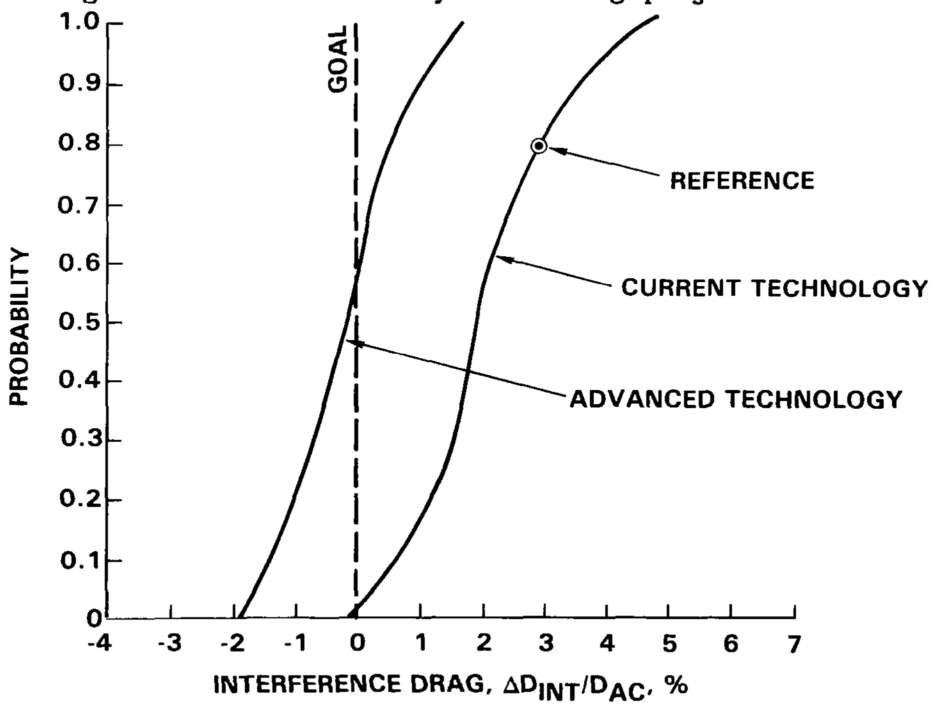


Figure 132. Interference drag risk assessment.

8. ADVANCED MATERIALS AND STRUCTURES

8.1 Introduction

For several decades high strength wrought aluminum alloys have been widely used by the air transport industry in airframe structures applications. Significant advances have been made in materials and temper conditions with high resistance to corrosion; i.e., high strength clad plate for wing skins, precision forgings with desirable grain flow, and exfoliation and stress corrosion resistant 7075-T76 and T73 products. Lockheed pioneered the development of the latter optimized overaged tempers which offered improved stress corrosion and exfoliation resistance. The use of these alloys, however, has resulted in some weight penalties because of reductions in strength properties. The projected fuel costs and fuel availability require the incorporation of energy-efficient technologies into the next generation transport aircraft. This demand necessitates improved performance and better structural reliability in advanced aircraft structures. There is a need for alloys that combine high strength, low density, and high modulus of elasticity with improved toughness, corrosion, and fatigue properties.

A number of aluminum alloy development programs have been and are being conducted to study the feasibility of improving these alloys for aerospace applications. Ingot metallurgy (IM), with appropriate thermomechanical processing, and powder metallurgy (PM) techniques, using selected consolidation and processing conditions, are being investigated.

In concurrence with aluminum alloy development is the ongoing research and development of composite materials for aircraft structural applications. Advanced composites by virtue of their high strength and stiffness, offer the potential for new and innovative design concepts that exploit the high strength, stiffness, and controlled anisotropy of the material. With the application of advanced composites to secondary and primary components of commerical aircraft, a substantial savings in energy (i.e., fuel consumption) may be realized. Further development into the use of this material is intended to provide the technology and confidence necessary so that the commerical transport manufacturers will have the option to commit to production large scale composite structures. This, in turn, will provide the support necessary to maintain the economic viability of the commercial transport industry through technology for improved energy efficiency of future U.S. aircraft.

8.2 Benefits of Advanced Materials

A list of proposed material candidates for use in aircraft designated for a 1986 and 1990 first flight date have been developed based on appropriate component design criteria and will serve as a guide to direct future research and development activities of the manufacturer. (Tables VIII, IX and X)

The product forms, alloy types, and design criteria relative to their respective components were established utilizing an L-1011 baseline aircraft. Although no extensive research activity has taken place to suggest that the material applications listed could indeed be applied to specific components, it is anticipated that those showing significant cost/weight benefits could be experimentally developed in the event a concerted effort is made to develop an advanced technology aircraft. This effort will also require some complementary government agency research and funding for programs such as the proposed "Transport Aircraft Composite Structures" (references 14 and 15) program, "Systems Study of Transport Aircraft Incorporating Advanced Aluminum Alloys" (reference 1).

For the wing program, potential advancements in aluminum alloys, composites, and metal matrix composites were selectively utilized. Three aircraft configurations were chosen for advanced material and structural applications and were defined as follows (table XI):

To optimize weight and cost consideration, major aircraft structures were reduced a percentage in weight. The methodology for predicting the cost and weight savings values, resulting in a material property substitution of a specific airframe component were utilized for this program. The derivation of the component weight reductions were established through results of several research studies of advanced material applications. Reference was made to NASA CR-145381-1 and -2 "Utilization of Advanced Composites in Commercial Aircraft Wing Structures," (references 14 and 15) and NAS1-16434 "Systems Study of Transport Aircraft Incorporating Advanced Aluminum Alloys" (reference 1). Since the fuselage structure of the baseline aircraft would remain unchanged for this particular program only the wing and empennage were affected by the advanced material mix. A weight reduction matrix was established (Table XII) and inputted into the ASSET program for each respective configuration. Results of the ASSET run are discussed further in this report.

8.3 Advanced Aluminum Material Development Plan

The study results encompassing property goals, product forms, and market factors for advanced aluminum alloy application were reviewed. The results indicated research needs for three alloy systems: (1) PM 7XXX alloy for high-strength and high-strength corrosion-resistant design; (2) PM 2XXX or PM 7XXX alloy for fatigue and damage-tolerant design; and (3) IM Advanced 2020-T6 alloy for low-density, high-strength design. The development plan, presented in figure 133 encompasses (1) alloy and product development, (2) mill and

TABLE VIII. - MATERIAL SELECTIONS FOR ADVANCED TECHNOLOGY AIRCRAFT FUSELAGE GROUP

COMPONENT	% WEIGHT OF FUSELAGE	CURRENT ALLOY	PRODUCT FORM	DESIGN CRITERIA	1982 TECH—1986 1ST FLT ALTERNATE MAT'L CAND.	1986 TECH—1990 1ST FLT ALTERNATE MAT'L CAND.
SKINS	23%	2024-T3 7075-T76	CLAD SHEET	DADTA & STRENGTH	2124 & AL PM	ADV. 2124 & ADV. AL PM
FRAMES	11%	7075-T6 7178-T6	CLAD SHEET FORGINGS EXTRUSIONS	STRENGTH	Al PM & Al Li	ADV. Al PM & Al Li
STRINGERS & LONG.	7%	7075-T6	EXTRUSIONS CLAD SHEET	STRENGTH	AL PM	ADV. AL PM
MISC. BULKHEADS	9%	7075-T6 7075-T73	EXTRUSIONS FORGINGS CLAD SHEET	STRENGTH	Al Li & GR/E	ADV. Al Li & GR/E ADV. SIC/Al
WHEEL WELL PRESSURE DECK KEELSON WEB	8%	7075-T6	EXTRUSIONS	STRENGTH	AL PM	ADV. AL PM
DOOR DOUBLERS SEAT TRACKS WINDOWS/FRAMES WINDSHIELD STRUCT DOOR SURROUND MISCELLANEOUS	25%	2024-T3 7178-T6 7075-T736 2024-T81 2024-T38	CLAD SHEET EXTRUSIONS FORGINGS EXTRUSIONS CLAD SHEET	DADTA & STRENGTH	2124 & AL PM	2124 & ADV. AL PM
FLOOR SUPPORTS	11%	7075-T6 7178-T6	EXTRUSIONS	STRENGTH	ADV. COMP. & AL PM	ADV. COMP. & AL PM
PASSENGER DOORS & FRAMES	5%	2024-T3 7075-T6	CLAD SHEET	STRENGTH	2124 & AL PM	2124 & ADV. AL PM
LANDING GEAR DOORS	1%	2024-T3	CLAD SHEET	DADTA	ADV. COMP. & Al Li	ADV. COMP. & Al Li

TABLE IX. - MATERIAL SELECTIONS FOR ADVANCED TECHNOLOGY AIRCRAFT WING GROUP

COMPONENT	% WEIGHT OF WING	CURRENT ALLOY	PRODUCT FORM	DESIGN CRITERIA	1982 TECH—1986 1ST FLT ALTERNATE MAT'L CAND.	1986 TECH—1990 1ST FLT ALTERNATE MAT'L CAND.
LOWER SURFACE SKINS, STIFF, BEAM CAPS	32%	7075-T6 7075-T76	H S CLAD PLATE EXTRUSIONS	CORROSION DATA STRENGTH	AI PM	MMC & GR/E
UPPER SURFACE SKINS, STIFF, BEAM CAPS	24%	7075-T6 7075-T76	H S CLAD EXTRUSIONS	CORROSION FATIGUE STRENGTH	AI PM	MMC & GR/E
RIBS & BULKHEADS	9%	7075-T6	CLAD SHEET EXTRUSIONS	STRENGTH	AI PM	ADV. AL PM
SPAR WEB & STIFF.	7%	7075-T6	BARE PLATE EXTRUSION	STRENGTH	AI PM	ADV. COMPOSITES
TRAILING EDGE FLAPS	11%	7075-T6 2024-T4 7075-T73 2024-T3 TI-6-6-2	EXTRUSION CLAD SHEET FORGING CLAD SHEET BAR	STRENGTH & STIFFNESS	AI LI & GR/E	ADV. AI LI & GR/E ADV. SIC/AL
LEADING EDGE SLATS	6%	2024-T6 7075-T6 2024-T62 TI-6AI-4V 2024-T81	CLAD SHEET EXTRUSION CLAD SHEET FORGING CLAD SHEET	STRENGTH & STIFFNESS	AI LI & GR/E	ADV. AI LI & GR/E ADV. SIC/AI
LEADING EDGE FIXED	4%	7075-T6	CLAD SHEET EXTRUSION FORGING	STRENGTH & STIFFNESS	AI LI & GR/E	ADV. AI LI & GR/E ADV. SIC/AI
TRAILING EDGE	3%	7075-T6	EXTRUSION PLATE CLAD SHEET	STRENGTH & STIFFNESS	AI LI & GR/E	ADV. AI LI & GR/E & SIC
AILERONS	1%	7075-T6 2024-T3	EXTRUSION CLAD SHEET FORGING	STRENGTH & STIFFNESS	GR/E	GR/E ADV. SIC/AI
SPOILERS	1%	7075-T6 2024-T62	EXTRUSION CLAD SHEET FORGING	STRENGTH & STIFFNESS	GR/E AI LI	GR/E ADV. SIC/AI ADV. AI LI
MISCELLANEOUS	2%	—	—	—	—	—

TABLE X. - MATERIAL SELECTIONS FOR ADVANCED TECHNOLOGY AIRCRAFT VERTICAL TAIL & HORIZONTAL TAIL

	COMPONENT	% WEIGHT OF TAIL	CURRENT ALLOY	PRODUCT FORM	DESIGN CRITERIA	1982 TECH—1986 1ST FLT ALTERNATE MAT'L CAND.	1986 TECH—1990 1ST FLT ALTERNATE MAT'L CAND.
VERTICAL TAIL	BENDING MATERIAL SKINS, STIFF., BEAM CAPS	19%	7075-T6	CLAD SHEET EXTRUSIONS	STRENGTH & STIFF.	GR/E COMPOSITES	GR/E COMPOSITES
	SHEAR MATERIAL WEBS & STIFF.	4%	7075-T6	BARE SHEET EXTRUSIONS	STRENGTH & STIFF.	GR/E COMPOSITES	GR/E COMPOSITES
	RIBS WEBS & STIFF.	6%	7075-T6	CLAD SHEET EXTRUSIONS	STRENGTH & STIFF.	GR/E & Al PM	GR/E & ADV. Al PM
	LEAD & TRAILING EDGES	8%	7075-T6	CLAD SHEET	STRENGTH	AL LI	ADV. Al LI
	RUDDER	21%	2024-T3	CLAD SHEET	STRENGTH	Al LI & GR/E	ADV. Al LI & GR/E
	MISCELLANEOUS	42%	———	———	———	———	———
HORIZONTAL TAIL	BENDING MATERIAL SKINS & BEAM CAPS	36%	7075-T6	EXTRUSION	STRENGTH & FATIGUE	GR/E COMPOSITE	GR/E COMPOSITE
	SHEAR MATERIAL WEBS & STIFF.	6%	7075-T6	EXTRUSION	STRENGTH & FATIGUE	GR/E COMPOSITE	GR/E COMPOSITE
	RIBS WEBS & STIFF.	12%	7075-T6	CLAD SHEET EXTRUSIONS	STRENGTH & FATIGUE	Al LI & GR/E	ADV. Al LI & GR/E
	LEAD & TRAILING EDGE	17%	7075-T6	CLAD SHEET	STRENGTH & FATIGUE	Al LI	ADV. Al LI
	ELEVATOR	18%	2024-T3	CLAD SHEET	STRENGTH & FATIGUE	Al LI & GR/E	ADV. Al LI & GR/E
	PIVOT FITTING	11%	4340	STEEL FORG.	STRENGTH & FATIGUE	NONE	NONE

fabrication process development, (3) material design data development, and (4) structural design development. This plan identifies the program elements necessary to develop standards, specifications, and data for production design application. The plan spans over a five year period at an estimated cost of 150 equivalent man years of effort.

Much of this cost is relegated to the aluminum producer and airframe manufacturer. The development and introduction of new alloys for design application requires a continuous and extensive interaction between the key scientific and technical personnel of both the aluminum producer-alloy research and airfame manufacturer-engineering research organizations. The work which is shared and duplication is confined to verification tests. The advanced material data are incorporated into the industry data bank as engineering specifications, standards, design handbooks, stress manuals, etc. Aluminum producer's mill processing needs and airframe builder's manufacturing research needs are identified through research planning and advanced design studies. The aluminum producers development results in new alloys and product forms for production application. Manufacturing standards and specifications are developed and made available for production design applications.

8.3.1 Alloy and product development.

8.3.1.1 Alloy development: The alloy development activity is a joint airframe manufacturer, aluminum producer, and NASA materials research effort. Alloy selection consists of a review of existing alloy systems and the selection of a candidate alloy systems which have the capability of attaining the target goals. The candidate alloys are proposed to be produced in small lot sizes in wrought product form to provide an assessment of their properties and microstructural behavior. Tensile and notch tensile tests, metallographic and fractographic analyses will be performed. Promising compositions will progress to the product development phase. The task description and key milestones are shown in the schedule (figure 134). The cost for the 18-month effort is estimated at 20 equivalent man-years.

8.3.1.2 Product development: The product development activity will commence when the powder and billet production of the alloy development task is to the point where the various product forms can be made. The various tasks shown in figure 135, encompasses the effort necessary to: make the sheet, extruded plate, and forged product forms; develop process specifications; and evaluate the various product forms. This includes the preproduction investigations to ensure the alloys can be produced on production equipment. The need to pursue sheet and plate products is imperative due to high predicted usage and limited development currently in progress. To support this activity the initial scale-up of billet sizes capable of providing sheet and plate products, large forgings, and heavy extrusions is also included. Process variables and control limits, heat treat, surface finish and prepration will be investigated to develop process specifications.

TABLE XI. - MATERIAL SELECTION BY CONFIGURATION

Configuration 9	Baseline	+	Advanced composites
Configuration 10	Baseline	+	Advanced aluminum alloys
Configuration 12	Baseline	+	Metal matrix composites

TABLE XII. - ADVANCED MATERIAL COMPONENT WEIGHT REDUCTION PERCENTAGE

Configuration 9		Configuration 10		Configuration 12	
Advanced composites		Advanced aluminum		Metal matrix	
Wing	27.0%	Wing	12.0%	Wing	18.0%
Empennage	20.0%	Empennage	12.0%	Empennage	17.0%
Fuselage	0.0%	Fuselage	0.0%	Fuselage	0.0%

The largest volume of product form occurs in sheet and plate. Plate and sheet capacity will require development of a PM billet of at least 2700 to 3600 kg (6000 to 8000 lb). Plate and sheet availability is targeted by Alcoa for a 1985 to 1986 timetable, which is in approximate agreement with the development plan.

A joint aluminum producer, airframe manufacturer, and government participation is anticipated. Major cost of the planned 24-month effort will be incurred by the aluminum producer (>20 equivalent man-years). The airframer and government development testing and evaluation effort is estimated at 10 equivalent man-years.

8.3.2 Mill and fabrication processing

8.3.2.1 Mill processing development: The mill processing development task will include the production of large billets capable of producing mill lots of sheet, plate, extrusions and forgings, as shown in figure 136. The initial processing of mill products will be in sufficient quantity to ensure reproducibility. Quality assurance testing, including nondestructive testing, mechanical property testing, and microevaluation will be performed on mill products.

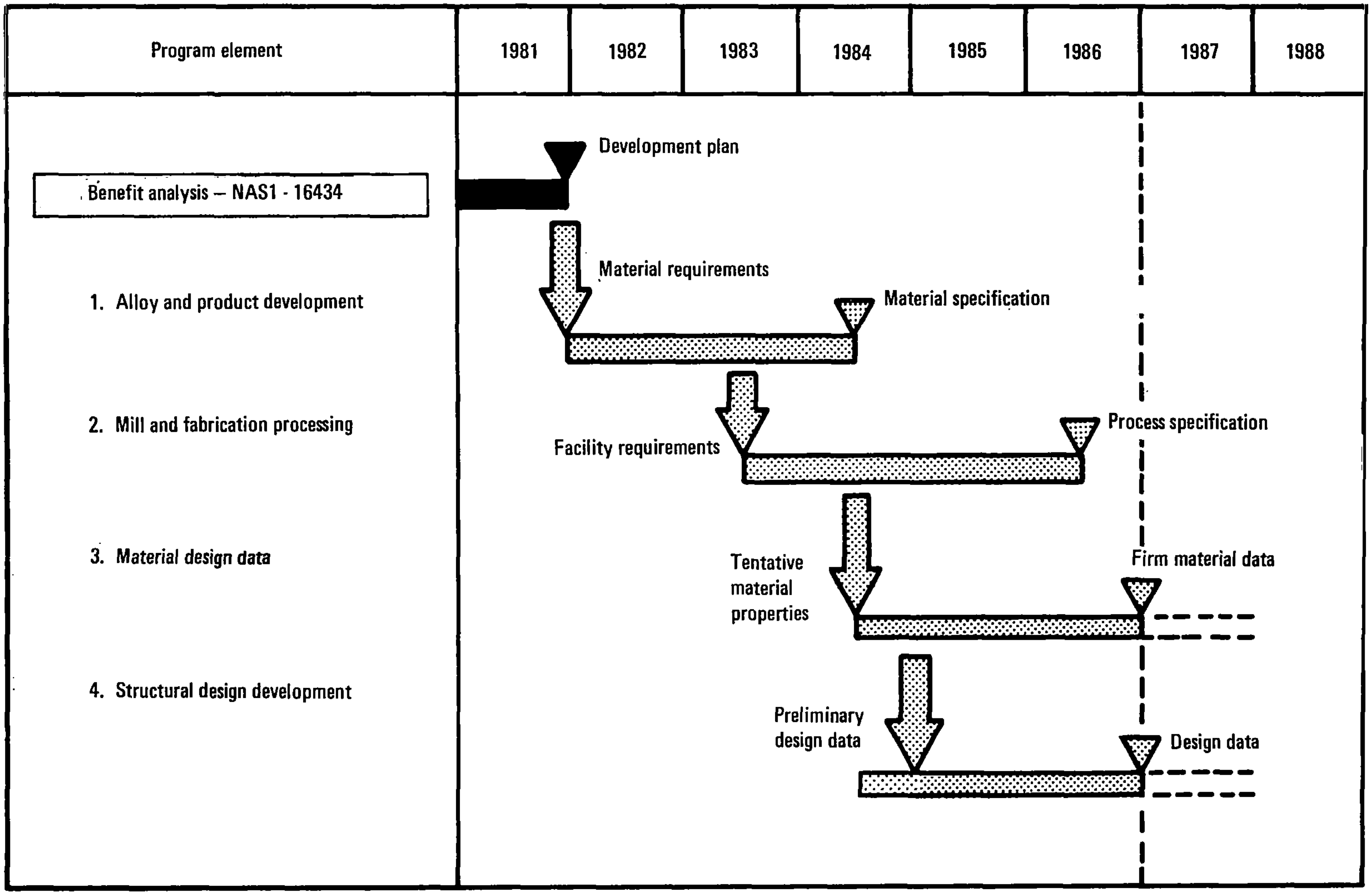


Figure 133. - Advanced aluminum alloy material development plan.

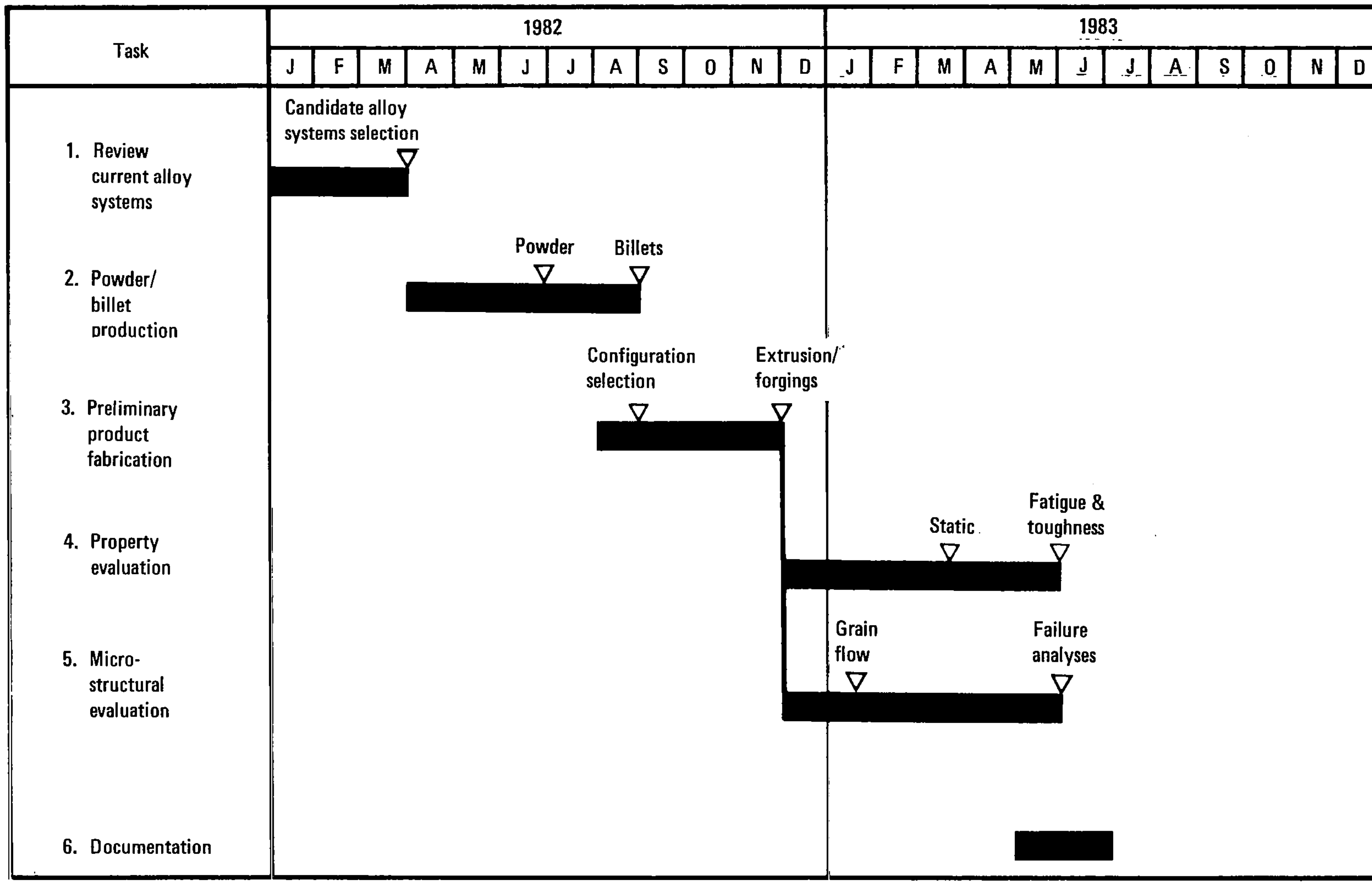


Figure 134. - Advanced aluminum alloy - alloy development.

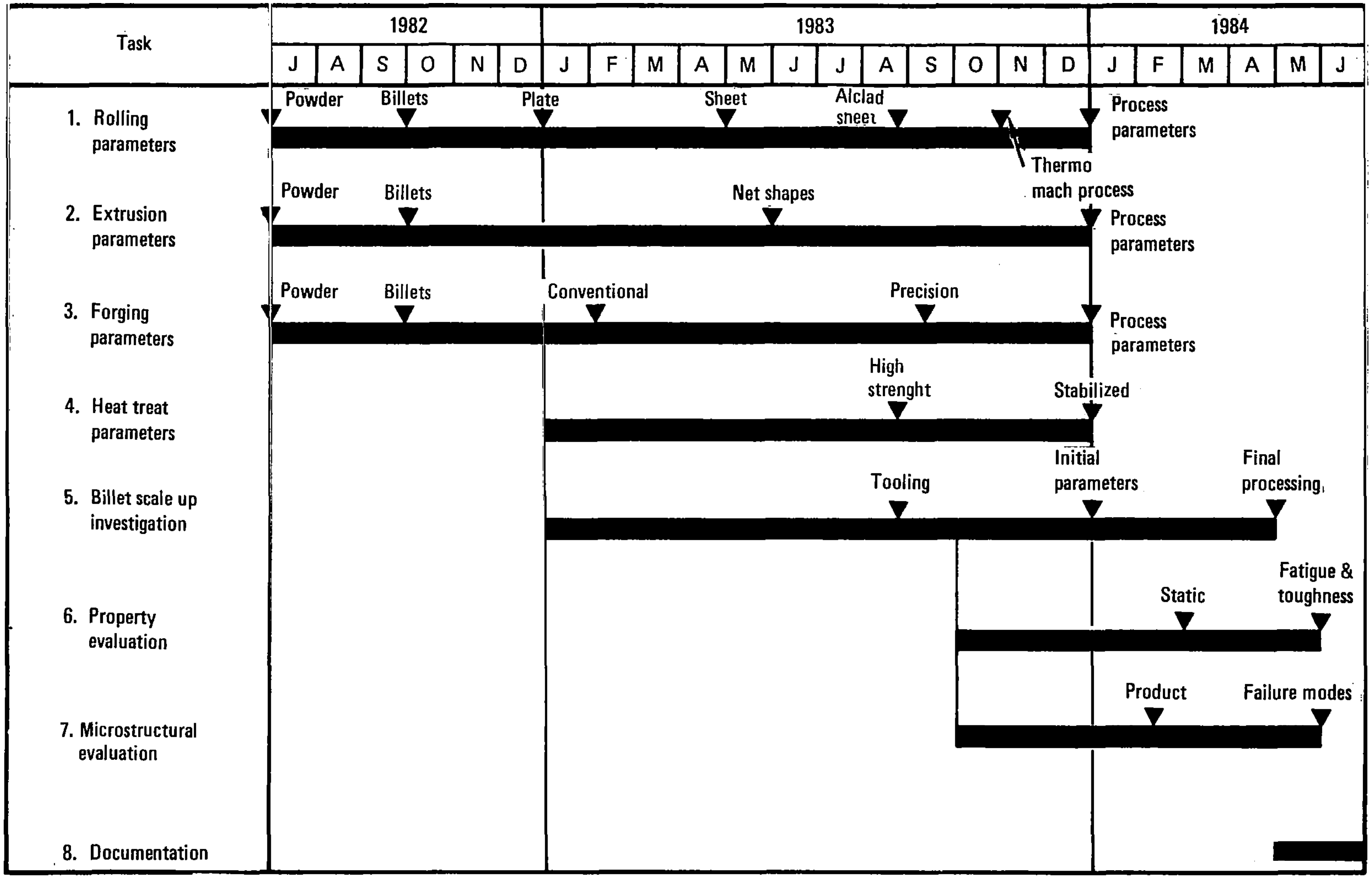


Figure 135. - Advanced aluminum alloy - product development.

The 30-month task is heavily oriented toward aluminum producer activity (> 20 equivalent man-years.) The extent and amount of funding required by the producers is being determined. The airframe and government development testing and evaluation effort is estimated at 10 equivalent man-years.

8.3.2.2 Fabrication processing development: The fabrication process development effort, shown in figure 137, will evaluate the more common fabrication practices, i.e., hole drilling, bending, stretch forming, joggling, etc., required for aircraft manufacture. All product forms will be evaluated and compared to current ingot alloy product behavior. Both preproduction and production products will be used to accelerate the fabrication behavior results.

The 30-month effort is primarily an airframe manufacturer activity with government participation in the processing and analysis efforts. An effort of 10 equivalent man-years is estimated.

8.3.3 Material design data.

8.3.3.1 Material properties: Material design data will be obtained from comprehensive evaluation of mill products to establish a base for MIL-HDBK-5 allowables as shown in figure 138. Static, fatigue, and fracture behavior of all products will be evaluated. Availability of preliminary design allowables is targeted for early 1985 to provide design data for structural element and small structural component design, test and evaluation.

Static properties will be developed from appropriate test coupon configurations for each product form, heat treat, and significant test direction. Design data encompasses: F_{tu}, F_{ty}, F_{cy}, F_{su},F_{bru}, e, E, and E_c, full-range stress-strain, target modulus, and Ramberg-Osgood parameters. Both constant-life and stress-lifetime (S-N) data will be obtained for a fatigue property evaluation. A minimum of three S-N curves will be developed, each for a different stress-ratio. These data will be used to determine constant-life curves. Fracture toughness evaluation will be conducted to obtain stress intensity-thickness data over a full thickness range. Plane-stress, plane-strain, and the transitional stress state will be included.

Fatigue crack growth tests will be performed to verify the predicted improvements in crack growth resistance for the new alloys using the specimen geometry specified for the fracture toughness test specimens. Crack growth tests will be performed over a range of a/w parameters. Stress intensities will be computed and crack growth (da/dN) versus stress intensity (K) data will be obtained.

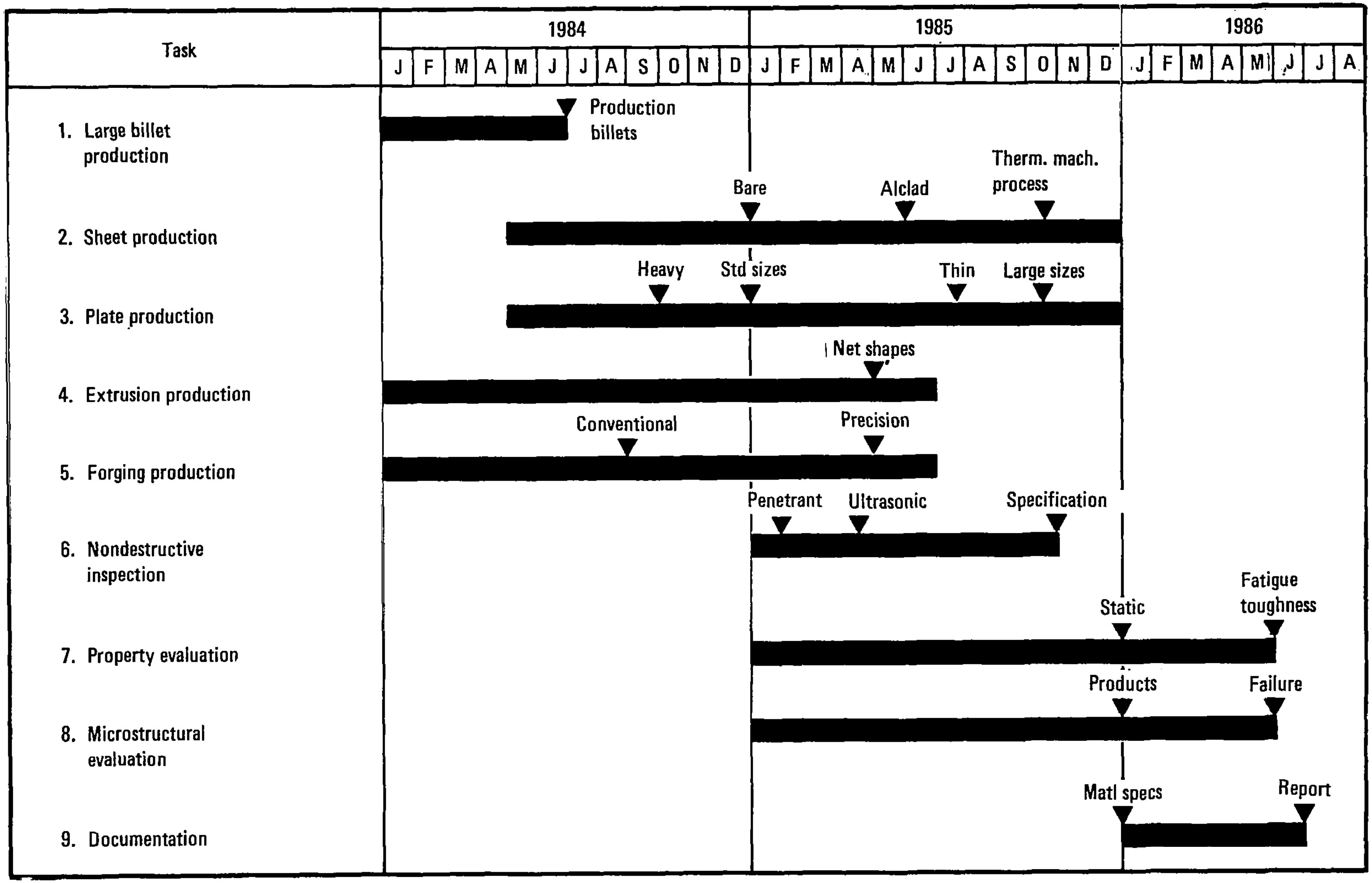


Figure 136. - Advanced aluminum alloy - mill processing.

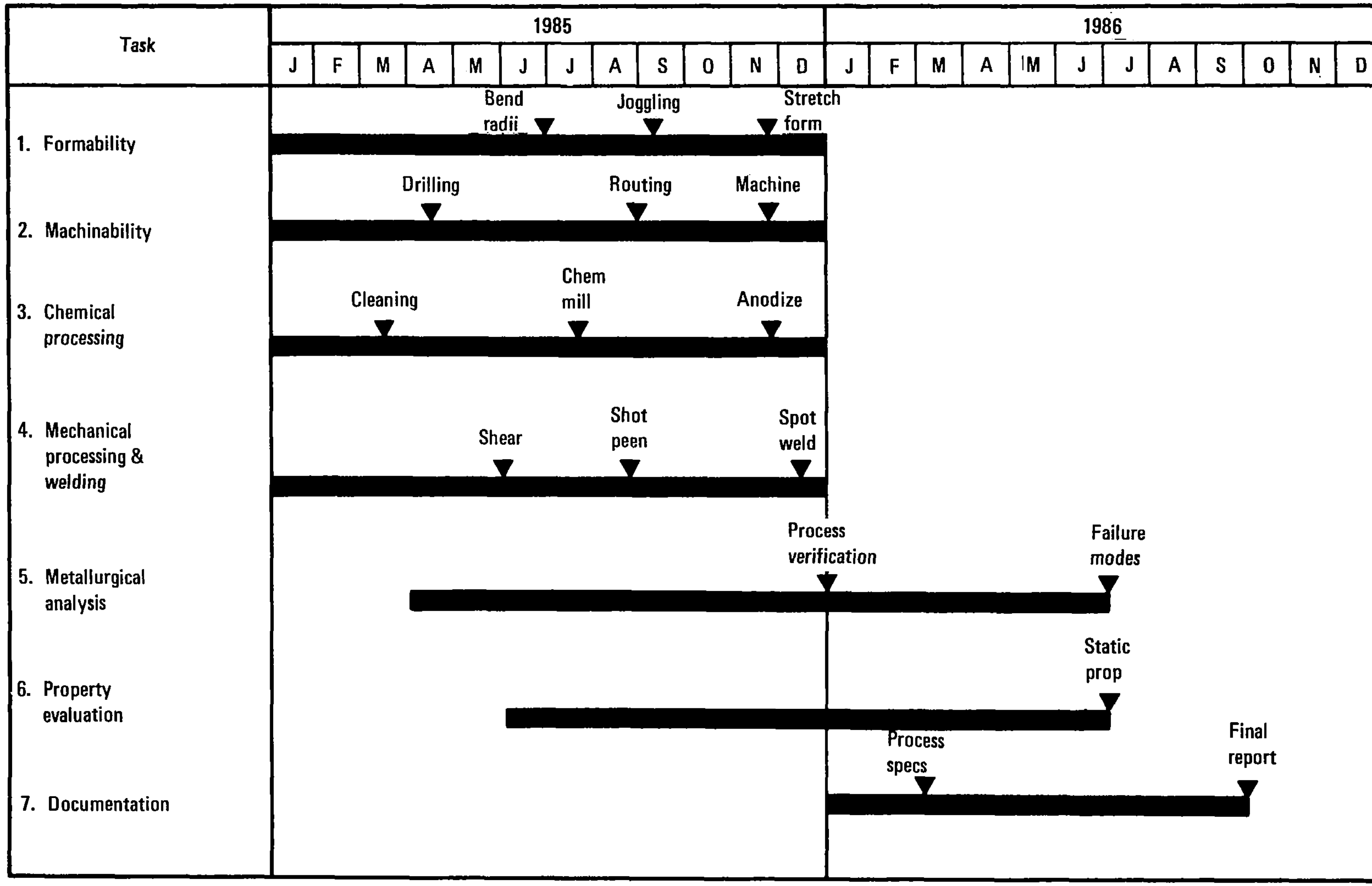


Figure 137. - Advanced aluminum alloy - fabrication processing.

Selected test specimens from several of the test groups will be metallurgically prepared to verify grain orientation, general microstructure, micrograin structure, gain size, etc., as appropriate. Selected test specimens will be examined by scanning electron microscope (SEM) fractography to characterize fracture surfaces. Comparisons will be made with existing data on IM products.

The 30-month effort will be performed by the airframe manufacturer, certified testing laboratories, and government testing facilities. The estimated cost for this effort is 15 equivalent man-years. Additional resources are required to obtain A-basis MIL-HDBK-5 data.

8.3.4 Structural design development. - An experimental program is proposed to be conducted over a 30-month period to verify the material property data of the new alloys as shown in figure 139. Structural element and small component tests will be performed to establish a database for detail design.

8.3.4.1 Structural element development: A building-block approach is proposed to develop structural element data necessary for detail design of primary airframe structure. Basic tests will encompass: single and multiple element crippling, column buckling, shear buckling, bending, and tension; compression panel static, spectrum fatigue, and crack growth; and joint configuration ranging from thin sheet fuselage configurations to more complex and heavily loaded wing joint arrangements. The estimated cost for the 18-month structural element development is 5 equivalent man-years.

8.3.4.2 Structural components development: Design analysis, fabrication, test, and evaluation of generic structural components are proposed. Baseline components and design requirements will be established to measure improvement in material performance. Design analyses are proposed using the baseline aluminum alloys and advanced PM or IM aluminum alloys designed to the same criteria. The baseline components will be fabricated using both baseline and selected alloys. Static, fatigue, fail-safe, and residual-strength tests will be performed. The baseline components will encompass:

- Curved fuselage shell
- Fuselage longitudinal splice
- Fuselage girth splice
- Wing upper surface
- Wing lower surface
- Wing upper surface with cutout

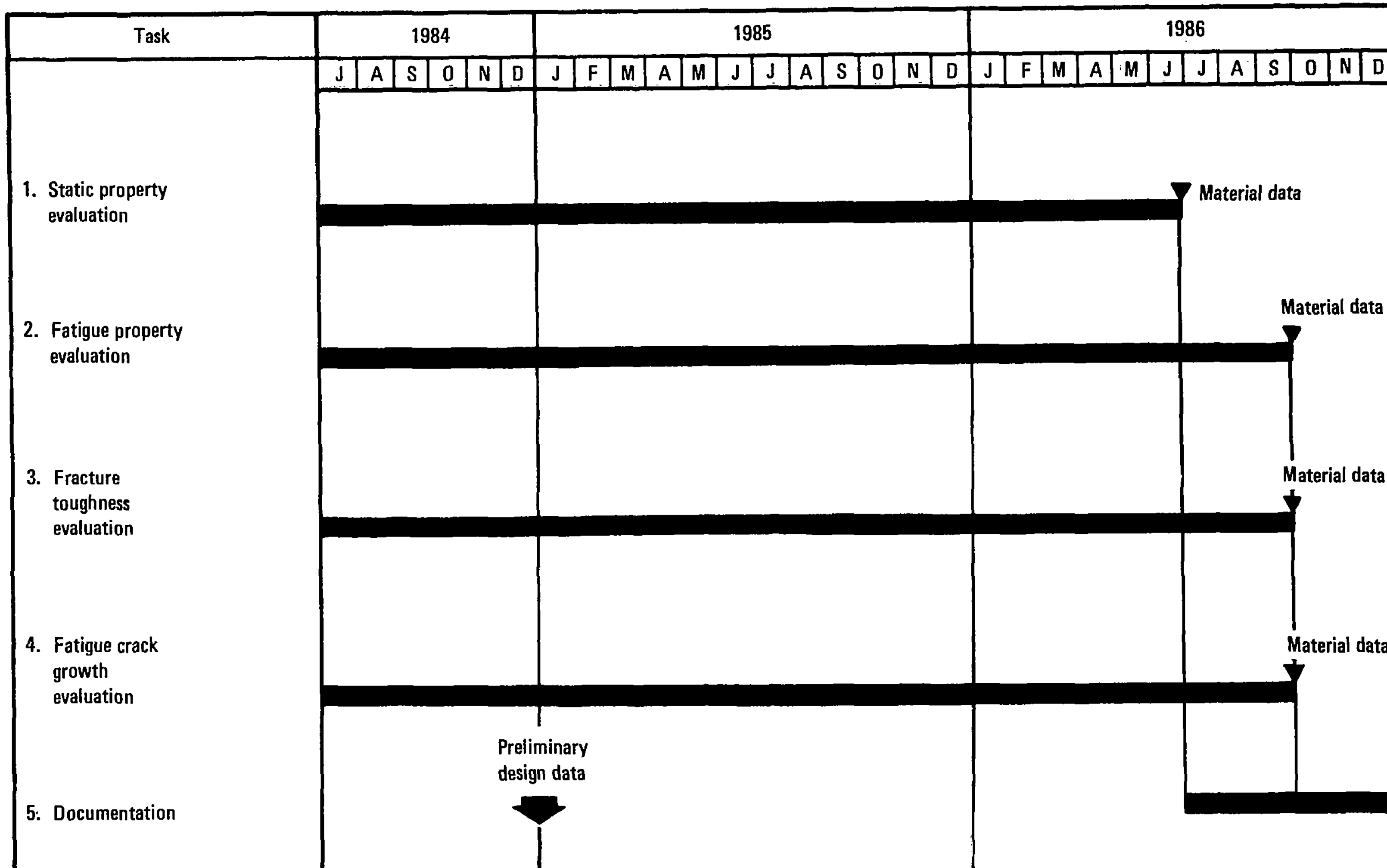


Figure 138. - Advanced aluminum alloy - material design data.

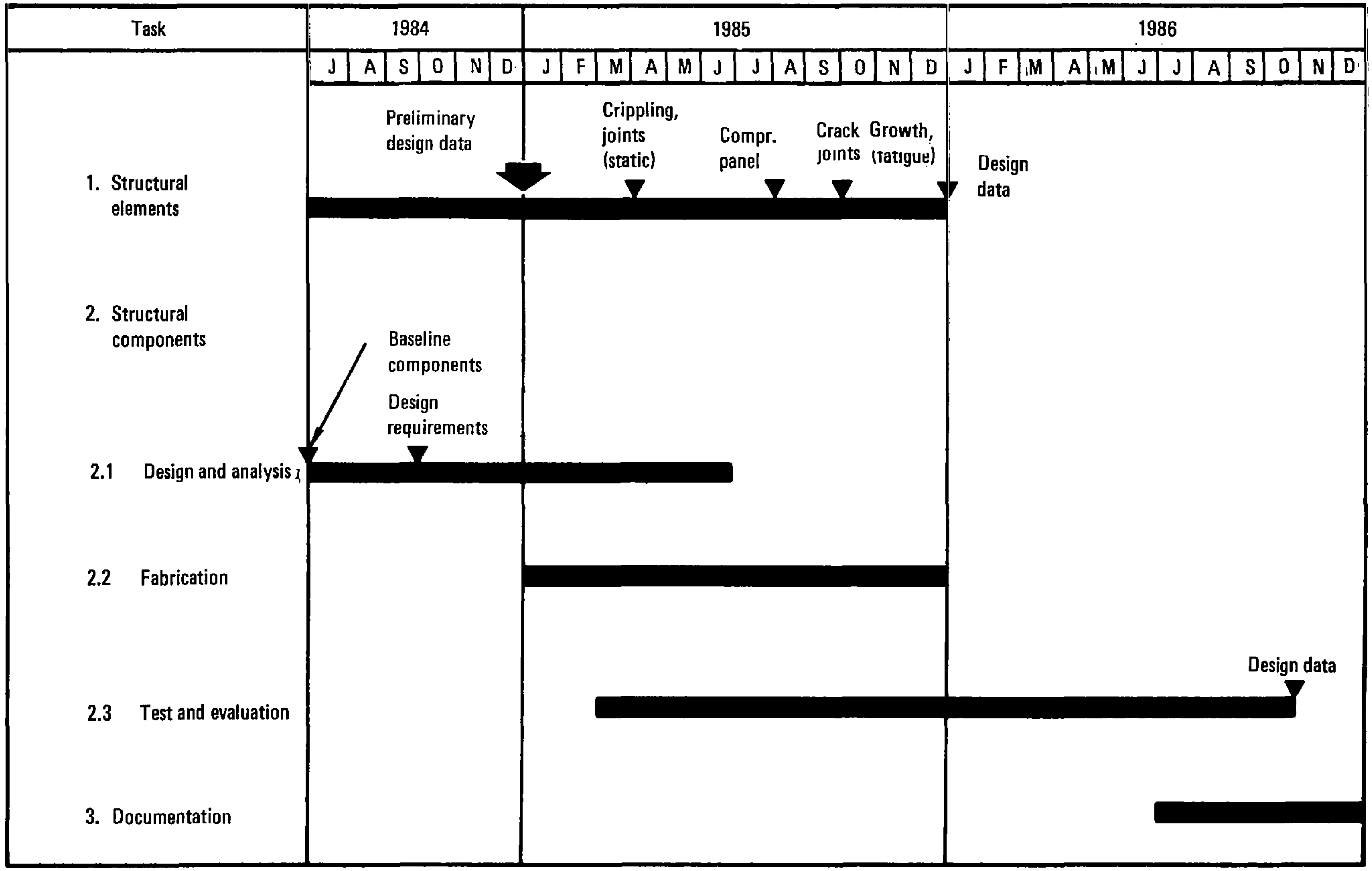


Figure 139. - Advanced aluminum alloy - structural design development.

- Wing lower surface with cutout

- Multibay lower surface.

The 30-month design, fabrication, and test effort will be a multidisciplined effort involving engineering, manufacturing, quality assurance personnel, and facilities. The estimated cost for this effort is 35 equivalent man-years.

8.4 Composite Wing Development Plan

The wing structure development program plan (figure 140) encompasses engineering and manufacturing studies; manufacturing development; and development testing - to generate composite wing design data, to support concepts development, and for design verification. The program culminates in the manufacture and test of full-scale demonstration articles of a representative wing structure.

The program will be conducted in four technical phases:

- In Phase I, Preliminary Design, design criteria and preliminary loads will be established, supplemental material design data will be developed, and preliminary design and analysis of an advanced technology transport will be performed to define a representative wing and fuselage structure for development purposes.

- In Phase II, Design Concepts and Manufacturing Development, promising structural approaches for composite wing structure will be evaluated through design, producibility, and manufacturing concepts studies; process development and fabrication method studies; and specimen fabrication and development testing of wing design and assembly concepts.

- In Phase III, Design and Manufacturing Verification, the composite wing structure design and manufacturing parameters will be verified; cost-weight trade studies will be performed; and verification tests conducted on a variety of wing subcomponents.

- In Phase IV, Full-Scale Demonstration, the fabrication of a large wing cover segment, and design, manufacture and testing of a representative wing box structure will be undertaken to demonstrate the readiness of composite wing structure technology.

8.4.1 <u>Phase I - Preliminary design (figure 141)</u>. - An advanced preliminary design of a future commercial transport aircraft that integrates the various emerging technological elements will be used as the reference airplane for the study. The wing and fuselage structure will employ graphite/epoxy materials in both the primary and secondary airframe component designs.

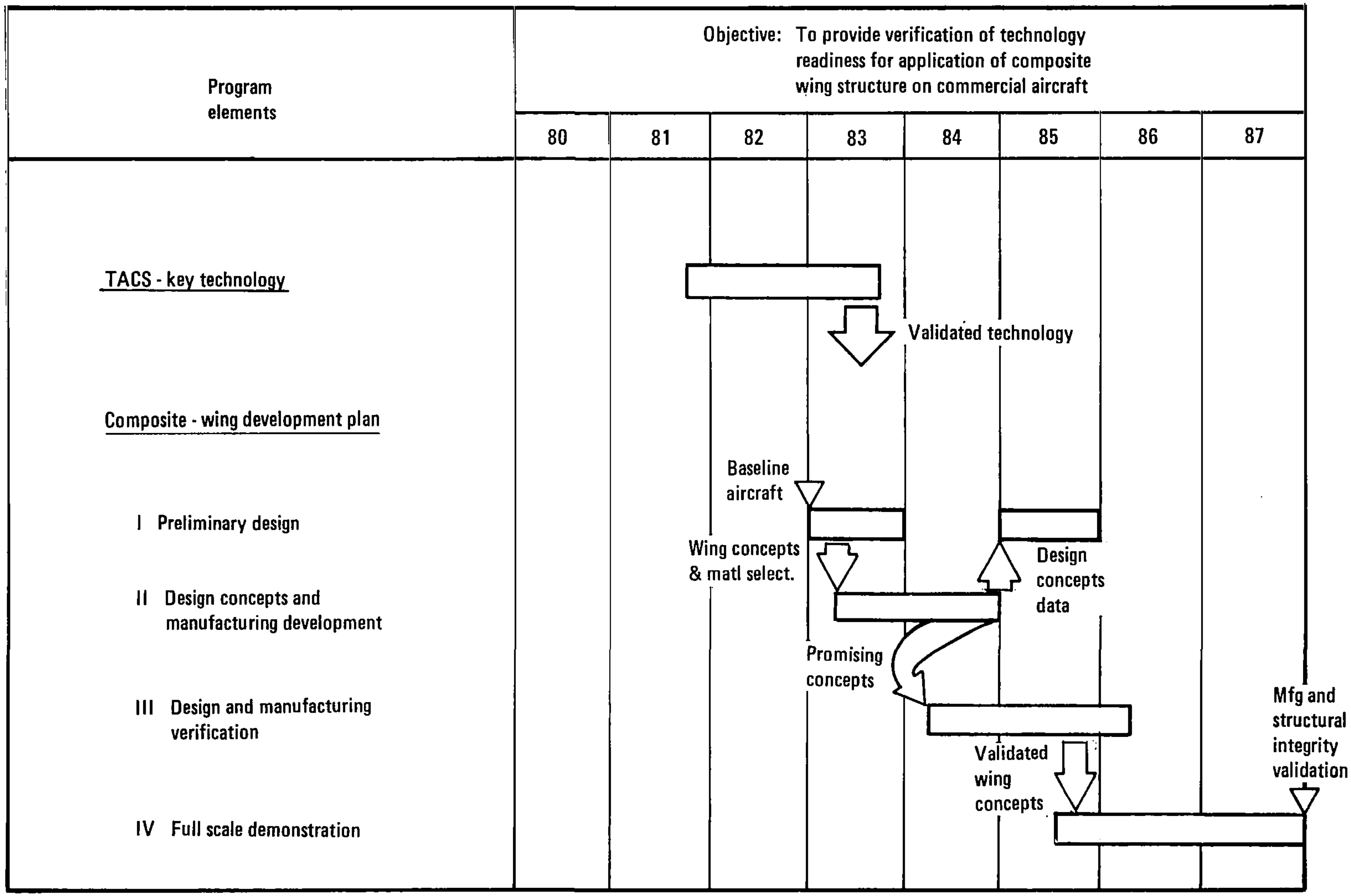


Figure 140. - Program element.

8.4.1.1 Design criteria and loads: Structural design criteria will be formulated based on the current understanding of Lockheed and FAA requirements. Aeroelastic loads will be developed for a limited number of symmetric and asymmetric flight conditions and ground conditions. This variety of conditions will provide representative design load envelopes for the wing box along the span of the wing.

8.4.1.2 Material evaluation and selection: The graphite/epoxy material systems available in this program's time-frame will be reviewed for use in the composite structures program. The applicability of new material systems to composite wing structure development will be based on the available material property data base considering toughness, environmental durability, and processibility improvements relative to the currently used graphite/epoxy material systems.

8.4.1.3 Design data: The results of the three key technology programs will be reviewed to establish the permissible design strain level to be used in this wing program. Additional tests will be performed to provide supplementary data to the selected graphite/epoxy database. These tests will verify/determine the strength and durability characteristics of the material when subjected to the wing design environment.

8.4.1.4 Design and analysis: A study will be performed to determine a representative composite material design for the wing structure of the baseline advanced technology aircraft. A systematic multidisciplinary design analysis process will be employed in the structural evaluation. The evaluation will include in-depth studies involving the interactions between airframe strength and stiffness, static and dynamic loads, flutter, fatigue and fail-safe design. Due to the complex nature of these studies, extensive use will be made of computerized analysis programs.

8.4.2 Phase II - Design concepts and manufacturing development (figure 142). - Promising concepts for composite wing primary structure will be identified through design/manufacturing studies of candidate concepts. In assessing the various structural concepts and materials for the major wing components, such factors as ease of fabrication and assembly, sealing of fuel tanks, maintenance and repair, and capability of analysis and design of such components consistent with applicable requirements, will be considered.

8.4.2.1 Producibility and fabrication methods: Producibility guidelines for the candidate structural configurations will be established and documented as design bulletins and guidelines. This information will be based on key technology program results and the latest material and fabrication technology. Based on the latest technology, preliminary process specifications to guide development of detail part and assembly fabrication and quality assurance schemes will be prepared.

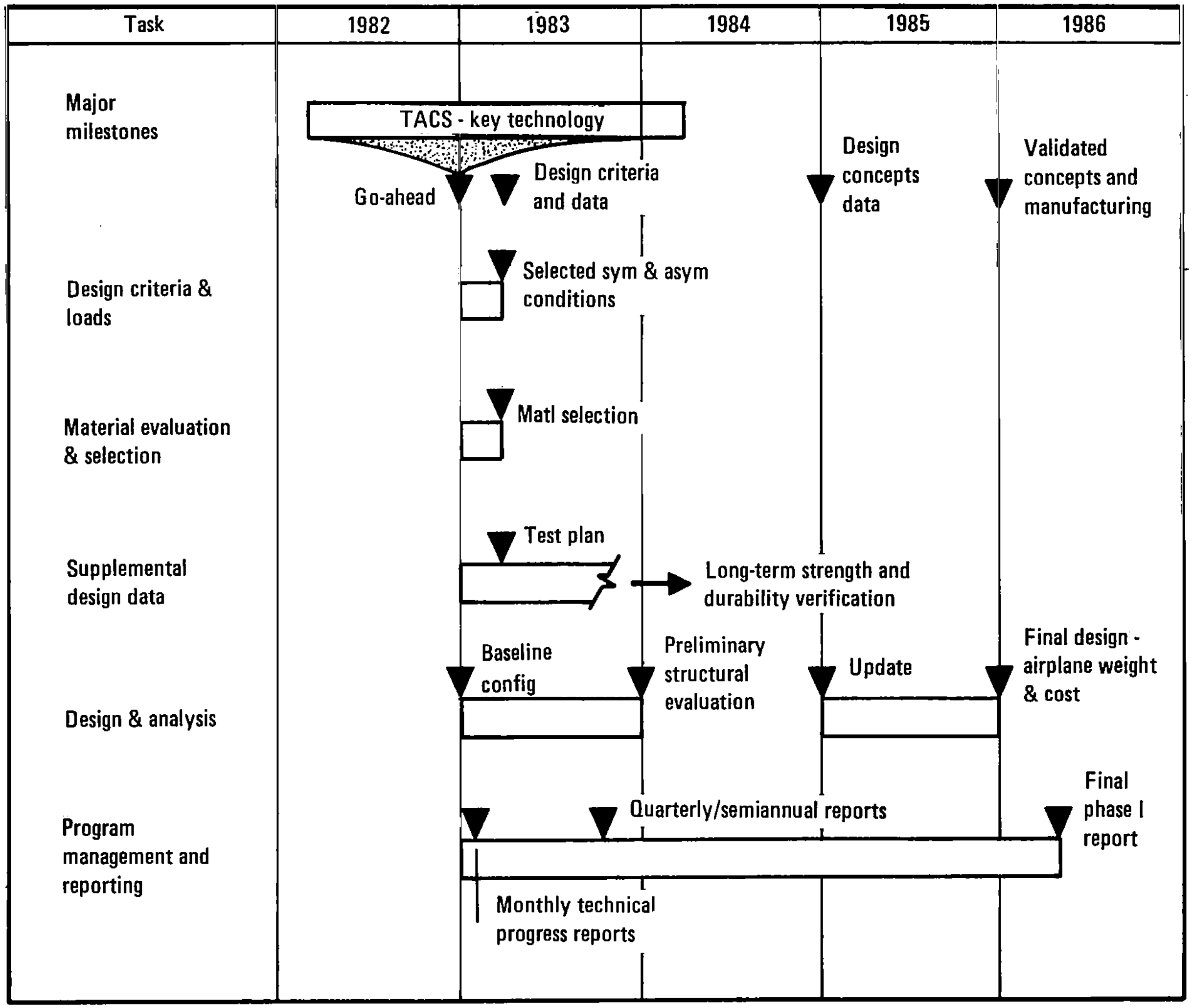


Figure 141. - Phase I - Prelimininary design.

As conceptual design studies and preplanning analysis on the composite wing begin to yield preliminary definitions of component detail parts, feasible fabrication plans will be developed for each configuration concept. These plans will include material types and forms, molding method and tool concepts, and a sequential list of essential fabrication operations such as layup, curing, and inspection points. These plans will be in the form of tooling sketches and draft operation sheets. Alternate plans will be developed for the major components or for portions thereof.

As a result of these conceptual tooling and fabrication studies, recommendations will be made as to which design concepts should be considered candidates for process development fabrication.

An assembly plan considering a preliminary assembly sequence, assembly elapsed times and units in process, preliminary manloading, and assembly tool requirements will be developed. These data will be used for facility requirement calculation and cost and schedule development.

8.4.2.2 Process development and fabrication: The development of fabrication and process techniques which would apply to particular elements of the design concepts will be made through fabrication of process development articles. The articles will be representative of design concepts under consideration and will be evaluated by visual examination, dissection, or dimensional checks.

8.4.2.3 Concept development testing: The concept development tests include structural element and subcomponent tests covering structural concepts for the wing covers, the spars and the ribs, and for significant assemblies. Both static strength and fatigue tests are specified for the concept development and verification effort. All fatigue testing will be conducted using appropriate flight-by-flight transport wing loading spectra. When fail-safe concepts are being evaluated, a combination of fatigue and static testing is specified. All of these development tests will be conducted in a room temperature, dry, environment.

8.4.3 Phase III - Design and manufacturing verification (figure 143). - Verification tests will be conducted to validate the most promising wing structure design concepts. A team of engineering and manufacturing/QA specialists will work together to select appropriate wing cover, spar, ribs and lightning strike protection system components for test. The engineering drawing release schedule will be in accordance with the required fabrication and testing time-table.

8.4.3.1 Fabrication methods verification: Fabrication plans including quality assurance procedures will be developed for each detail part and assembly emanating from structural design based on latest revision of drawings, and process specifications. For selected critical components, it is planned

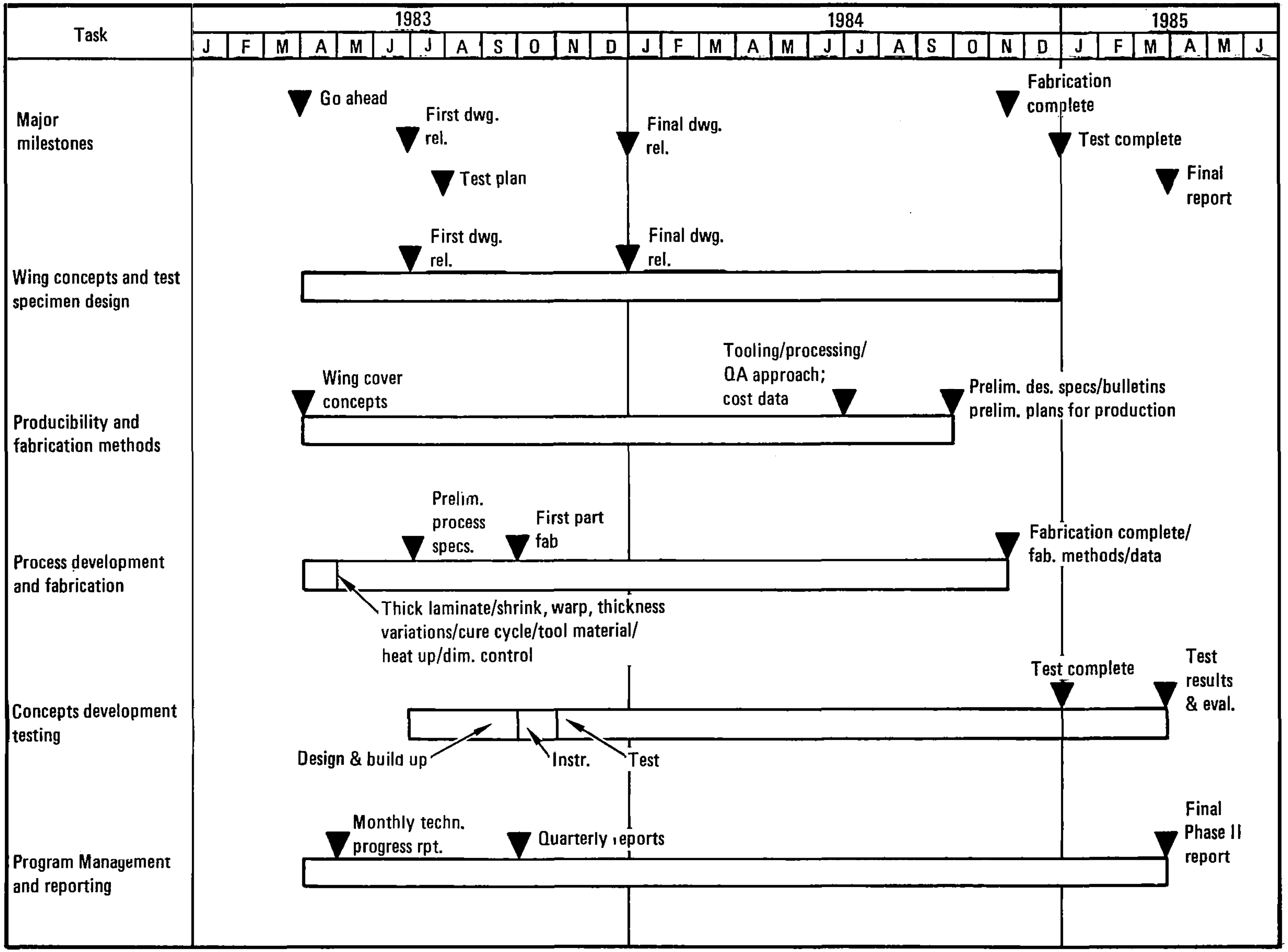


Figure 142. - Phase II - Design concepts and manufacturing development.

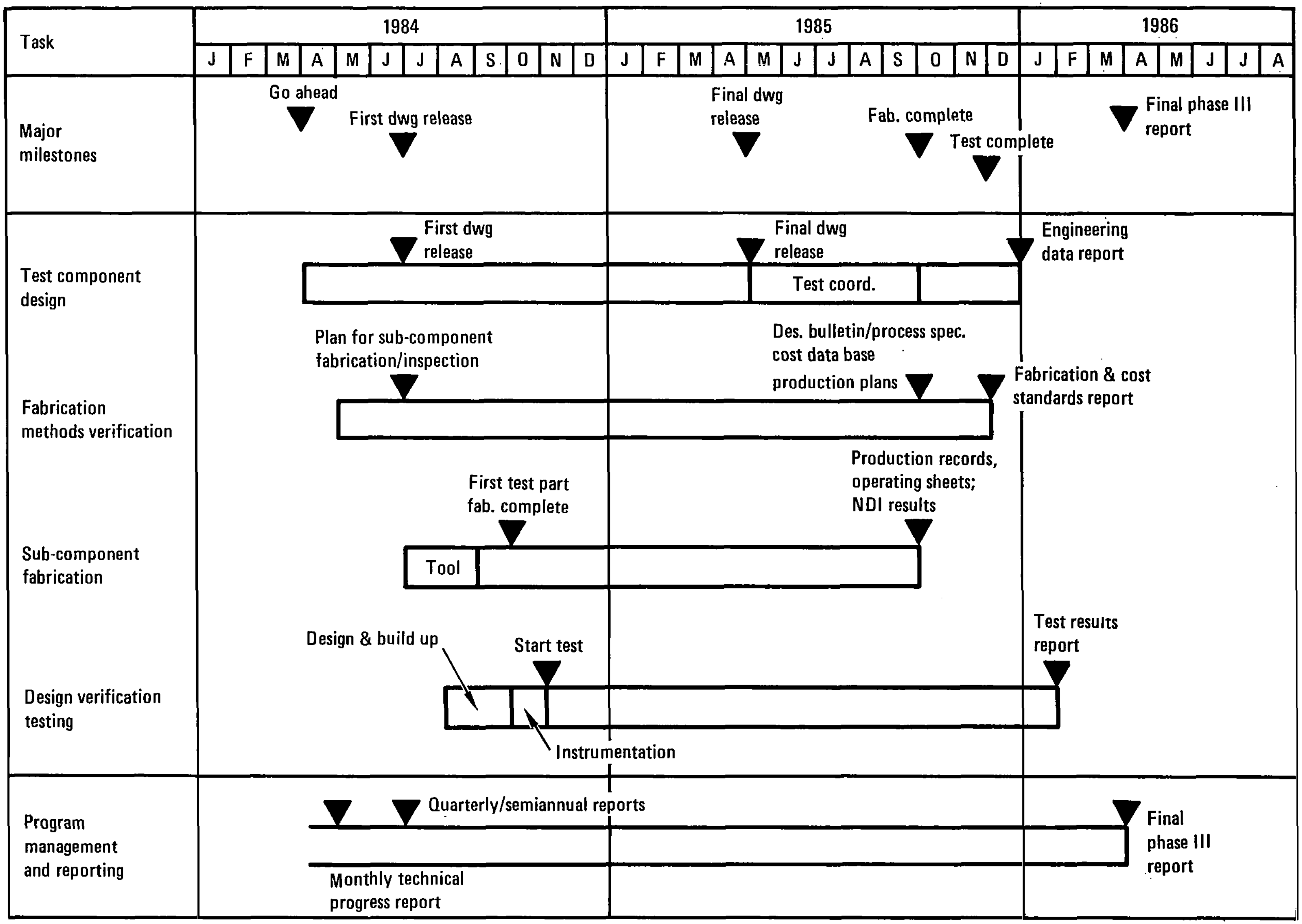


Figure 143. Phase III - Design and manufacturing verification.

to prove or verify that fabrication methods selected will produce hardware which meets design drawing requirements by constructing extra units of selected subcomponent test articles. These articles will be evaluated by visual and dimensional inspection, nondestructive test, and sectioning the component for laboratory tests. Any indicated deficiencies will be corrected by modification of tools or processes before construction of articles designated for engineering tests is commenced.

Following fabrication of the components for engineering test, an update of the production cost estimates will be made. The new estimate will be based on a tool plan which will have been partially proven through the design, manufacture, and use of the development tooling, and through the accumulation of actual cost data in the fabrication of the test components. Additional cost experience from the L-1011 composite fin program and other on-going ACEE programs will be available to provide additional confidence in forecasting composite manufacturing costs. Thus, more data will be accumulated toward establishing cost standards necessary for accurately predicting production costs in the final phase of this program.

8.4.3.2 Subcomponent fabrication: The manufacture of design verification test specimens will be similar to the manufacture of process development specimens. The components will basically consist of modifications of previous designs. Tools built to produce the earlier specimens are expected to be usable as is or with modifications to produce the components for these test articles. Minimum type assembly tooling will be built to demonstrate alignment for the joint and attachment point specimens.

In addition to the nondestructive tests which will be performed on all specimens, a single unit of each basic configuration type, i.e., skin surface, root joint, spar, and rib segments will be fabricated for laboratory evaluation by sectioning, visual examination, and dimensional inspection.

8.4.3.3 Design verfication testing: Both static strength and flight-by-flight spectrum fatigue testing are provided for the design verification. In addition, temperature and humidity are included in selected tests to assess environmental effects on the strength and durability of built-up, complex composite wing structures. Tests also are included to verify design approaches for impact resistance, fuel pressure loadings, fail safety, and lightning strike protection.

The wing cover design verification tests include the following: upper surface panel with access door cutout; outboard lower surface panel; upper and lower surface wing root joints; upper and lower surface pylon rib interfaces; upper and lower surface impact resistance; upper surface manhole, fail safe; upper surface panel, fail safe; and lower surface panel with cutout, fail safe.

The wing spar design verfication tests include: front and rear spar shear and bending; front spar web, fuel pressure; spar web slat track coutout; and spar web slat track cutout, fail safe.

The wing rib design verification tests include: fuel bulkhead ribs and intermediate rib crushing.

Lightning strike protection system design verification tests will be conducted.

8.4.4 Phase IV - Full-scale demonstration (figure 144).

8.4.4.1 Wing cover design: Engineering drawings of the large wing cover design will be prepared. The necessary design layouts and details of the wing cover segment will be released for full-scale manufacturing feasibility and process verification demonstration.

8.4.4.2 Manufacturing process demonstration: Production type tools will be employed in the fabrication of the surface panel specimen. Shop orders and other controlling documents will assure full conformance to Engineering and Quality Assurance requirements.

The wing cover segment will, by configuration, provide a practical look at the task of constructing a large composite structure. The segment, which is the largest continuous span structure which can be accommodated in the existing autoclave, will validate such processes as: layup of very thick sections, cure cycles for structures with thick and thin sections, tooling for cocuring stiffeners to skin, thermal expansion effects between tool and part, and handling problems due to size of part. The inspection techniques found applicable to critical wing cover segments in the previous design task will be employed to verify adequacy of NDI methods and to demonstrate cover integrity.

The completed article will also be evaluated by visual examination, dimensional inspection and mechanical tests of panels cut from the cover. Suspect areas may be sectioned and samples subjected to laboratory tests. Determinations such as fiber-resin ratio, void content, and detection and identification of defects would be made.

8.4.4.3 Wing box test section design: The wing box segment will be designed, fabricated, and tested to demonstrate that both Engineering and Manufacturing/QA requirements can be met when integrating major wing components into a box assembly.

Layout and detail drawings required to fabricate and assemble an untapered box section will be developed. To conserve resources, the subcomponents designed and fabricated for design verification testing will be employed in the box specimen to the maximum extent possible.

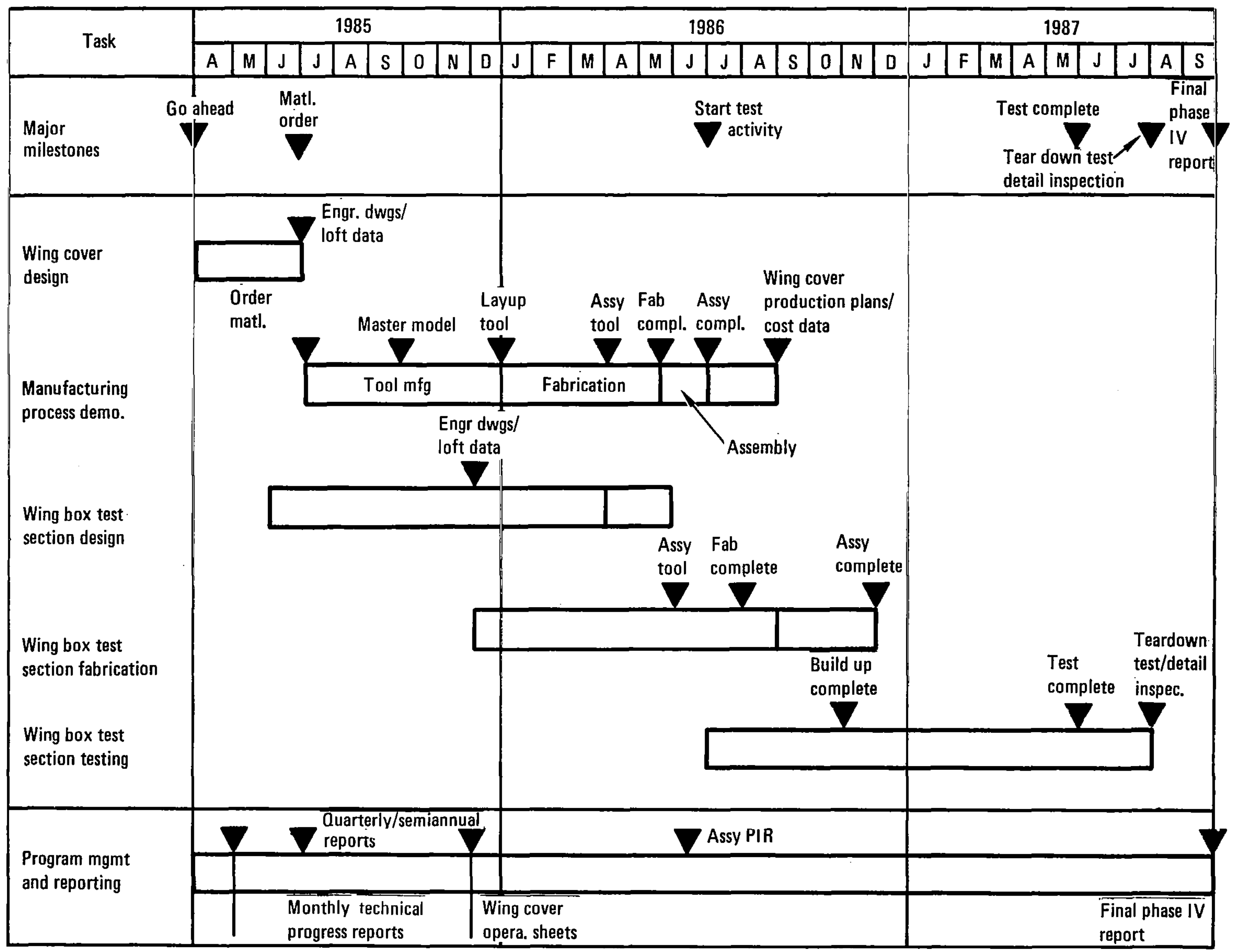


Figure 144. - Phase IV - Full scale demonstration.

8.4.4.4 Wing box test section fabrication: The representative wing box will contain covers for the upper and lower surface, the front and rear spar, and full structural ribs. Major joints and variations of spar and rib concepts can be employed. All components will be fabricated by production personnel in a production environment. The fabrication of the components and the assembly of the components into a structure which meets Engineering and Quality Assurance requirements will demonstrate the validity of all tooling and processing concepts involved.

8.4.4.5 Wing box test section testing: A series of limit load tests, fail safe tests, damage growth characteristic tests, repair verification tests and an ultimate load test will be conducted. In the fail safe tests, major members will be severed or impact damage imposed and the structure loaded to demonstrate fail safe capability. After testing, these imposed damages will be repaired, and the integrity of the repairs verified in subsequent tests. Upon completion of the prescribed tests, tear-down inspection will be conducted.

The applied loads will match the design shear, bending moment and torsional moment loading for the particular area of investigation. The box will be arranged for testing in a universal testing frame and loads applied by hydraulic jacks.

The demonstration tests will provide the necessary full-scale data to validate design philosophy, design allowables, design analysis methods, fabrication techniques, inspection methods, and repair techniques, and thereby, provide the confidence needed to proceed with design and manufacture of a production wing. A summary of the man years required for the wing structure development program is shown in table XIII.

TABLE XIII. - WING STRUCTURE DEVELOPMENT PROGRAM/TASK LABOR SCHEDULE (MAN-YEARS)

	Year								
Program Task	1981	1982	1983	1984	1985	1986	1987	1988	Total
A. Design data testing	2.9	6.7	2.5	0.1	0.1				12.4
B. Design concepts evaluation		25.8	105.1	34.2					165.1
C. Preliminary design				55.0	113.7	30.3			199.0
D. Demonstration article development						42.0	19.3	1.0	62.3
Total	2.9	32.5	107.6	89.3	113.8	72.4	19.3	1.0	438.8

8.5 Advanced Metal Matrix Composites Plan

The design and development of advanced metal matrix composites will be addressed by the Lockheed-Georgia Company, having been awarded an Air Force contract to modify the outer wing box structure of a C-5A. Whisker/aluminum and fiber/aluminum materials will be incorporated into the aircraft. A preliminary program schedule has been developed by Lockheed-Georgia and included in this section of the report. (Figures 145 through 149.) The program is a multiyear material and structural technology development program encompassing the following: (1) design studies, (2) material development, (3) process development, (4) detail design, (5) fabrication, (6) component testing, and (7) technological impact analysis. The estimated cost for this technology development is 12.5 million dollars and it is estimated that an additional $10.5 million will be required for complete development resulting in a total cost of $23 million. Since this program is being funded by the Air Force no attempt has been made to identify the cost of each task and the detail costs for follow on work should be addressed following development work currently underway.

Preliminary studies have shown that whisker/aluminum applications have several unique advantages:

- 30% to 50% increase in strength.
- 50% to 100% increase in stiffness.
- 12% to 18% reduction in structural weight.
- Potential cost of structural weight saved of approximately $10 to $20 per pound.

Since advanced metal matrix composite applications development will have to be carried out systematically prior to a production commitment, the necessary material property data will have to be available in a reasonable time frame. This requirement is so that the new material and processes can be incorporated with confidence into the next generation of energy efficient transport aircraft.

8.6 Titanium Development Plan

Metal removal and fastener joining have been identified as major cost drivers in airframe production, with high hogout blank-to-part weight ratios a major contributor. Greater use of titanium has been deterred by high inherent fabricating costs, especially forging, hot forming, and machining, coupled with rising material prices. The urgent need for low cost shaping and joining methods will be accentuated for military and commercial airframes of the future as the demands for weight reduction with improved performance dictate increased use of titanium, advanced aluminum alloys, and composites.

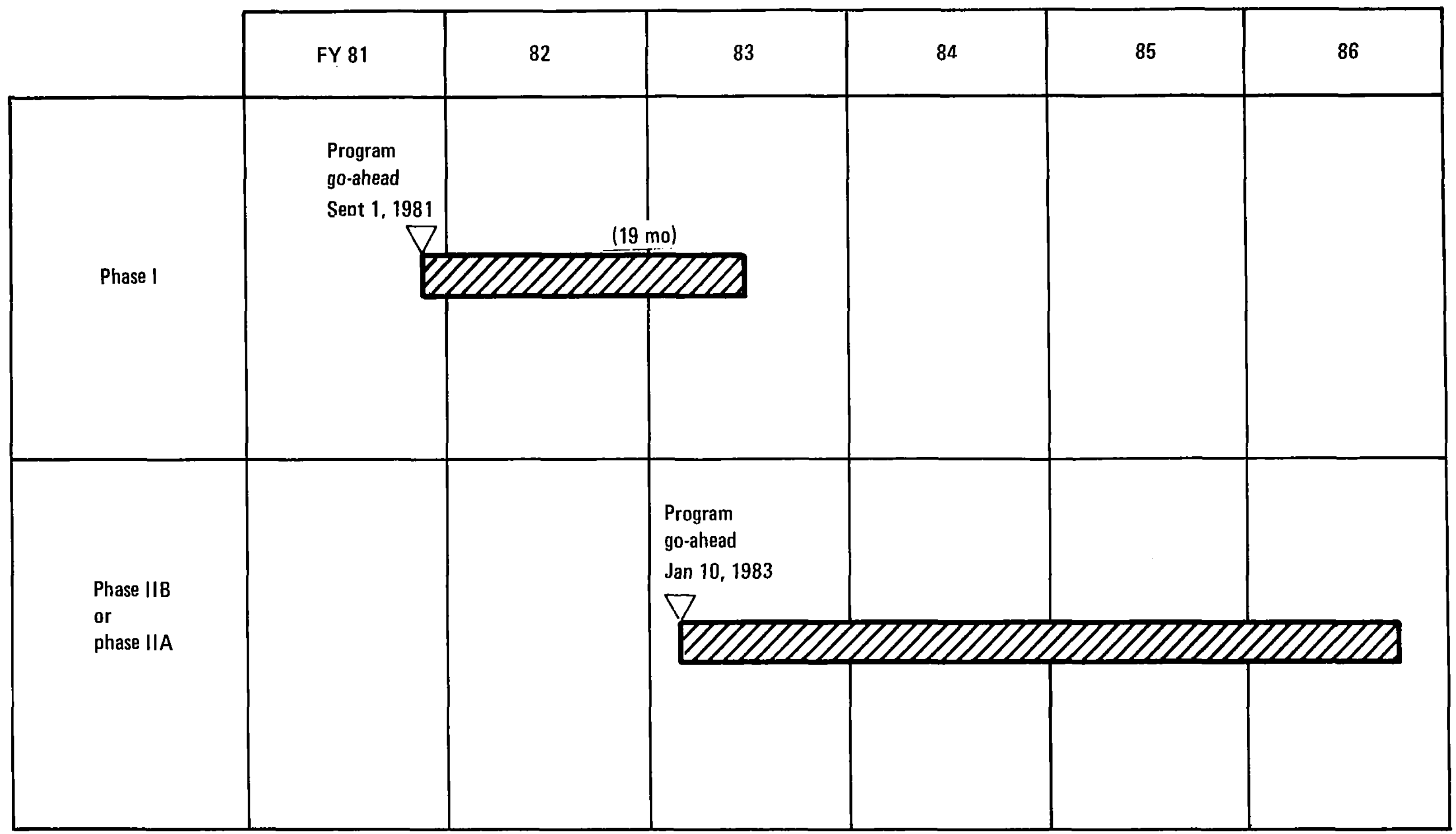


Figure 145. - Program phases.

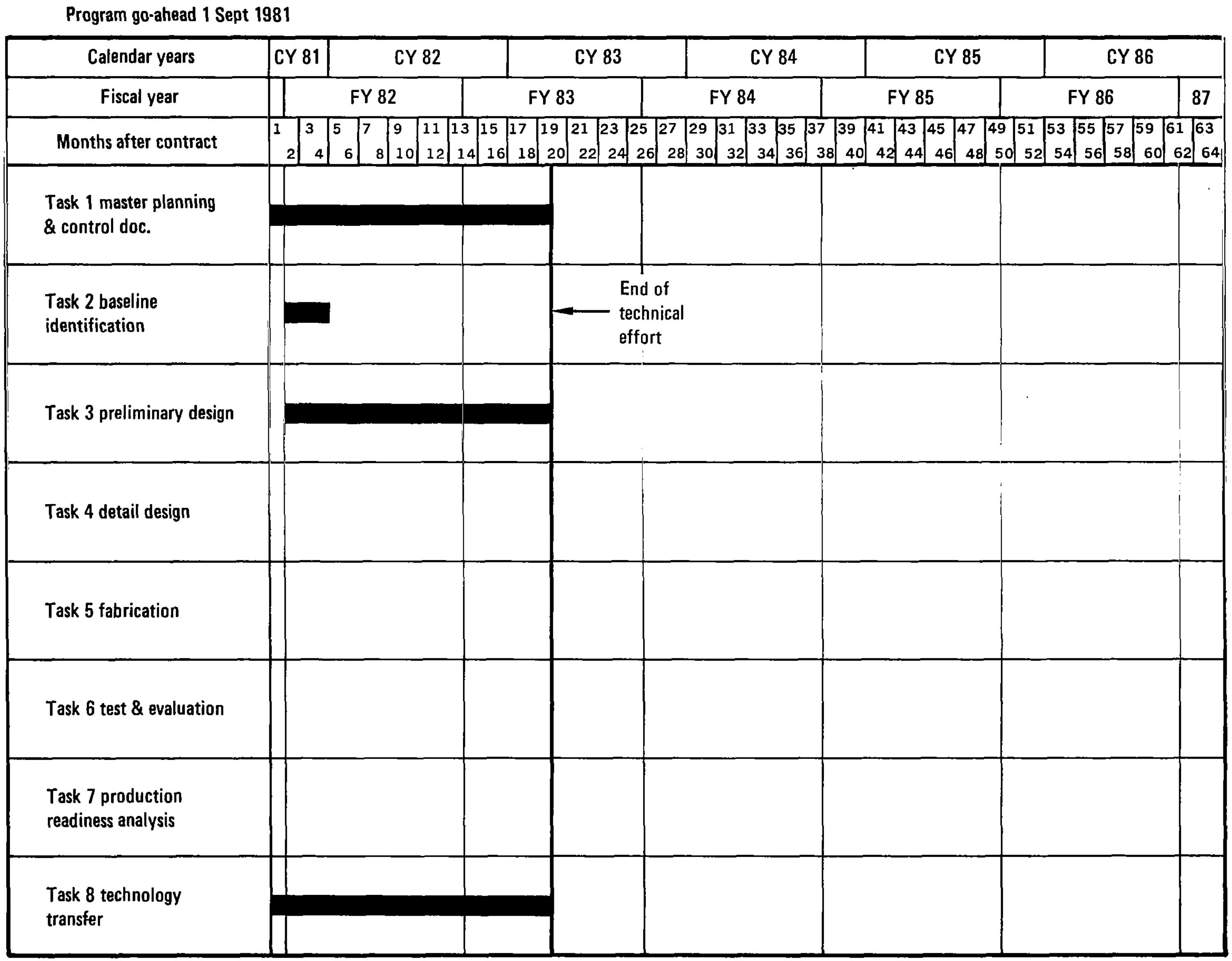


Figure 146. - Phase I program schedule.

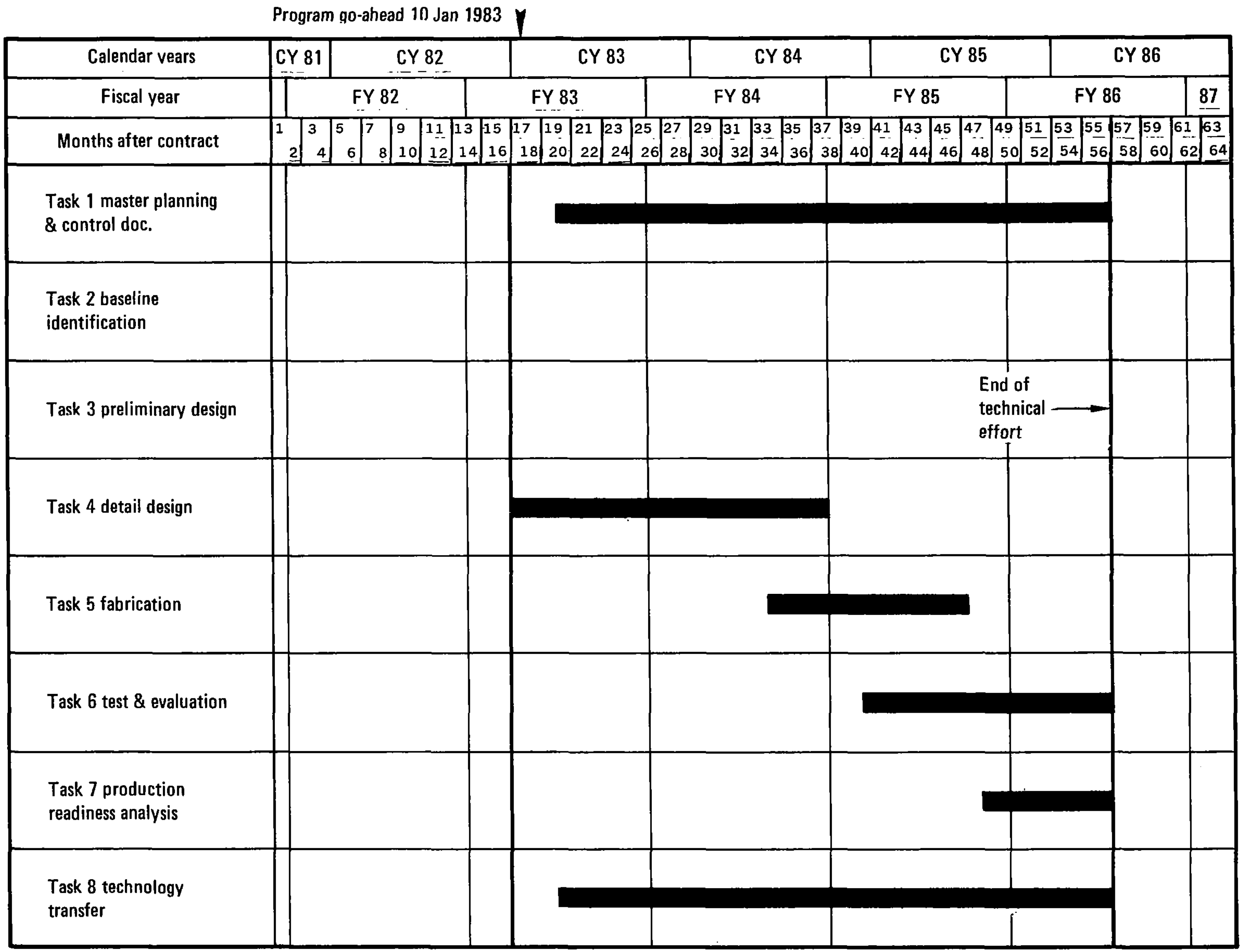


Figure 147. - Phase IIA program schedule.

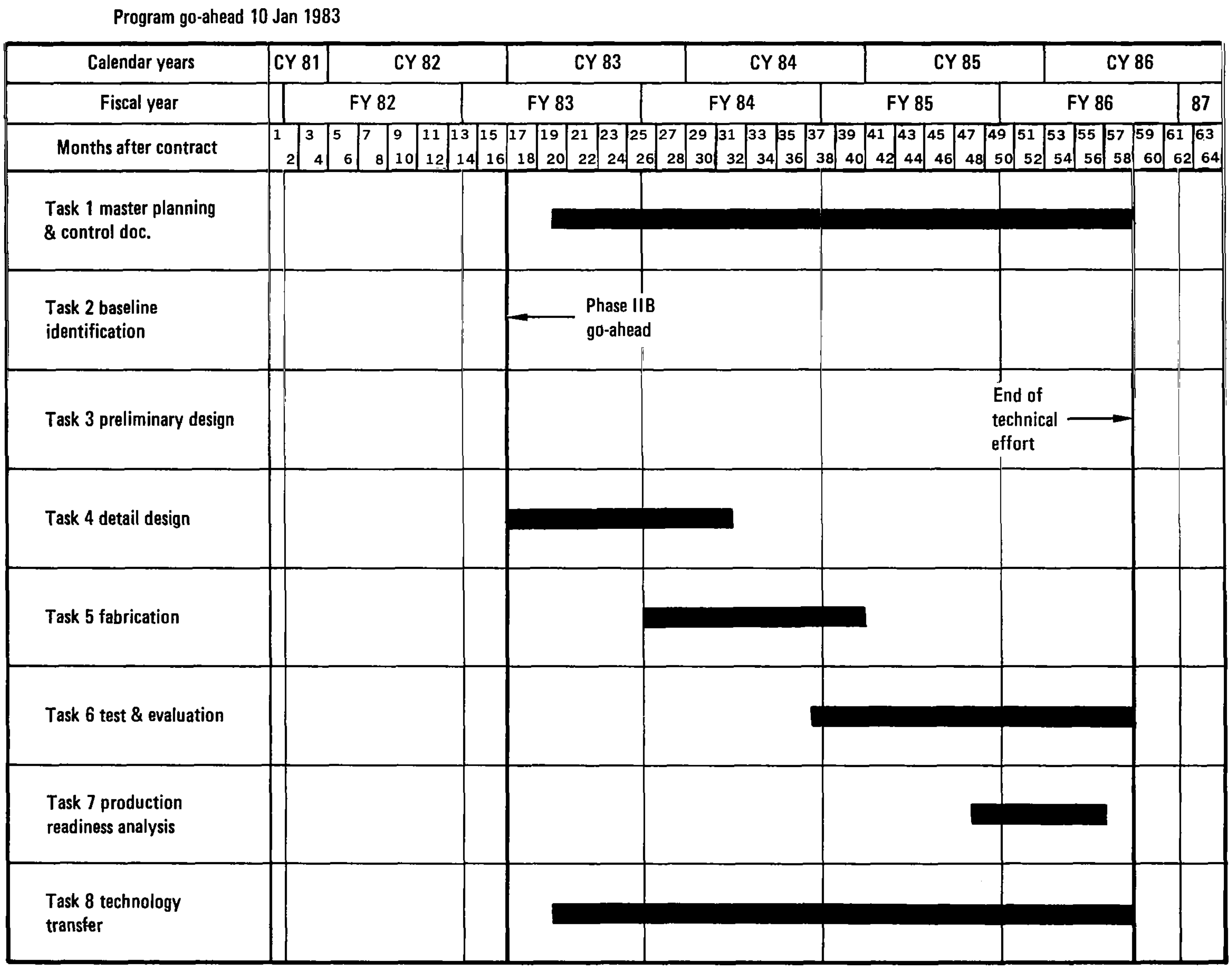


Figure 148. - Phase IIB program schedule.

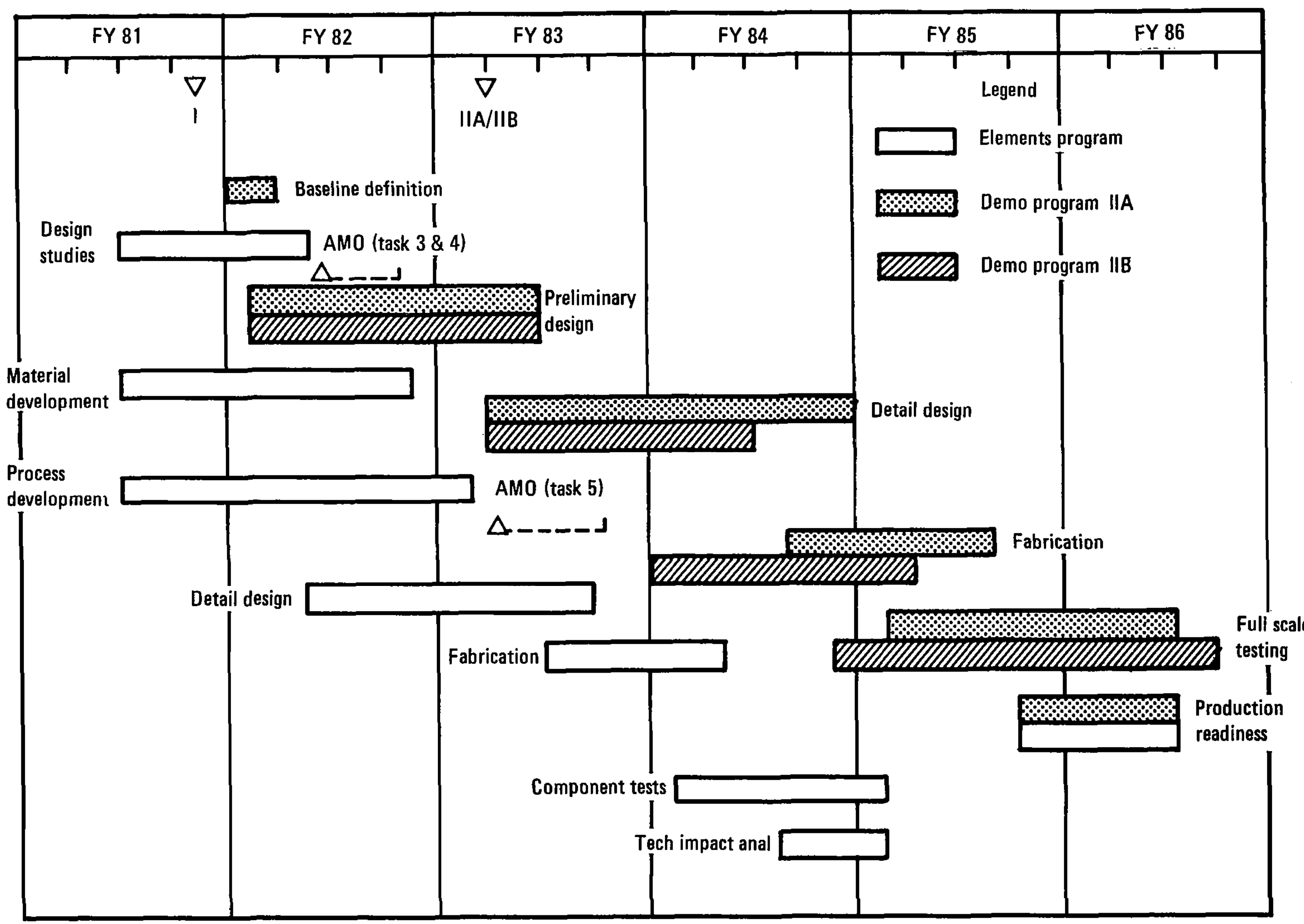


Figure 149. Elements program vs demonstration programs.

Titanium alloys represent optimum materials for airframe design because of their strength to density ratio, elastic modulus 40% higher than aluminum, and resistance to corrosion at moderately elevated temperatures. Development of cold formable beta alloys and new fabrication processes which reduce installed cost and improve structural efficiency can increase titanium's usage in airframe construction.

Lockheed-California is currently conducting research activities in areas of superplastic forming of advanced aluminum alloys; titanium superplastic forming/diffusion bonding (SPF/DB); aluminum powder metallurgy (PM) and titanium precision forging; beta titanium alloy cold forming, brazing, and welding; and titanium flange forming-focusing on enhanced materials utilization and processing efficiency.

Figure 150 shows a proposed five year development plan for low cost titanium. Incorporated into this plan are the following: (1) producibility and cost weight trade studies, (2) structural design and analysis, (3) full scale manufacturing development, and (4) testing and evaluation. Although at present the use of titanium in current commercial aircraft is limited and none other than fasteners is used in structural wing applications, a change in engines could implement the use titanium technology for the wing pylons and center engine support structure. For the Integrated Technology Wing Study, no extensive use of titanium is anticipated.

8.7 Materials Cost Summary

Technology development costs for advanced aluminum, advanced composites, and metal matrix composites as summarized in table XIV.

8.8 Risk Assessment

By virtue of their high modulus reinforcing fibers, advanced composites have become a new concept in aircraft design. It has become a technology that combines high strength, stiffness, and controlled anisotropy with light weight. Development has been underway for over 15 years, and a sufficient database has been developed for design and fabrication purposes. Properly designed, hybrid applications can deliver cost/performance characteristics unattainable with a single reinforcing fiber form.

Current development in composite technology for commercial aircraft include the fabrication and in-flight service of composite structures which range from lightly loaded fairings to secondary structures such as vertical fins, floor posts, and aircraft beams. Lockheed's comprehensive background in the development of composite design concepts, analysis methods, fabrication techniques, and inspection and repair methods can play a significant role in reducing any program risks that might be considered.

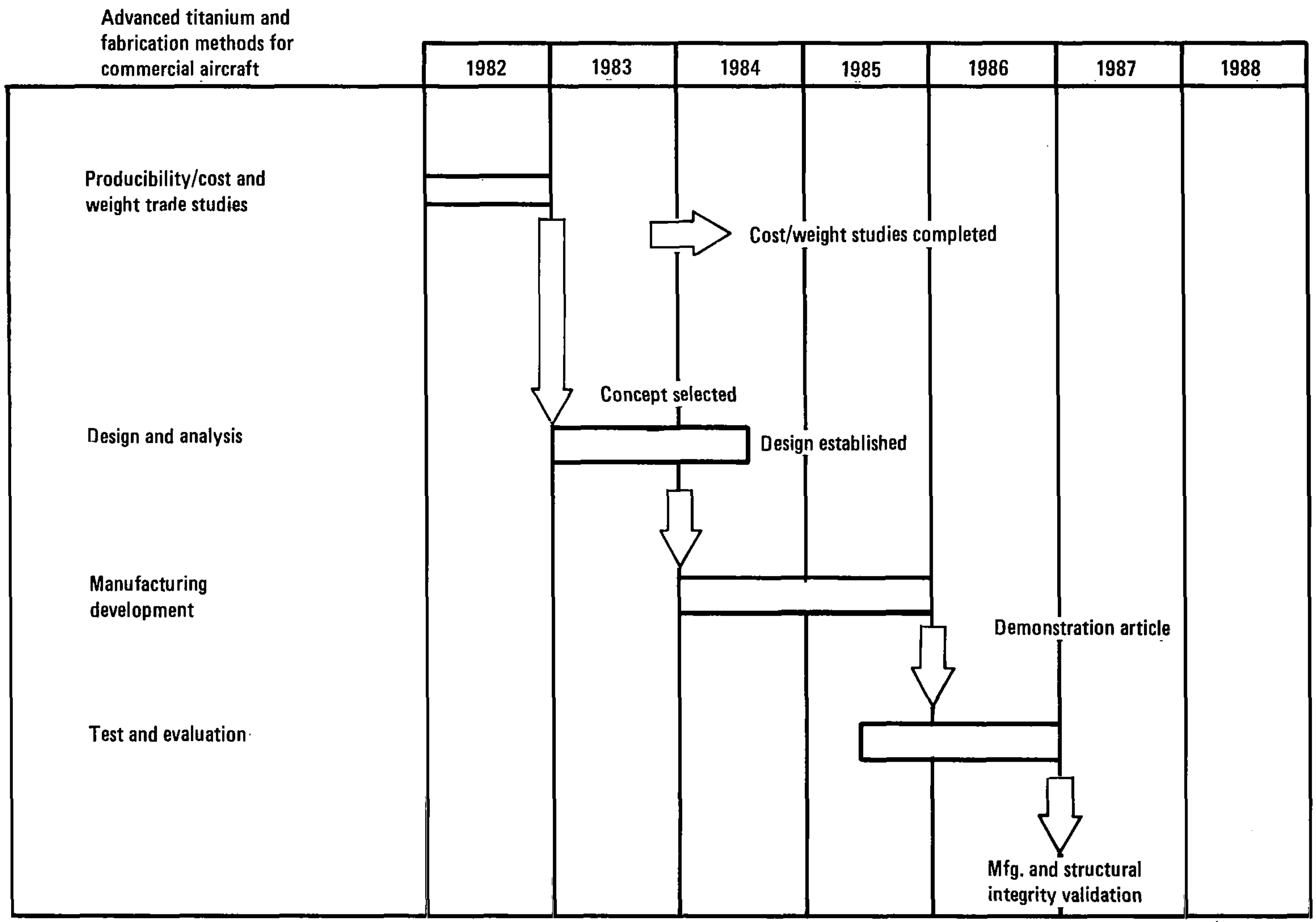


Figure 150. Proposed low cost titanium development.

TABLE XIV. - SUMMARY OF TECHNOLOGY COSTS AND BENEFITS

Technology Application	Tech.* Dev. Cost	SFC or Drag	Structural Weight	Tech. Readiness Date
Advanced aluminum alloy	$14M		12%	1986
Advanced composites	$43M**		20%	1986
Metal matrix (Sic/AL) composites	$23M		18%	1986
Titanium	Not costed		–	–

*Tech. dev. cost includes material and subcontractor costs.

**Includes $3.0M for material development (toughened-resin technology).

Some of the items that could be considered as risk are those involving object impact, erosion, galvanic corrosion, and lightning strikes. These items would be addressed using laboratory data that would be defined by the time of detail design. While the aircraft industry database for composite structures service experience is more limited than for aluminum, it is constantly being expanded so as to provide timely information on the serviceability of these composite structures, thus aiding the engineer in his design concepts.

Circumstances	Corrective Action
• Object impact	Reduce design allowables through laboratory testing.
• Erosion	Apply special finishes per MIL-C-8231, Type II.
• Galvanic corrosion	Isolation of graphite by using faying surface sealant or by fiberglass or Kevlar buffer plies; standard anodic coatings of the metallic components.
• Lightning strike	Metallic surface treatment such as flame sprayed aluminum, aluminum filled fiberglass, or metal diverter strips.

The technology database on composites does exist to prevent these factors from creating an undue risk situation. Further material property characterization tests will provide detail design criteria for design optimization, and can prevent these problems from creating risks higher than for an equivalent metal strucuture.

Lockheed perceives there may be some technical and cost associated problems due to the application of composites, since the technology itself has not matured to the same point aluminum alloys have. However, the opportunities are present for improvements in structural weight savings which can lead to overall reduced operating costs. The potential for future weight and cost reductions is available through continued design refinements, and as the technology matures the benefits to be gained from use of advanced composite materials far exceed any potential risk implied in large scale aircraft applications.

9. DEFINITION OF ADVANCED CONFIGURATION

9.1 Introduction

As described in Section 1.3, the sequence of derivation of different configurations was to define both the reference configuration and the advanced configuration, and then to add or to subtract technology elements as appropriate, reoptimizing the configurations where necessary. The advanced configuration contains all the advanced technology elements described in Sections 5 through 8.

The first step involved optimization of the wing planform. Because of the limited duration of this contract, derivation of the optimum planform was carried out in parallel with refinement of the advanced technology database (figure 151). In addition, the advanced configuration was used as the basis for reference configurations involved in other NASA contract studies mentioned in Section 1.3. The configuration described here (Configuration P16) is therefore slightly different from Configuration 16, and significant differences are indicated in table XV. None of these differences would significantly affect the choice of optimum planform.

9.2 Definition of Unconstrained Optimum Wing Planform

This step involves optimization of the wing planform and area, and air craft thrust/weight in terms of

- Quarter chord sweep, Λ
- Aspect ratio, AR
- Average thickness/chord ratio, t/c
- Thrust/weight ratio, T/W
- Wing loading, W/S

These parameters were all varied independently in order to find the optimum combination. Consideration had been given to selecting combinations of Λ and t/c such that the wing would operate with a specified compressibility drag rise, but since the required drag rise for an optimized configuration was not known, it was decided to treat the two parameters as independent variables.

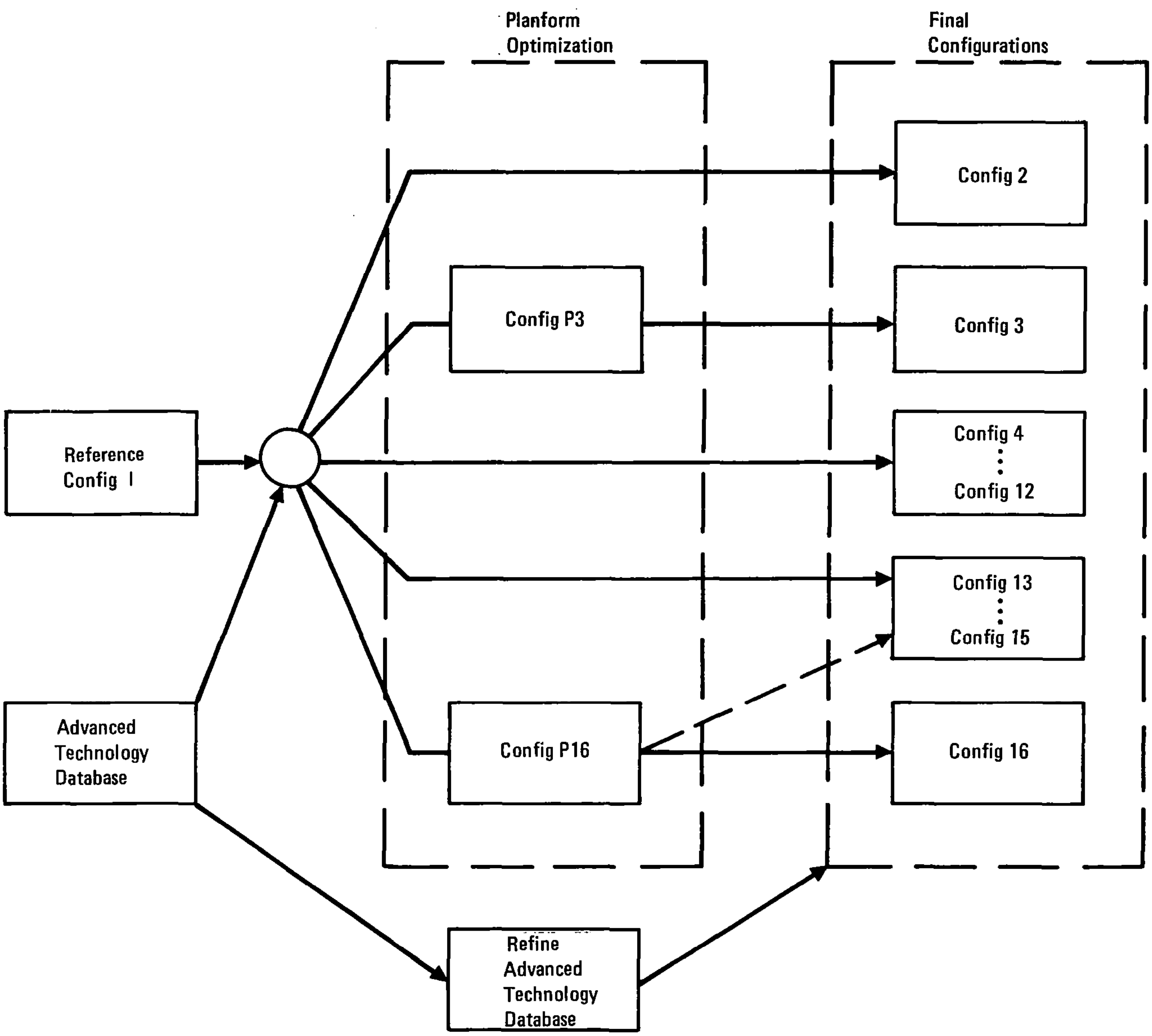


Figure 151. - Derivation of final configurations.

TABLE XV. - DIFFERENCES BETWEEN CONFIGURATION USED FOR WING OPTIMIZATION AND CONFIGURATION 16

Design Feature	Configuration P16 Wing Optimization Configuration	Configuration 16 Configuration
Cockpit	Advanced cockpit displays	Conventional cockpit
Cg for performance calculations	40% MAC	55% MAC
Fuel management	None	Fuel tanks above S-duct and in stabilizers
$\overline{V}_H$	0.95	0.78
Wing weight reduction factor	20%	27%

The following values were selected for wing planform parameters

Λ = 25°, 30°, 35°

AR = 8, 10, 12, 14

t/c = 8, 10, 12, 14%

For each combination of , AR, and t/c, a total of 16 (4 x 4) combinations of T/W and W/S were run on ASSET. Each configuration was sized to achieve the design mission and then flown at the average stage length to determine block fuel. A carpet plot was generated and constraints applied as defined in Section 3.3.

A plot of block fuel at the average stage length for different values of Λ, AR and t/c is shown in figure 152. Each point represents a constrained optimum value of T/W and W/S.

The results of figure 152 may be presented in an alternative format by taking horizontal cuts through each carpet and plotting isograms of constant block fuel using axes of t/c and AR, as shown in figure 153 and 154. The figures show that the optimum configuration has the following wing characteristics:

$\Lambda = 30^o$

AR = 13

t/c = 12%

9.3 Landing Gear Constraint on Wing Planform

Under the ground rules of

- Aft cg at 42% MAC for ground operations
- Wing batt shape and size (section 2.1.1)
- Flap chord of 26% local wing chord
- L-1011 design of landing gear

it was found that to allow for a tip-up margin for tail scrape at 10^o, the landing gear could not fit ahead of the rear auxiliary beam.

The carpet plot of figure 155 shows the percent chord at the landing gear butt line which corresponds to a cg position of 42 percent MAC, plus 10^o tip-up margin. It shows that as sweep or aspect ratio increase, the required position of the landing gear moves further aft along the butt line. In addition, a check must be made that the wing section has enough thickness at the landing gear location.

Preliminary landing gear layouts had shown that the main landing gear could be put at about 74 percent of the wing chord at the gear butt line. If this constraint is applied to figure 155, it shows that wing sweep of 30^o is constrained to AR = 10, and sweep of 25^o is constrained to AR = 12.

If these constraints are applied (figures 156 and 157), it can be seen that the optimum configuration with landing gear constraints has the wing characteristics of

$\Lambda = 25^o$

AR = 12

t/c = 10%

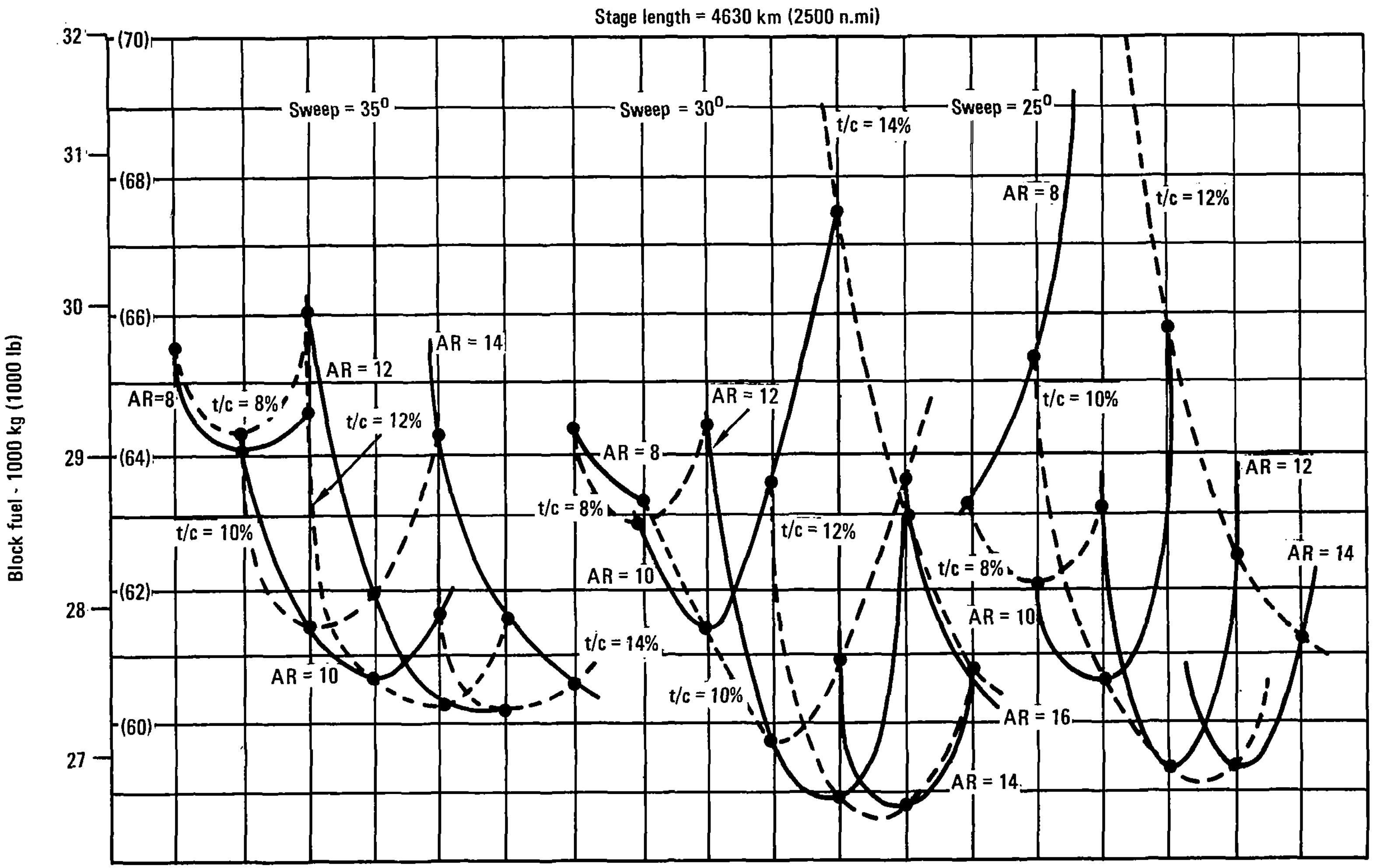


Figure 152. - Configuration P16 - block fuel.

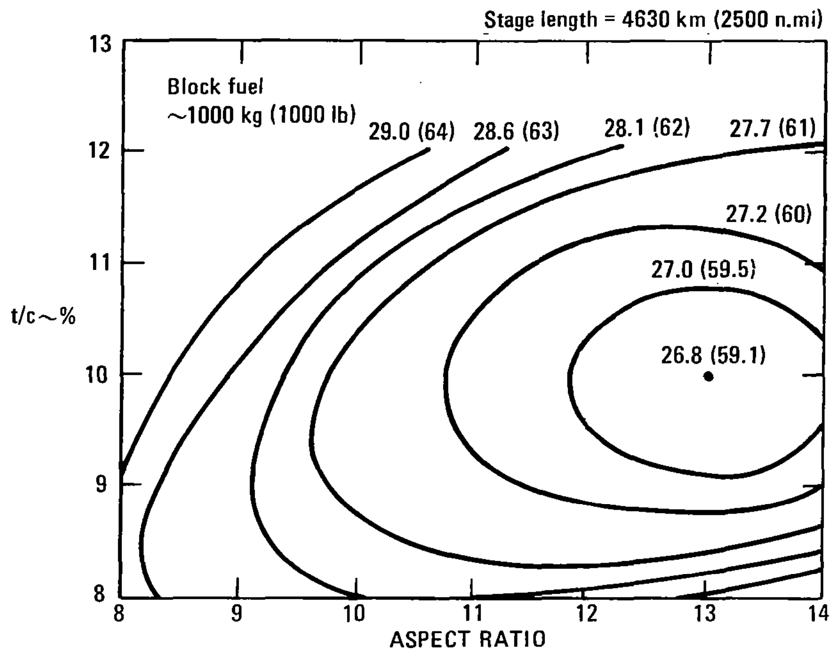


Figure 153. - Configuration P16 - block fuel knothole, $\Lambda = 25^{\circ}$.

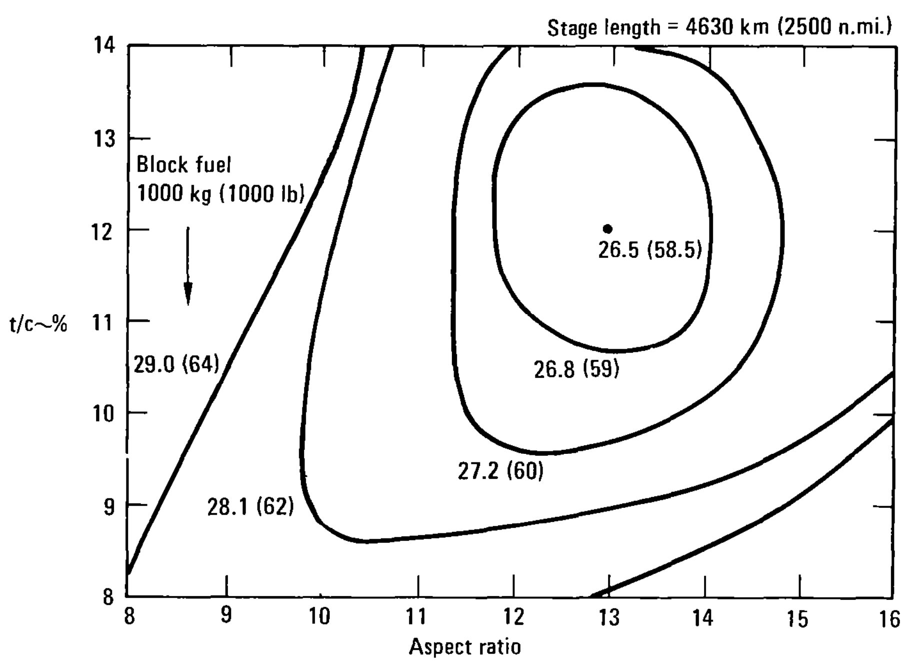


Figure 154. - Configuration P16 - block fuel knothole, $\Lambda = 30^{\circ}$.

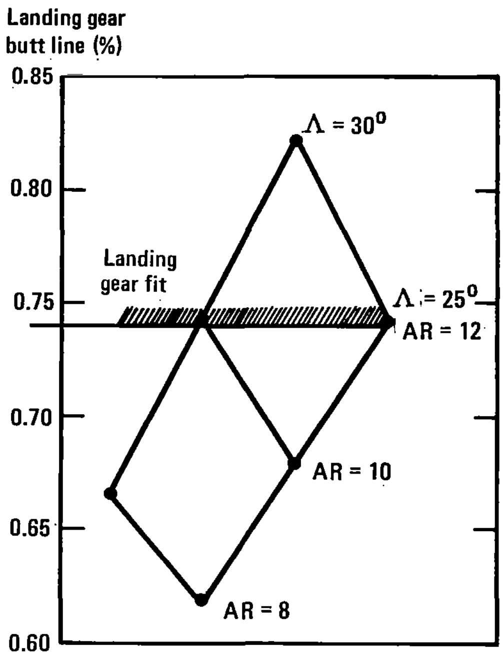


Figure 155. - Position of 42% MAC (plus tip-up margin) on landing gear butt line.

The corresponding thrust/weight and wing loading are

$$T/W = 0.237$$

$$W/S = 6512 \text{ N/m}^2 \text{ (136 lb/ft}^2\text{)}$$

A carpet plot of T/W and W/S is shown in figure 158; engine-out takeoff field length is the design constraint. The final configuration (with updated technology) is shown in figure 159. Planforms are compared in figure 160.

9.4 Cg Range

As shown in figure 161 the cg range for ground operations is 17 percent to 42 percent MAC. At cruise, fuel is pumped into aft tanks, as described in Section 6.1.1.4, and the cg is moved aft to 55 percent MAC. This value is used for performance calculations.

9.5 Horizontal Tail Sizing

For this configuration (and for Configurations 14 and 15) the horizontal tail was sized for a neutrally stable airplane, even though the aircraft is flown with the cg 10 percent of the MAC aft of the neutral point.

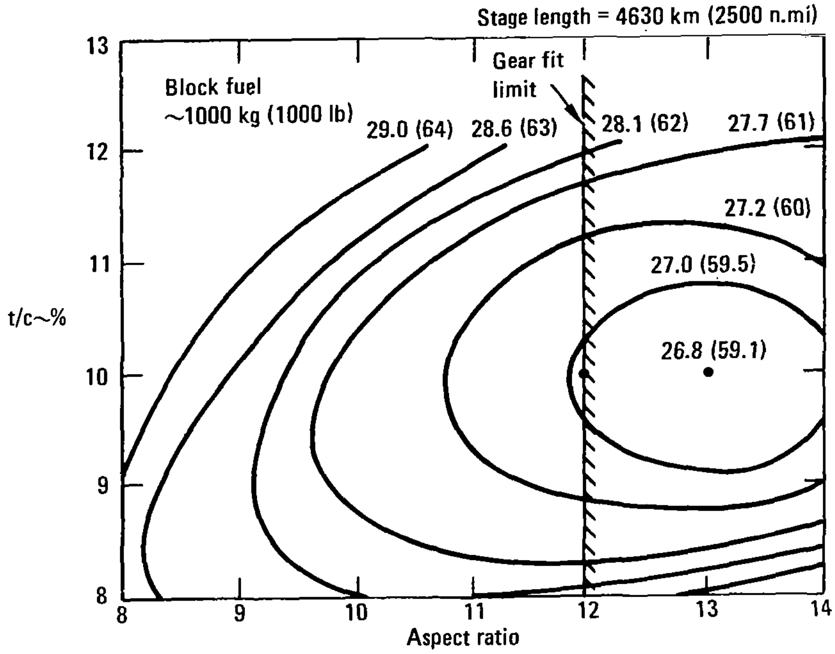


Figure 156. - Configuration P16 - block fuel knothole, $\Lambda = 25^{\circ}$, with landing gear constraint.

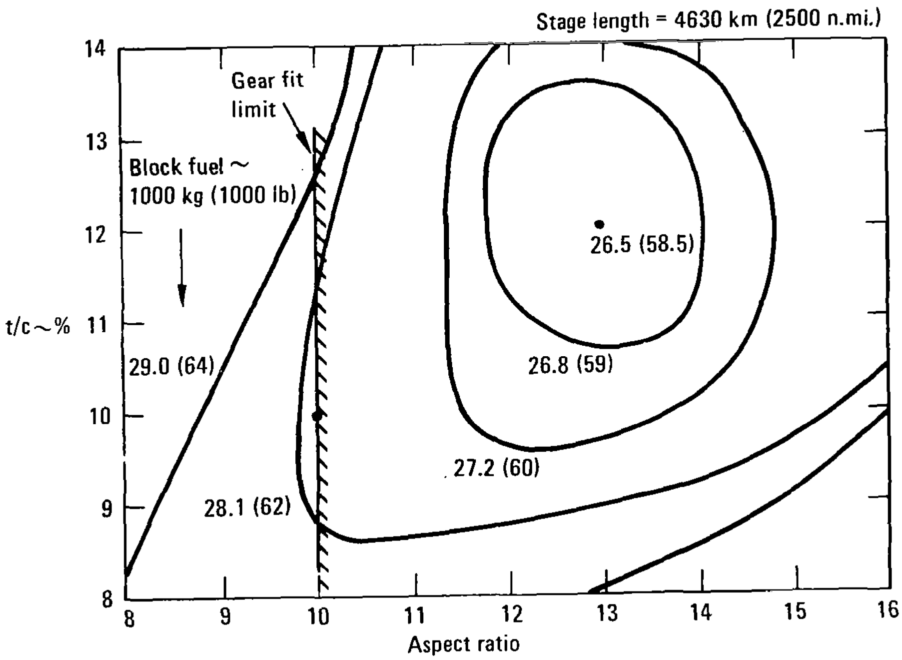


Figure 157. - Configuration P16 - block fuel knothole, $\Lambda = 30^{\circ}$, with landing gear constraint.

This philosophy of tailsizing for a stable airplane gives rise to the possibility of further downsizing the tail for a configuration which is statically unstable. The problem with this approach is that the criteria to define these unstable control limits are currently inadequate. A suitable definition of these control limits for a particular unstable airplane requires a thorough definition of aerodynamic characteristics and control system networks to be used as a mathematical model for detailed dynamics analysis. This model must then be exercised in various levels of turbulence, discrete gusts, and critical flight maneuvers simultaneously to determine combined augmentation and control requirements which dictate the horizontal tail size for that particular design. This depth of analysis is clearly beyond the scope of the current study. However, it is conjectured that if this detailed study were performed, the resulting horizontal tail size would not be much smaller than that which is sized to maintain neutral stability.

The horizontal tail is sized in accordance with the following requirements:

- Total cg range of 1.46 m (4.8 ft).
- At least neutral stability at aft cg.
- Takeoff nose wheel liftoff at forward cg with maximum takeoff flaps at 1-g stall speed.
- Control-to-stall at forward cg with maximum landing flaps and idle thrust.

It was assumed in the analysis that the positive stabilizer authority can be designed to provide the required nose-down angular acceleration at stall recovery. Therefore, the nose-down control requirement at aft cg was not considered in the tail sizing exercise.

The horizontal tail was assumed to be an all-moving surface with 30 percent chord geared elevator yielding a usable $C_{L_{max}}$ of -1.26.

Downwash data at the tail were obtained by modifying L-1011 data to account for an increase in aspect ratio of the wing.

The cg limits are dependent on horizontal tail volume coefficient as shown in figure 162. The forward limit is imposed by the requirement for nose wheel liftoff, and the aft limit is defined by the condition for neutral static stability. This assumes a relaxed static stability design with stability augmentation system to provide satisfactory handling qualities. These data show that a volume coefficient, $\overline{V}_H$, of 0.78 is needed to provide the required cg range.

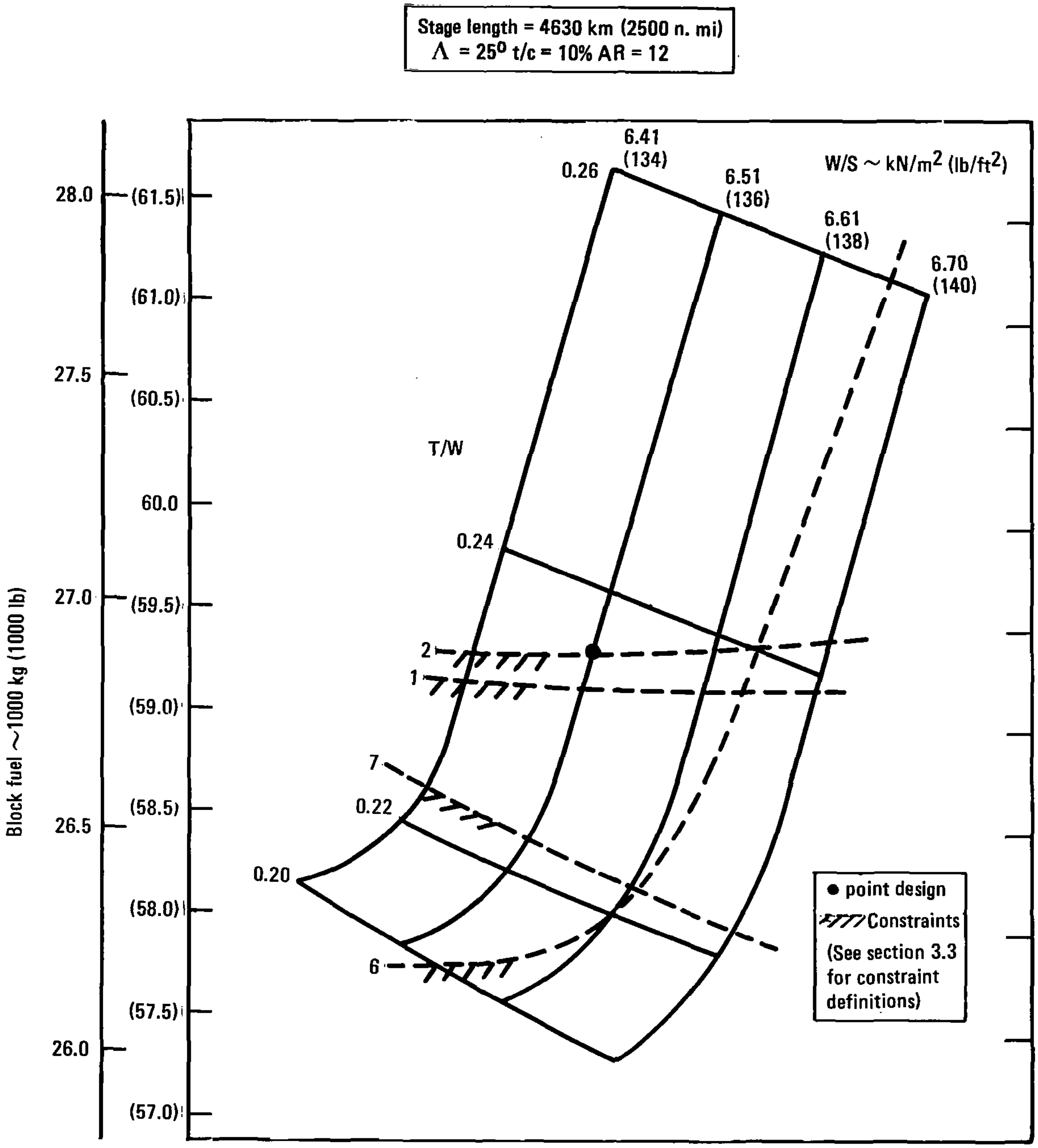


Figure 158. - Configuration P16 - block fuel at 4630 km (2500 n.mi.) stage length.

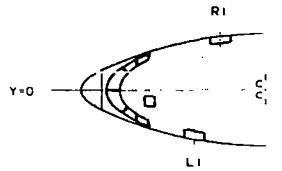
CHARACTERISTIC	WING, BASIC	WING, ACTUAL	HORIZ. TAIL	VERT. TAIL
AREA (SQ FT)	3108.4	3923.0	627.70	524.29
ASPECT RATIO	12.0		5.00	1.54
SPAN (THEO)	202 FT- 3 IN		56 FT- 0 IN	28 FT 5 IN
ROOT CHORD (IN)	324.63	466.64	206.68	341.88
TIP CHORD (IN)	79.85		61.98	101.56
TAPER RATIO	0.246		.300	.297
M.A.C. (IN)	226.93		147.32	243.43
SWEEP AT .25% CHORD (DEG)	25		35.0	34.7
T/C ROOT (%)	12.98		11	12
T/C TIP (%)	8.96		8	10
DIHEDRAL AT T.E.	INBD 9 05 50" OUTBD 5 30"		3.0	--

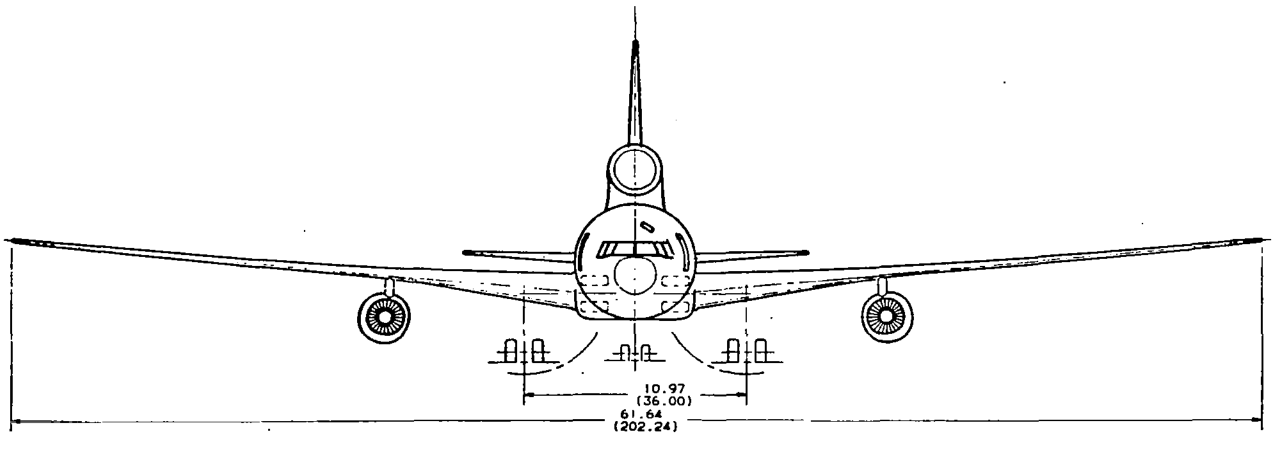
DESIGN GROSS WEIGHT-210 263 KG(463,543 LB)

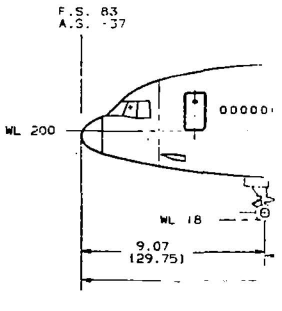
POWER PLANT-(3) G.E. E^3 TURBOFAN

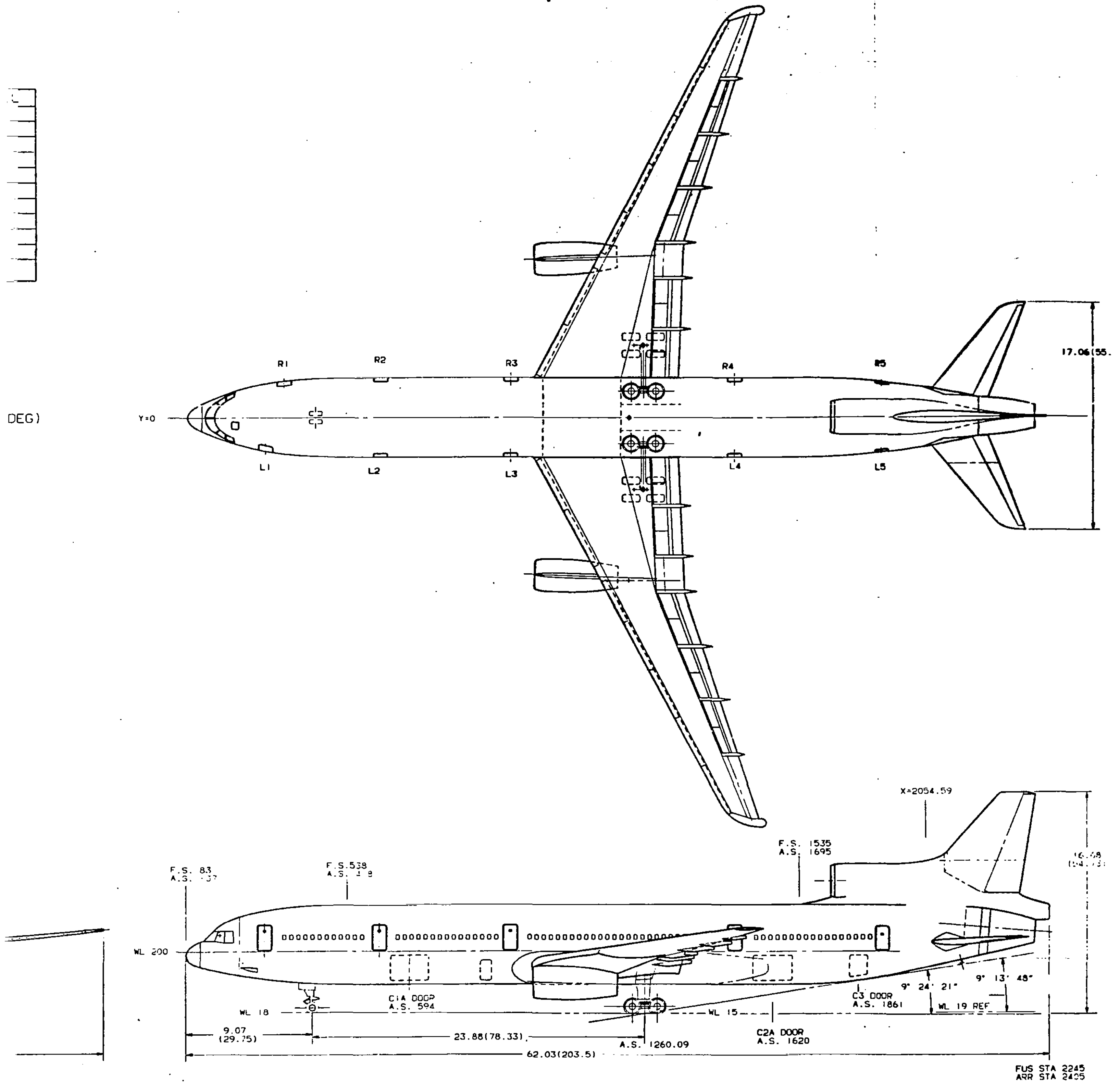
INSTLD T.O. THRUST- 122 578 NEWTONS(27,556 LBS) M 0.2 SL 30 DEG C (85 DEG)

UNINSTLD SLS FLAT RATED- 162 896 NEWTONS(36,620 LBS)









DEG)
Y=0
R1
R2
R3
R4
R5
L1
L2
L3
L4
L5
17.06(55.
X=2054.59
F.S. 1535
A.S. 1695
F.S. 83
F.S.538
WL 200
WL 18
C1A DOOR
A.S. 594
9.07
(29.75)
23.88(78.33)
A.S. 1260.09
62.03(203.5)
WL 15
C2A DOOR
A.S. 1620
C3 DOOR
A.S. 1861
9° 24' 21"
9° 13' 48"
WL 19 REF
FUS STA 2245
ARR STA 2405

Figur

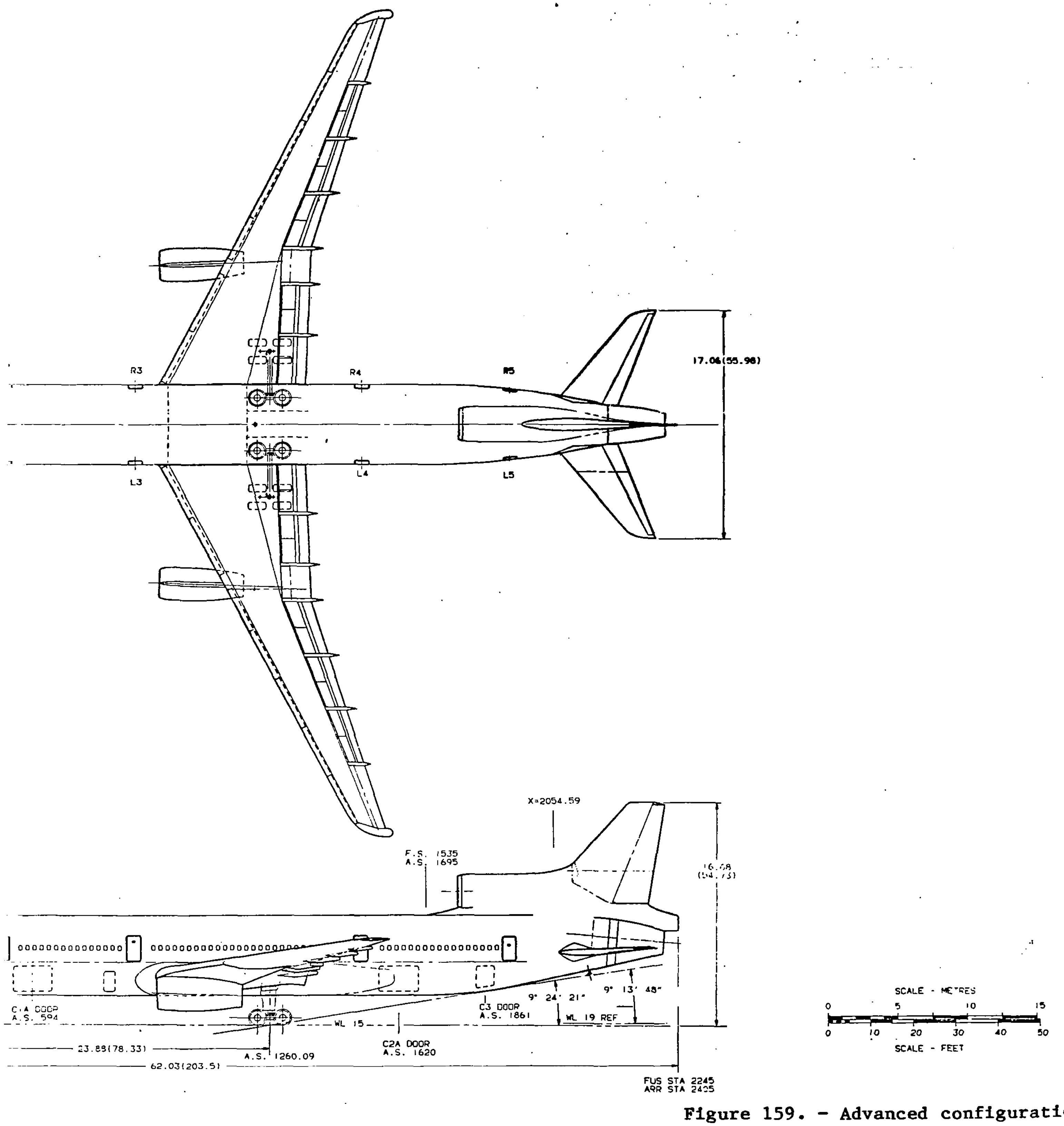


Figure 159. - Advanced configuration

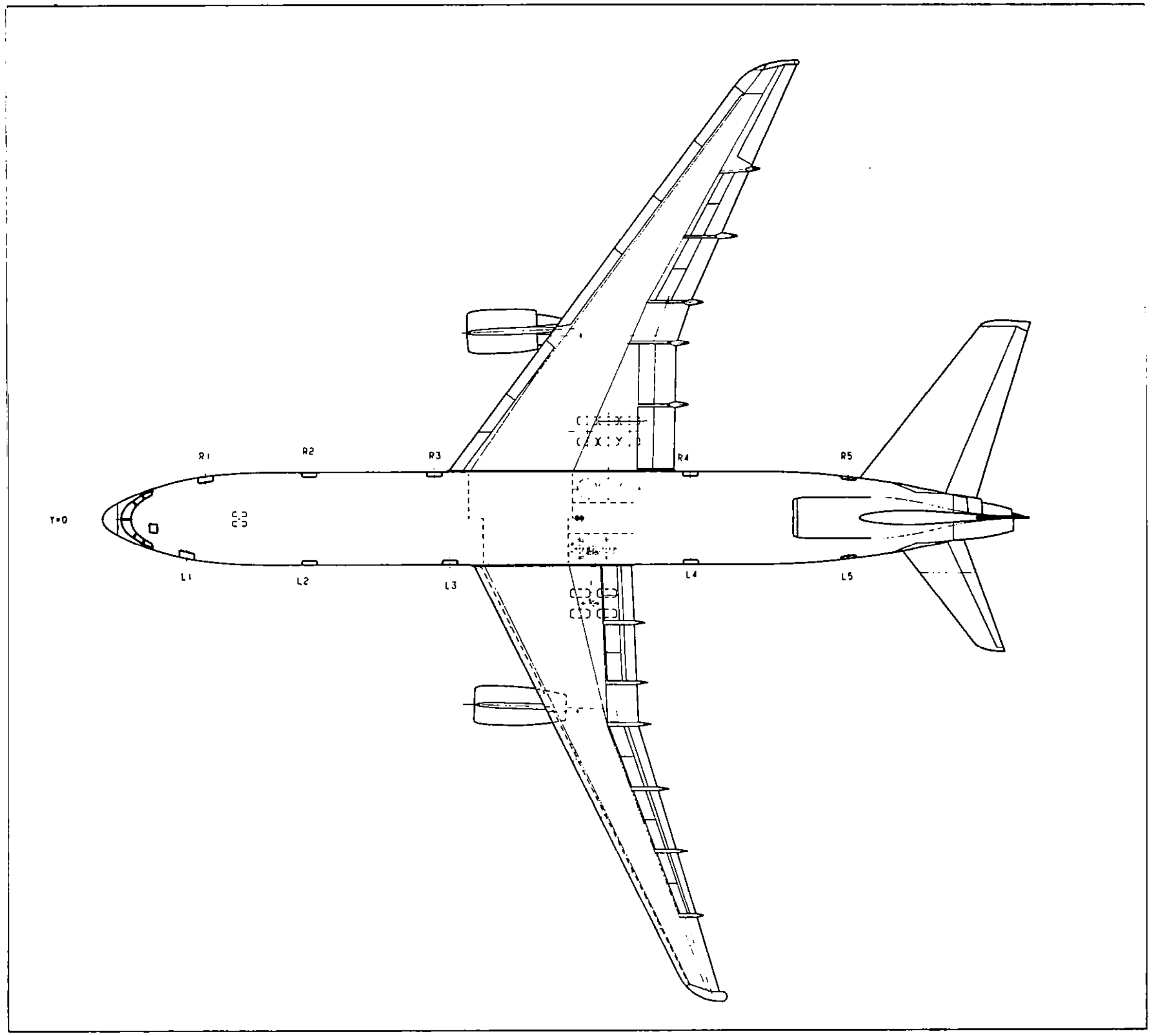
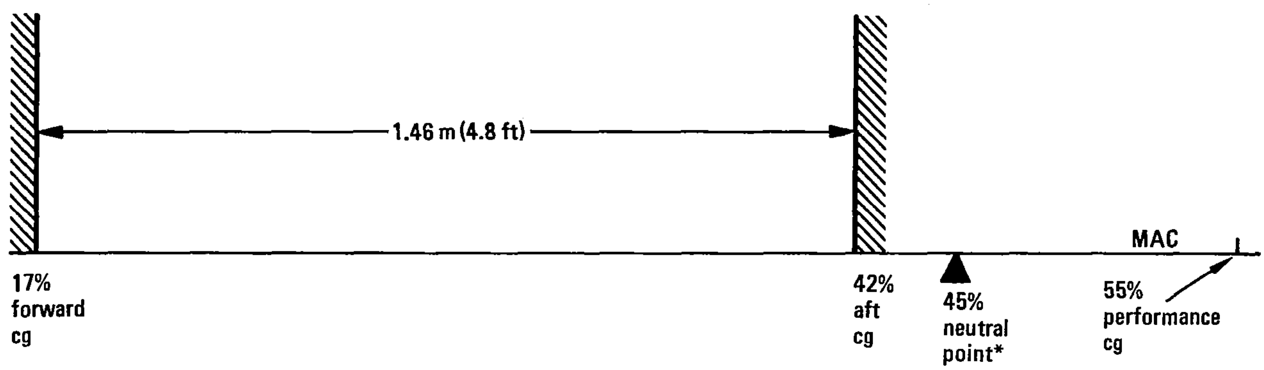


Figure 160. - Comparison between reference and advanced configuration planforms.



*Neutral point based on

$\bar{V}_H = 0.78$

No wing load alleviation

$\Lambda = 25^0$

AR = 12

Figure 161. - Configuration 16-cg limits.

The horizontal tail size is the minimum for the specified loadability range and the stability and control requirements; however, the resulting aft cg limit will not permit operation of the airplane at the minimum trim drag condition. This is illustrated in figure 163 which shows the variation of trimmed drag with cg location as a percentage of tail-off-drag. If the philosophy is adopted that at least a neutrally stable airplane will be maintained, the data in figure 163 show that it is far better to minimize tail size than it is to oversize the tail to achieve a neutrally stable configuration with minimum trim drag. For the minimum size tail (V_H = 0.78), the data also show that a trim drag penalty of only 0.7 percent results from maintaining the cg far enough forward to be at least neutrally stable.

9.6 Effect of Ground Rule Perturbations

This section describes the effect of perturbing the design of the con strained optimum by either:

- Moving the aft cg limit forward
- Increasing the batt size

- Decreasing the flap chord

- Revising the design of the landing gear

Where the results can be quantified, they show either a negative benefit, or a small positive benefit, suggesting that although the configuration selected may not be a completely optimized design, it is very close to the optimum, and deviations from the optimum will not affect the conclusions of this study.

9.6.1 <u>Move aft cg limit forward</u>. - Fuel pumping to auxiliary tanks in the empennage area permits the performance cg limit to be held at 55 percent MAC whilst holding the aft cg limit for ground operations to 42 percent. table XVI shows the effect of moving these limits forward by 10 percent MAC, thus permitting higher aspect ratio on a wing with $\Lambda = 30^{o}$. Although block fuel is decreased, it is still higher than for a wing with $\Lambda = 25^{o}$ and AR = 12.

9.6.2 <u>Increase batt size</u>. - With the wing planform of $\Lambda = 30^{o}$ and AR = 12, batt area must be increased to permit landing gear to fit. This results in an increase in compressibility drag rise of 6 counts resulting from effective sweep reduction at the 60 percent chord line. This represents approximately 2.4 percent increase in block fuel, or a block fuel of 27 352 kg (60, 300 lb), which is more than for the constrained optimum of 26 943 kg (59,400 lb).

Alternatively, a wing glove could be added to maintain the shock sweep angle. Additional weight penalties may result, which would probably offset the block fuel gains. It is possible that a larger wing box permissible with the larger batt and glove would actually permit a lighter wing, but this trade is outside the scope of this study.

9.6.3. <u>Decrease flap chord</u>. - It may be possible to design a flap system with decreased flap chord, but without significant adverse impact on takeoff field length. This would permit the auxiliary rear beam, and hence the landing gear, to be moved further aft. Alternatively, if the flap section inboard of the landing gear could be eliminated, this would permit the landing gear to be moved aft without restriction.

This tradeoff warrants further study, but is outside the scope of this contract.

9.6.4 <u>Revise design of landing gear</u>. - Figure 155 indicates that to arrange the landing gear in a wing with $\Lambda = 30^{o}$ and AR = 12, the main landing gear bogey must be at about 82 percent of the gear butt line chord. This would require a 14^{o} aft cant in the gear post.

TABLE XVI. - EFFECT OF MOVING AFT CG LIMIT FORWARD

Condition	Aft cg Limit (% MAC)	Position of Gear On Butt Line (%)	Allowable AR	Trim Drag Penalty (%)	Block Fuel Penalty (%)	Block Fuel 1000 kg (1000 lb)	Block Fuel With Drag Penalty 1000 kg (1000 lb)
Reference	55%	74%	10	–	–	28.0 (61.8)	28.0 (61.8)
Perturbation	45%	68%	11.5	1.5%	1.8%	27.1 (59.7)	27.6 (60.8)

In order that the improvement in block fuel in switching to a $\Lambda = 30^\circ$ wing should not be offset by an increase in landing gear weight, the percentage increase in gear weight must be less than 12 percent. Preliminary estimates are for an 8-10 percent increase in main landing gear weight for a 14° aft cant.

9.6.5 Potential design improvements. - Design features which appear to have the highest probability of improving the performance of this configuration are:

- Use of a leading edge glove in combination with increased batt size.
- Canting the landing gear aft.

Either of these modifications would permit increase in wing sweep with possible performance improvement.

9.7 Technology Impact

The impact of individual technologies are described in Section 10. This section therefore summarizes these benefits which may be grouped under the following headings:

9.7.1 L/D increase. - Increase in L/D occurs as a result of using an advanced airfoil, high aspect ratio wing and reduced trim drag. Figure 164 compares the drag polar of this configuration with that of the reference configuration, and shows that the aircraft is operating at less than maximum L/D at cruise. It is therefore not possible to determine precisely which elements contribute to the improvement in L/D, but based on the findings of Section 10, it is estimated that 75 percent of the benefits is due to airfoil and planform changes and 25 percent due to trim drag reduction.

9.7.2 <u>SFC decrease</u>. - Of the 15.5 percent reduction in SFC, approximately 14 percent is attributed to the addition of the E^3 engine and 1.5 percent due to the elimination of engine bleed resulting from all-electric secondary power systems.

9.7.3 <u>OEW decrease</u>. - Contributions to the decrease in OEW (before resizing) are as follows:

Wing aspect ratio	+ 14%
All electric secondary power	- 3%
E^3 engine	+ 2%
Advanced materials	- 6%

The net result is that the application of advanced technology would result in a 6 percent increase in OEW before resizing. The contributions to increases in weight are the effect of aspect ratio and addition of E^3 engines, but these increases are more than offset by the increase in L/D and decrease in SFC.

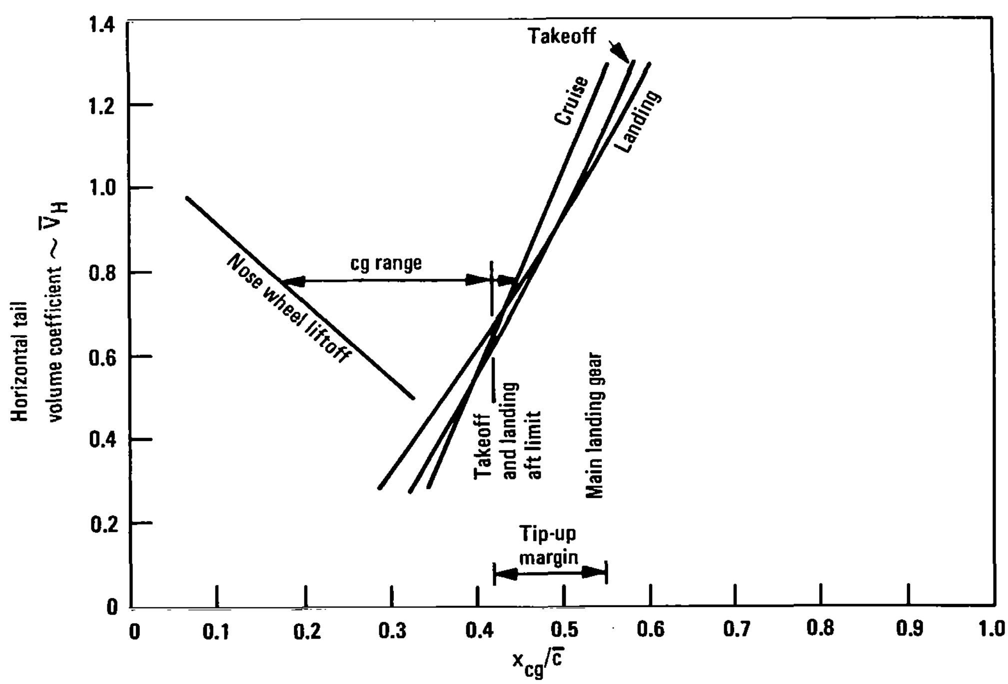


Figure 162. - Configuration 16-horizontal tail sizing summary chart.

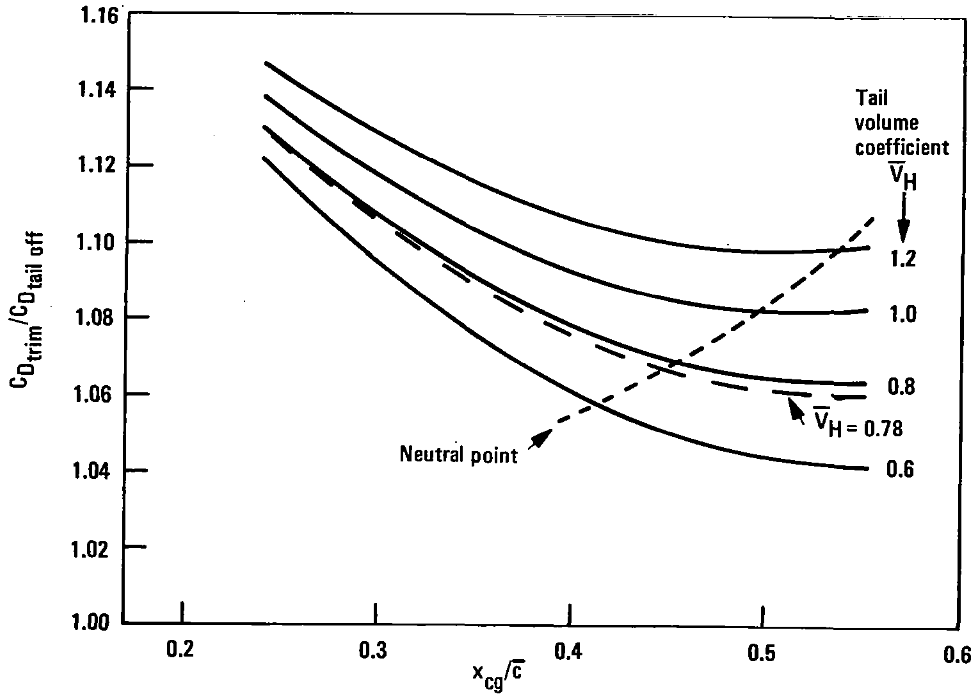


Figure 163. - Configuration 16-horizontal tail drag effects in cruise.

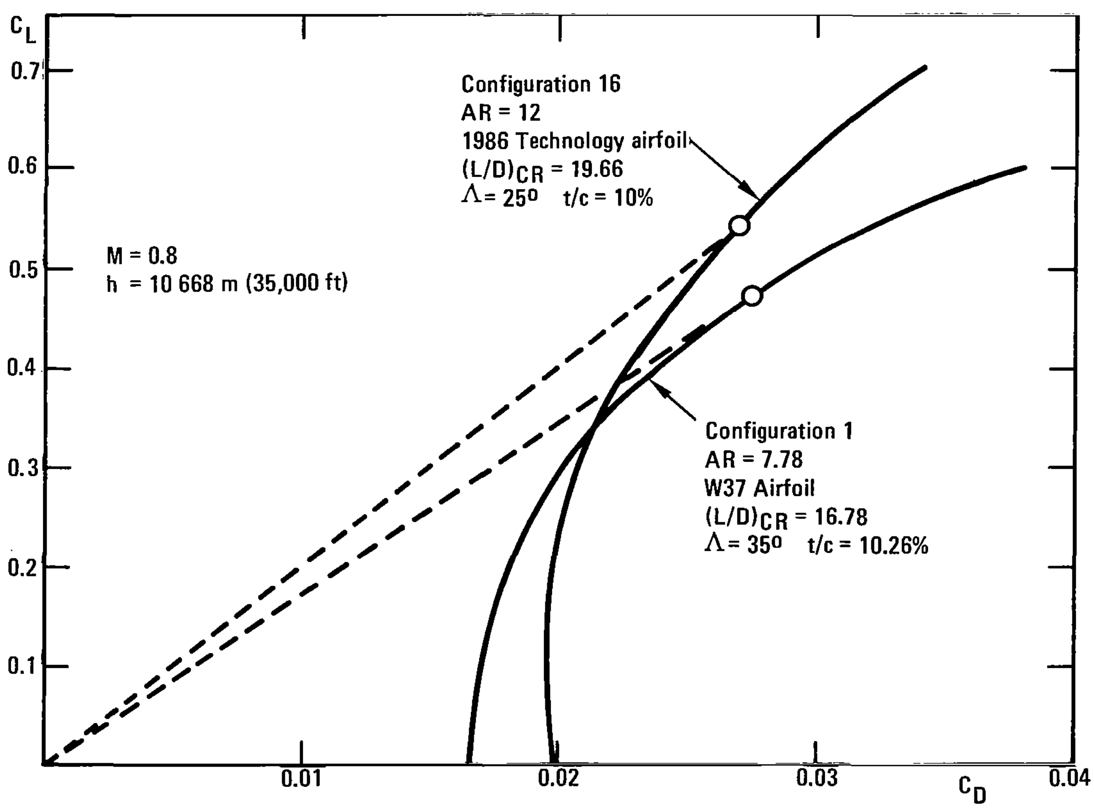


Figure 164. - Drag polar comparison, Configurations 1 and 16.

10. TECHNOLOGY IMPACT

This section describes the implementation of the different advanced technologies, both individually and in combination. In this way the benefits may be quantified of the individual technologies by comparing these configurations with the reference configuration.

There are several pitfalls in this method, one of which is that the application of one technology may require the application of other technologies for any meaningful benefits to accrue. An example of this occurs in Configuration 2, in that the benefits from advanced airfoil technology would be completely offset by drag penalties from airframe/propulsion interference drag if no work were performed to eliminate this drag. A letter suffix is therefore added to the configuration number to indicate when the configuration differs from the original configuration definition.

For advanced airfoil configurations, choice of cg for performance calculations is based on a neutral point at 45 percent MAC. This determination assumes that:

- $\overline{V}_H = 0.78$
- There is no wing load alleviation (WLA)
- $\Lambda = 25^{\circ}$
- $AR = 12$

For configurations which do not use pitch active control systems (PACS) and maintain a positive static margin at the aft cg, tail size should be increased, moving the neutral point about 2 percent further aft. The application of WLA would move the neutral point about 3 percent further forward. Thus for configuration without PACS, the neutral point for performance calculations is in the correction position; for Configurations 14, 15, and 16 the neutral point should be moved about 3 percent further forward.

The impact of advanced technologies are summarized in table XVII.

10.1 Configuration 1: Reference Configuration

Derivation of this configuration is described in Section 4.

10.2 Configuration 2A: Reference Configuration Plus Advanced Airfoil Technology and Airframe/Propulsion Integration

10.2.1 Description. - This configuration is used to determine the benefits of advanced airfoil technology. The configuration uses the reference aircraft wing, i.e.,

- $= 35^{o}$
- AR = 7.79
- t/c = 10.26%

It should be noted that this value of t/c is very close to the optimum value of t/c for a wing of $\Lambda = 35^{o}$, AR = 8, as shown in figure 153.

Changes from the reference aircraft are as follows:

- The airfoil section is changed to reflect 1986 technology readiness
- Neutral point is assumed to be at 45% MAC so that cg for performance calculations is at 30% MAC with 6% static margin at the aft cg limit (figure 165).
- The propulsion system is assumed to be integrated with the wing such that there is no interference drag.

10.2.2 Technology impact. - Benefits accrue from two areas:

- Higher cruise L/D (17.7 for this configuration compared with 16.8 for the reference configuration) (figure 166).
- Higher cruise C_L (0.49 compared with 0.47 for the reference) so that wing area, and hence wing weight, can be reduced.

10.3 Configuration 3: Reference Configuration Plus Advanced Planform

10.3.1 Description. - As described in Section 9.1, planform optimization was carried out using a preliminary advanced technology database. The output data from which the planform was deduced refer to Configuration P3 (figure 151), and the final configuration (with updated advanced technology data) is Configuration 3.

In this configuration the level of airfoil technology remains as for the reference configuration, but the planform characteristics (, AR, and t/c) are optimized. The cg for performance calculations is at 25 percent MAC.

Provided that the wing is not operating in the compressibility drag rise region at cruise, block fuel is relatively insensitive to sweep. Quarter chord sweep of 30^{o} was therefore selected for this configuration, with variation of the following parameters:

TABLE XVII. - SUMMARY OF CONFIGURATION CHARACTERISTICS

Configuration	T/W	W/S	TOFL	SEP	Fuel† limit	Eng out Ceiling	TOGW	Block fuel	Δ Block fuel %
		$N/m^2 (lb/ft^2)$	m (ft)	m/s (ft/sec)		m (ft)	kg(lb)	kg(lb)	
1. Ref.	0.265	6 176.5 (129)	3 123.6 (10,248)	1.5 (5)	1.265	4 592 (14,901)	280 302 (617,950)	43 827 (96,620)	0
2A. Ref + airfoil	0.265	6 224.4 (130)	3 192.5 (10,474)	2.4 (8)	1.392	4 552 (14,933)	271 256 (598,008)	41 341 (91,139)	–5.7
3. Ref + planform param	0.235	6 272.3 (131)	3 096.2 (10,158)	1.5 (5)	1.108	4 584 (15,038)	284 821 (627,912)	41 147 (90,711)	–6.1
4. Ref + high lift	0.265	6 511.7 (136)	3 199.5 (10,497)	1.5 (5)	1.161	4 434 (14,516)	278 041 (612,965)	43 479 (95,853)	–0.8
5. Ref + active controls	0.264	6 176.5 (129)	3 177.2 (10,424)	1.5 (5)	1.259	4 596 (15,079)	274 815 (605,854)	42 702 (94,140)	–2.6
6. Ref + advanced systems	0.26	6 176.5 (129)	3 166.0 (10,387)	1.8 (6)	1.247	4 694 (15,399)	265 771 (585,915)	40 961 (90,302)	–6.5
7F. Ref + adv. propulsion + propulsion integration	0.279	5 985.0 (125)	3 199.5 (10,497)	2.1 (7)	1.448	5 119 (16,793)	268 046 (590,931)	37 819 (83,375)	–13.7
9. Ref + composites	0.264	6 176.5 (129)	3 166.6 (10,389)	1.5 (5)	1.201	4 496 (14,750)	256 247 (564,918)	39 999 (88,181)	–8.7
10. Ref + adv. aluminum	0.264	6 176.5 (129)	3 173.6 (10,412)	1.5 (5)	1.233	4 502 (14,769)	268 198 (591,266)	41 922 (92,420)	–4.3
12. Ref + metal matrix	0.264	6 176.5 (129)	3 156.5 (10,356)	1.5 (5)	1.219	4 496 (14,750)	263 045 (579,905)	41 118 (90,648)	–6.2
13A. Config. 1 + 2 + 3 + 4	0.231	6 511.7 (136)	3 091.6 (10,143)	1.5 (5)	1.123	4 550 (14,928)	272 952 (601,745)	38 856 (85,661)	–11.3
14A. Config. 13 + 5 + 6	0.222	6 511.7 (136)	3 197.7 (10,491)	1.8 (6)	1.115	4 738 (15,545)	247 385 (545,382)	33 782 (74,475)	–22.9 (–13.1)*
15. Config. 14 + 7	0.237	6 511.7 (136)	3 161.4 (10,372)	2.4 (8)	1.2	5 546 (18,195)	232 938 (513,531)	28 828 (63,554)	–34.2 (–14.7)*
16. Config. 15 + 9	0.237	6 511.7 (136)	3 180.9 (10,436)	2.1 (7)	1.118	5 473 (17,955)	210 263 (463,543)	26 276 (57,928)	–40.0 (–8.8)*

*Based on previous configuration

† Ratio of available to required fuel volume

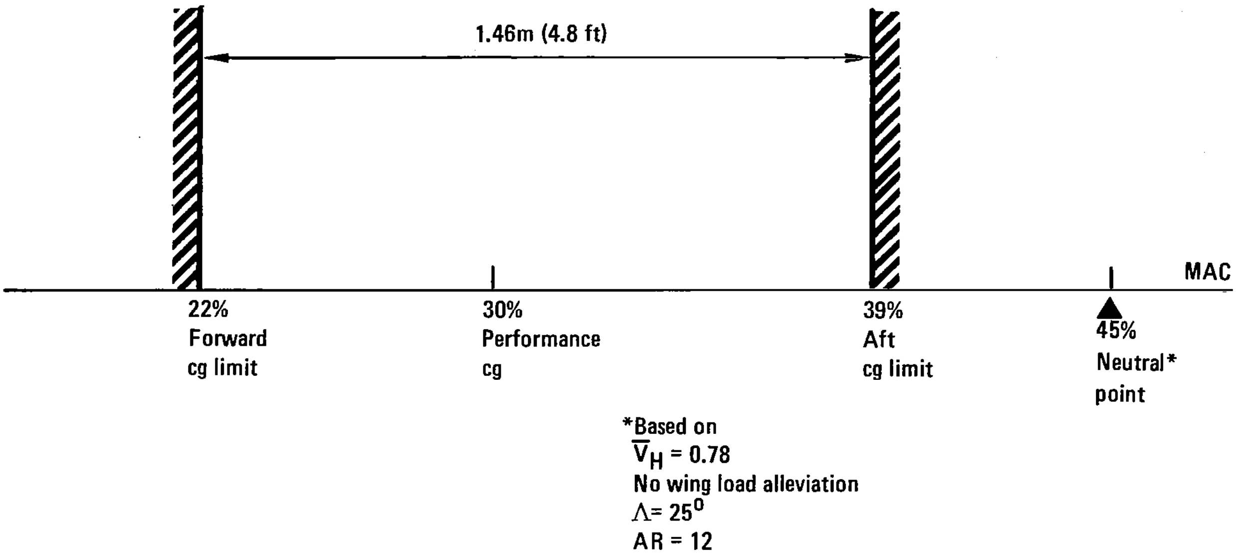


Figure 165. - Center-of-gravity range for Configuration 2A.

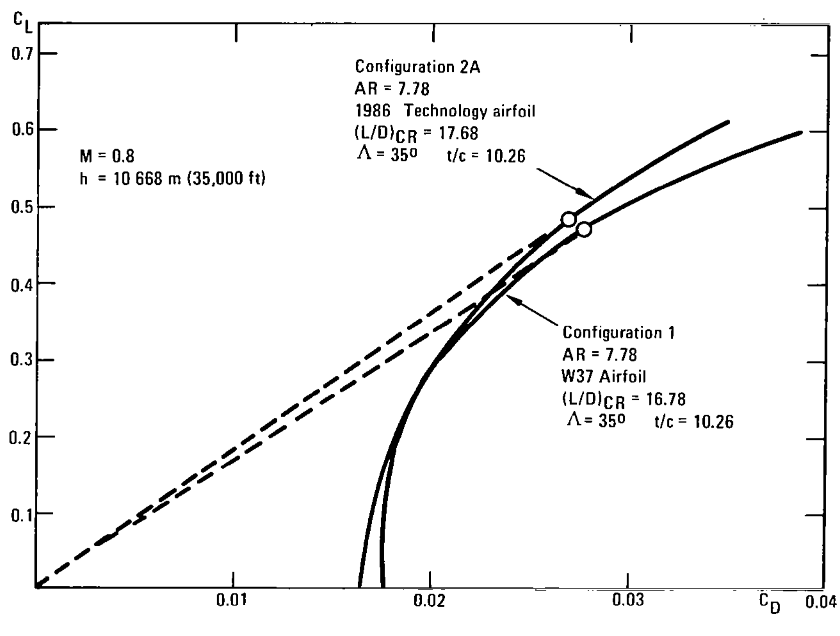


Figure 166. - Drag polar comparison Configurations 1 and 2A.

- t/c = 10%, 12%, 14%
- AR = 10, 12, 14

Block fuel at the average stage length is shown as a carpet plot in figure 167, and the same data is transformed into a knothole plot in figure 168. Each configuration defined on the carpet plot represents a configuration with the optimum T/W and W/S within the constraints defined in Section 2.2.1. A design which is unconstrained by landing gear fit has the following characteristics:

• Λ	30 deg
• AR	12
• t/c	10%
• W/S	6.32 kN/m^2 (132 lb/ft^2)
• T/W	0.236
• Takeoff gross weight	284 821 kg (627,912 lb)
• 4630 km (2500 n.mi.) block fuel required.	41 147 kg (90,711 lb)

The addition of the landing gear constraint has a similar effect as that on Configuration 16 and described in Section 9, except that the aft cg is at 34 percent MAC, compared with 42 percent for Configuration 16.

The position of the 34 percent MAC point on the landing gear butt line is shown in figure 169, indicating that for $\Lambda = 30°$, aspect ratio is restricted to 11.25.

Characteristics of this constrained design are shown in the summary chart of table XVII.

10.3.2 Technology impact. - The major benefit of increased aspect ratio is a 17 percent increase in L/D at cruise (figure 170). However, much of this benefit is offset by a 52 percent increase in wing weight, (figure 19) corresponding to an 11 percent increase in OEW.

10.4 Configuration 4: Reference Configuration Plus Advanced High Lift Systems

This configuraton has the same design characteristics as the reference configuration, except that the wing aerodynamic data have an increment in

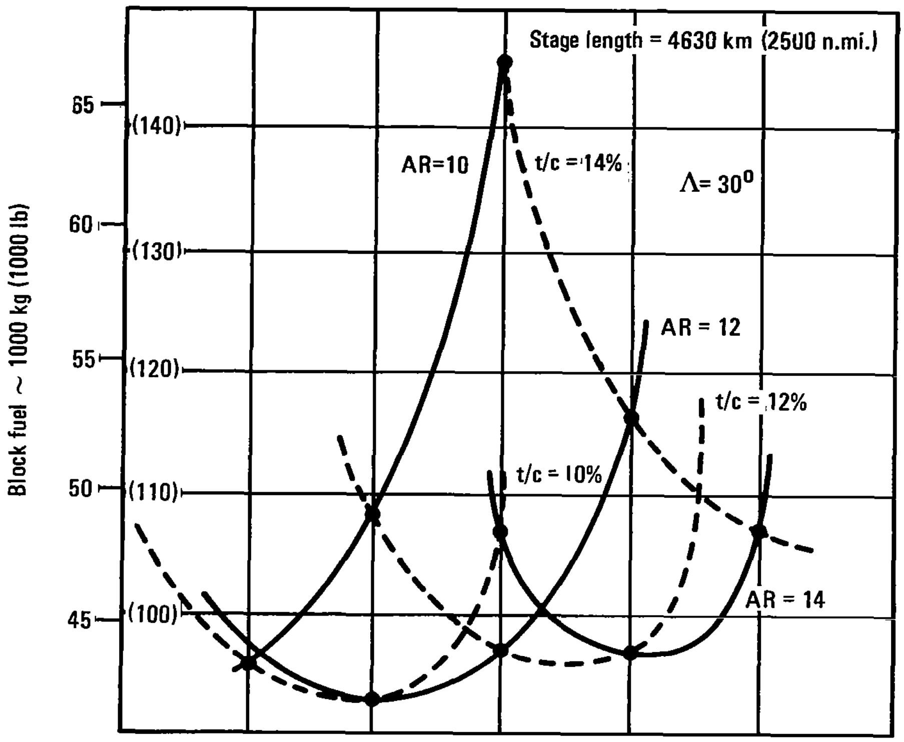


Figure 167. - Configuration P3 - block fuel.

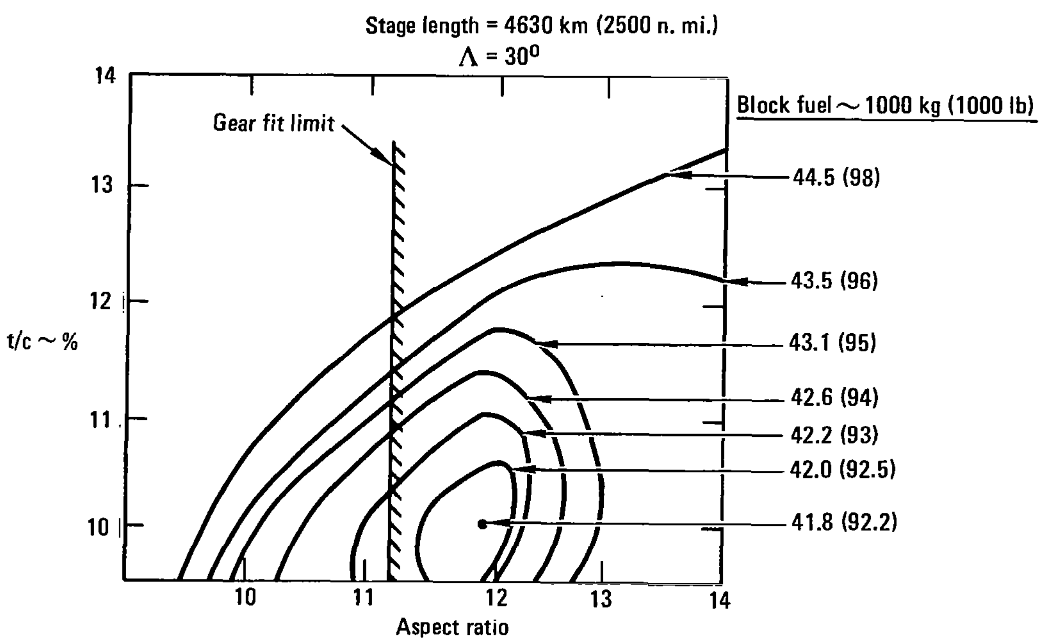


Figure 168. - Configuration P3 - block fuel knothole.

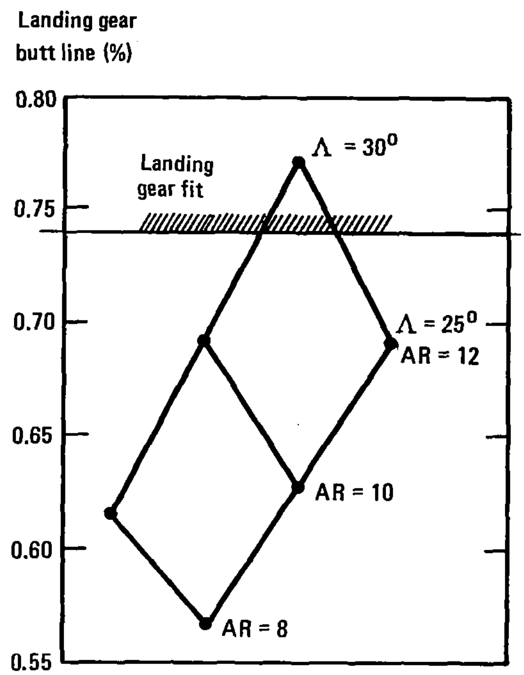


Figure 169. - Position of 34% MAC (plus tip up margin) on landing gear butt line, Configuration P3.

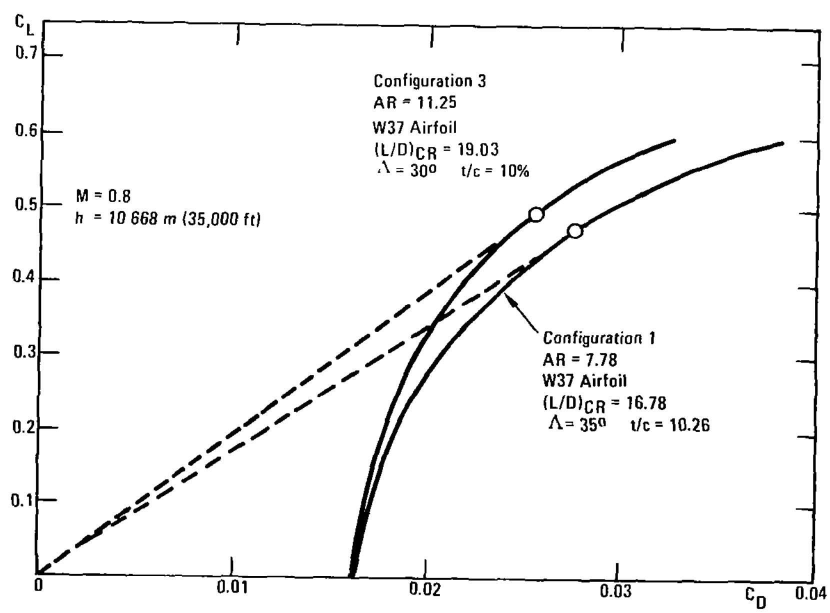


Figure 170. - Drag polar comparison, Configurations 1 and P3.

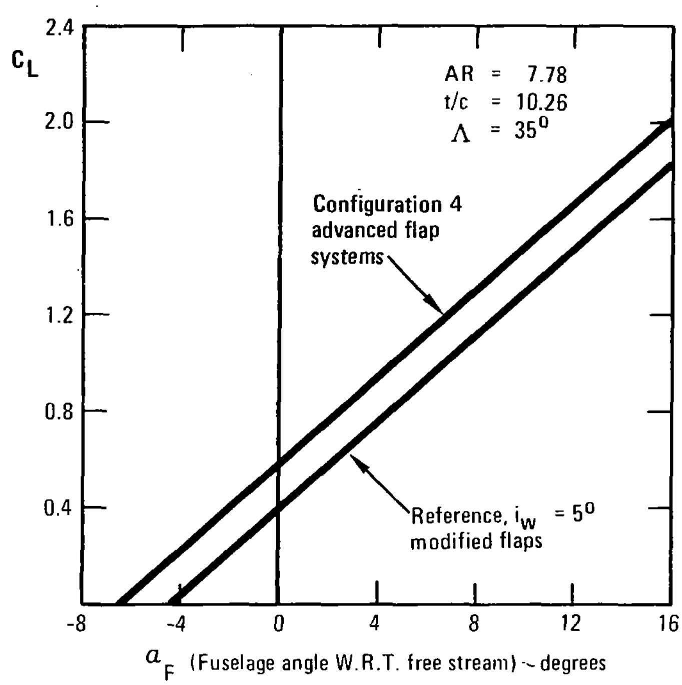


Figure 171. - Advanced flap system C_L vs in ground effect.

$C_{L_{MAX}}$ of 0.15 at takeoff and landing plus a decrease of 2° in $\alpha_{C_L = 0}$ (figure 171). These changes are achieved through modifications in leading and trailing edge flap designs, although the flap mounting system is assumed to be unchanged, so that there is no change in flap weight or cost.

Figure 24 shows that, because the reference configuration is takeoff field length limited and maximum achievable C_L at takeoff is tail scrape limited, decrease in $\alpha_{C_L = 0}$ permits higher takeoff C_L and hence higher wing loading (figure 172); block fuel is reduced by 0.8%. Configuration 16 is not field length limited, so that these benefits do not apply.

10.5 Configuration 5: Reference Configuration Plus Pitch Augmentation Control System

10.5.1 Description. - L-1011 data show that the optimum cg position for minimum trim drag is at about 32 percent MAC. Cg travel is shown in figure 173.

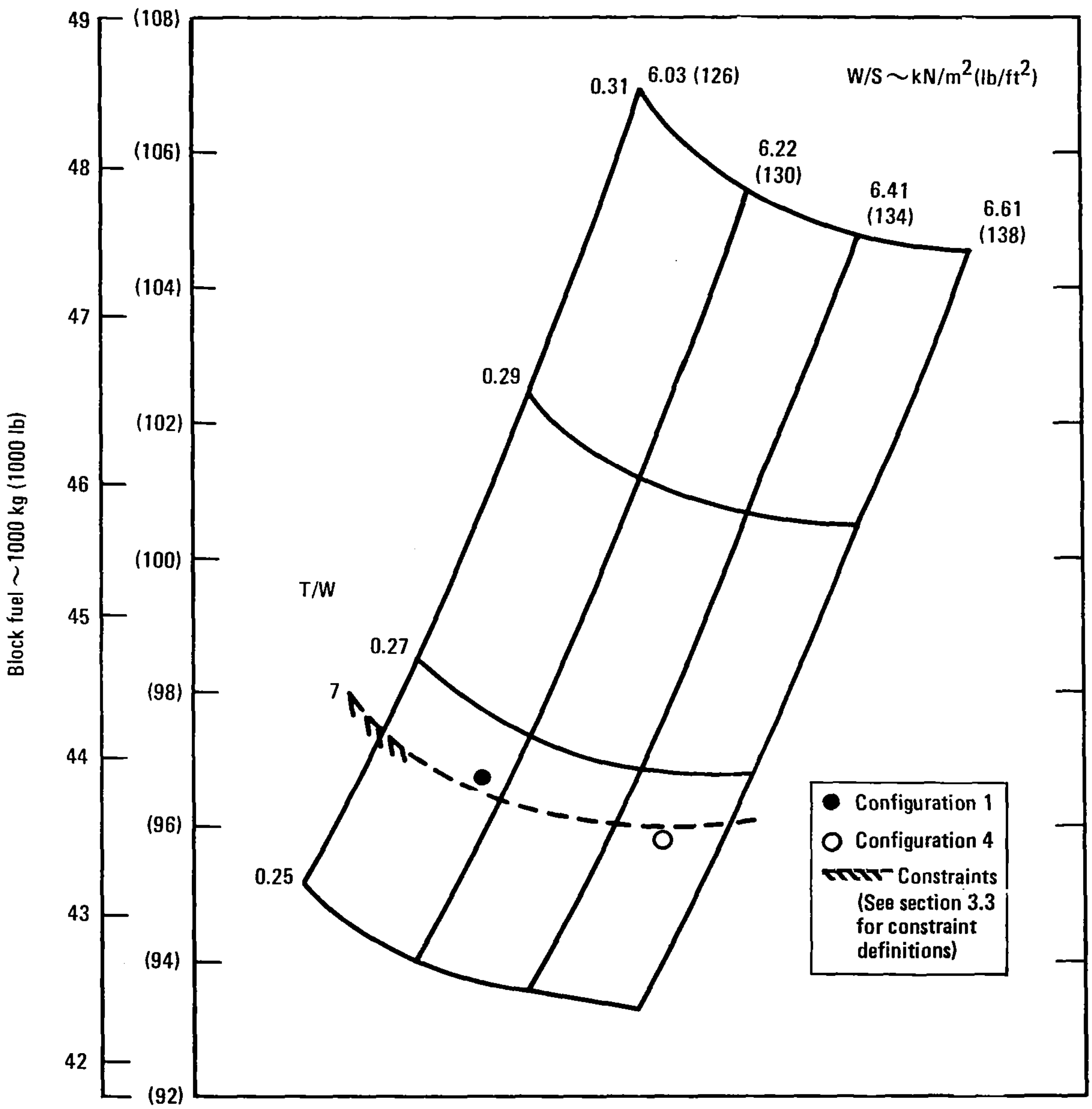


Figure 172. - Configuration 4, block fuel 4630 km (2500 n.mi.) stage length.

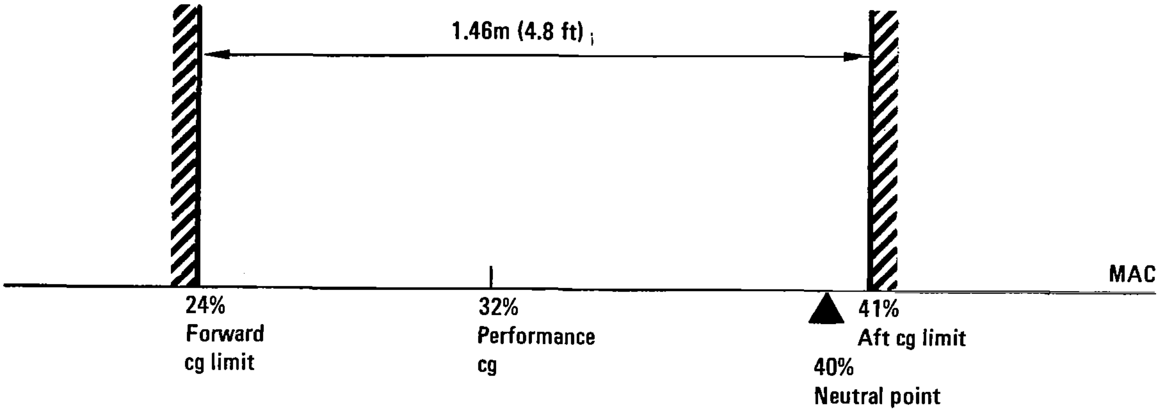


Figure 173. - Center-of-gravity limits for Configuration 5.

The following are added:

- Pitch active control system
- Fly-by-wire
- Multiplexing for flight controls

No cg management with fuel pumping is used.

10.5.2 Technology impact. - The major impact of PACS is through reduction in trim drag, resulting in an increase in cruise L/D of 0.8 percent. This benefit is small because the airfoil used on the reference configuration has a smaller value of C_m than for an advanced airfoil, and no benefit accrues if the cg is moved further aft than 32 percent MAC. Configuration 14 describes the impact of PACS on an advanced airfoil.

The use of fly-by-wire and multiplexing saves 1032 kg (2275 lb) in the weight of flight controls, equivalent to 0.8 percent weight saving in OEW.

10.6 Configuration 6: Reference Configuration Plus Advanced Systems and Controls

10.6.1 Description. - This configuration represents the all-electric aircraft concept as applied to the reference configuration (using the CF6-50C engine).

The major effects are:

- Removal of
  - Hydraulic system
  - Pneumatic system
  - Engine bleed for ECS and deicing
- Addition of
  - Advanced secondary power system
  - Advanced electrical system
  - Electrically driven ECS with 50% recirculation
  - Electromechanical actuation system (EMAS) for flight control and services
  - Integrated avionics

10.6.2 Technology impact. - The use of all-electric secondary power systems result in 1.7 percent reduction in SFC due to bleed elimination and 50 percent recirculation in the ECS. In addition, there is a total systems weight saving of 2677 kg (5900 lb), equivalent to a 1.9 percent decrease in OEW.

10.7 Configuration 7: Reference Aircraft Plus Advanced Propulsion

This configuration is evaluated in Section 7.

10.8 Configuration 8: Reference Aircraft Plus Propulsion Integration

The impact of propulsion integration is evaluated in Section 7.

10.9 Configuration 9: Reference Aircraft Plus Advanced Composite Materials

10.9.1 Description. - This configuration has the same design characteristics as the reference configuration, except that component weights are modified to reflect the use of graphite epoxy material on selected wind and tail components as identified in Section 8, Tables IX and X. The graphite epoxy composite usage in wing covers (upper and lower) in lieu of the conventional aluminum alloy can potentially result in a 34 percent weight savings. The net percentage from the reference configuration considering the other material usage is as follows:

- Wing -27%
- Empennage -20%

Wing weight reductions from the use of toughened-resin technology are based on results from NASA contract NAS1-16856 (Lockheed, CA). Toughened-resin development costs are included in the materials developments costs for composites (Table XIV). Empennage weight reductions are based on conventional resin technology. In practice some additional weight savings can be achieved through the use of composites in the nacelle and air induction system, but as their combined weight is only about 8 percent of structural weight, the weight saving would be very small. Weight reduction from the use of composites in the nacelle and air induction system are embodied in Configuraton 16.

10.9.2 Impact. - Wing and empennage represent 25 percent of OEW so that 27 percent weight reduction of these components is the equivalent of 7 percent reduction in OEW. The resulting block fuel reduction is 8.7 percent.

10.10 Configuration 10: Reference Aircraft Plus Advanced Aluminum

10.10.1 Description. - The use of advanced aluminum results in the following percentage weight reductions:

- Wing -12%
- Empennage -12%

The use of advanced aluminum could also produce 10 percent reduction in landing gear weight, and since landing gear represents about 14 percent of structural weight, this weight reduction would be significant. However, for comparative purposes, no reduction in landing gear weight is assumed for this configuration. This weight reduction is included in Configuration 16.

10.10.2 Impact. - Twelve percent weight reduction of wing and empennage of these components is the equivalent of 3 percent reduction in OEW. The resulting block fuel reduction is 4.3 percent.

10.11 Configuration 11: Reference Plus Titanium Alloys

It is predicted that the use of titanium alloys will be restricted to some engine support components, plus some secondary structures using super-plastic forming and diffusion bonding (SPF/DB). The economic impact can better be evaluated on a component by component basis, and it was therefore decided not to evaluate titanium using the methods of this study.

10.12 Configuration 12: Reference Plus Metal Matrix Alloys

10.12.1 Description. - The use of silicon carbide (SiC) fibers in an aluminum matrix are predicted to have the following weight reductions:

- Wing -18%
- Empennage -17%

The use of metal matrix alloys and other advanced materials could also produce 10 percent reduction in landing gear weight, and since landing gear represents about 14 percent of structural weight, this weight reduction would be significant. However, for comparative purposes no reduction in landing gear weight is assumed for this configuration. This weight reduction is included in Configuration 16.

10.12.2 Impact. - The effect of these weight reductions on block fuel is similar to that of advanced composites, producing a block fuel reduction of 6.2 percent.

10.13 Configuration 13A: Reference Plus Advanced Aerodynamics (Airfoil, Planform and High Lift) and Airframe/Propulsion Integration

10.13.1 Description. - This configuration is modified from the reference configuration with the following changes:

- Advanced Airfoil Section
- Planform

  Λ = 25%

  AR = 12

  t/c = 10%

- High-lift

  $\Delta C_{L_{MAX}}$ = +0.15 from reference level

- Cg

  Cg for performance calculations at 27% MAC (figure 174)

10.13.2 Impact. - The advanced technology airfoil permits wing sweep to be reduced. This in turn permits a wing of higher aerodynamic efficiency and, under the ground rules used in this study, a higher aspect ratio without landing gear installation problems. The combination of advanced airfoil and planform parameters offer a benefit in fuel consumption about equal to the sum of the individual technology benefits.

10.14 Configuration 14A: Configuration 13A plus Active Controls and Advanced Systems

10.14.1 Description. - The active controls and advanced systems applied to this configuration are those defined in Sections 10.5 and 10.6. There are two additional significant differences. The first is that the optimum cg for maximum M(L/D) is now at 55 percent MAC. In addition, the combination of aft movement of the neutral point and relaxed static stability permits tail volume to be reduced to $\bar{V}_H$ = 0.78.

10.14.2 Impact. - The total impact is a reduction in block fuel of 13.1 percent of Configuration 13. Of this, about 6.5 percent is attributed to all-electric technology (as derived in Configuration 6). This leaves 6.6 percent block fuel reduction from RSS and reduction in tail size. The reduction in tail volume coefficient from $\bar{V}_H$ = 0.95 to 0.78 contributes 2.4 percent reduction in block fuel; thus 4.2 percent of this reduction is due to trim drag.

10.15 Configuration 15: Configuration 14 Plus Advanced Propulsion and Propulsion Integration

10.15.1 Description. - This configuration adds an E^3 propulsion system to Configuration 14. The propulsion system is fully integrated with the wing such that there is no interference drag.

10.15.2 Impact. - Impact on block fuel is a reduction in 14.7 percent from the fuel consumption of Configuration 14. This is more than the reduction achieved in Configuration 7F in which an integrated E^3 propulsion system is installed on the reference configuration. The difference is due to the reduction in pylon weight associated with installing a smaller and lighter engine than used in Configuration 7F.

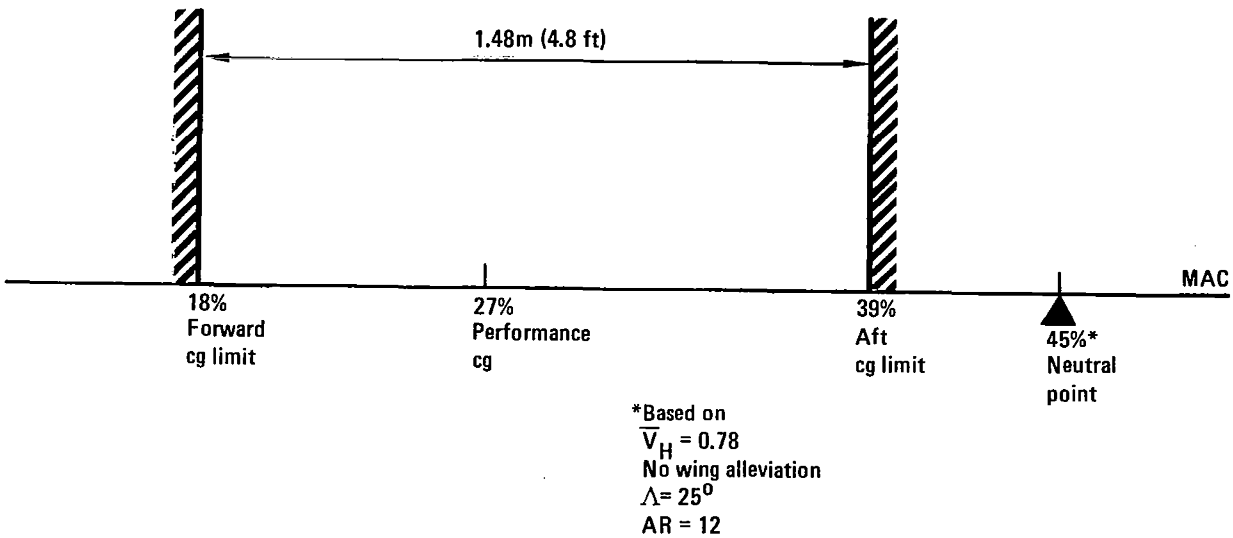


Figure 174. - Center-of-gravity range for Configuration 13A.

10.16 Configuration 16: Configuration 15 Plus Advanced Composites

10.16.1 Description. - This configuration is described fully in Section 9, and may be derived from Configuration 15 by the substitution of advanced composites for aluminum in the wing and empennage, plus the use of metal matrix and other advanced materials in the landing gear; this results in a 10 percent reduction in landing gear weight.

10.16.2 Impact. - This results in a 8.8 percent reduction in block fuel from the fuel consumption of Configuration 15. This compares with a reduction of 8.7 percent in block fuel when advanced composites are applied to the reference configuration. This difference is due to landing gear weight reduction.

11. PRIORITY ASSIGNMENT

In this section the technology development costs are compared with the changes in block fuel from the reference configuration. In addition, the technology development costs which were developed in Sections 5 through 8 are compared with the net value of technology defined in Section 3.

The approach used in this section to grade the different technologies is somewhat simplistic; if these results are used in any decision making regarding priorities for further research, there are many other factors that should also be taken into consideration. These include the applicability of this technology to other commercial and military aircraft, and nonaerospace applications. If the basis for the allocation of costs is changed, the cost numbers themselves would change drastically.

An attempt has been made to ensure that all technologies have been developed to the same confidence level. This is somewhat of a subjective judgment, so that there may be inconsistencies. It may be argued that aerodynamics technology is not fully validated until the aircraft is certified, whereas the position taken in this report is that aerodynamics technology can probably be validated without full scale flight testing. These factors should be borne in mind when comparing technology development cost and benefits.

11.1 Net Value of Technology vs Block Fuel

An example of the effect of block fuel reduction on direct operating cost is shown in figure 175. In addition there are small reductions in maintenance and depreciation.

Figures 176 and 177 show the block fuel reductions achievable with the application of the individual and combined technologies. Figure 178 shows the result of comparing these reductions with the associated technology development cost.

11.2 Net Value of Technology vs Technology Development Cost

The net value of technology is calculated by finding the difference in total operating cost between the selected configuration and the reference, and multiplying this by the total distance flown in the life of the aircraft and the number of aircraft in the production run. Table XVIII shows the net value of technology and technology development cost for both individual technologies and combinations of technologies. These figures are also shown graphically in figure 179. Differences between this figure and figure 178 are due to the fact that block fuel reduction and net value of technology do not have a simple relationship for all configurations (figure 180). For example, Configuration 3, with a high aspect ratio wing, has a higher takeoff gross weight than the reference configuration, resulting in a higher first cost and thus a lower net value of technology.

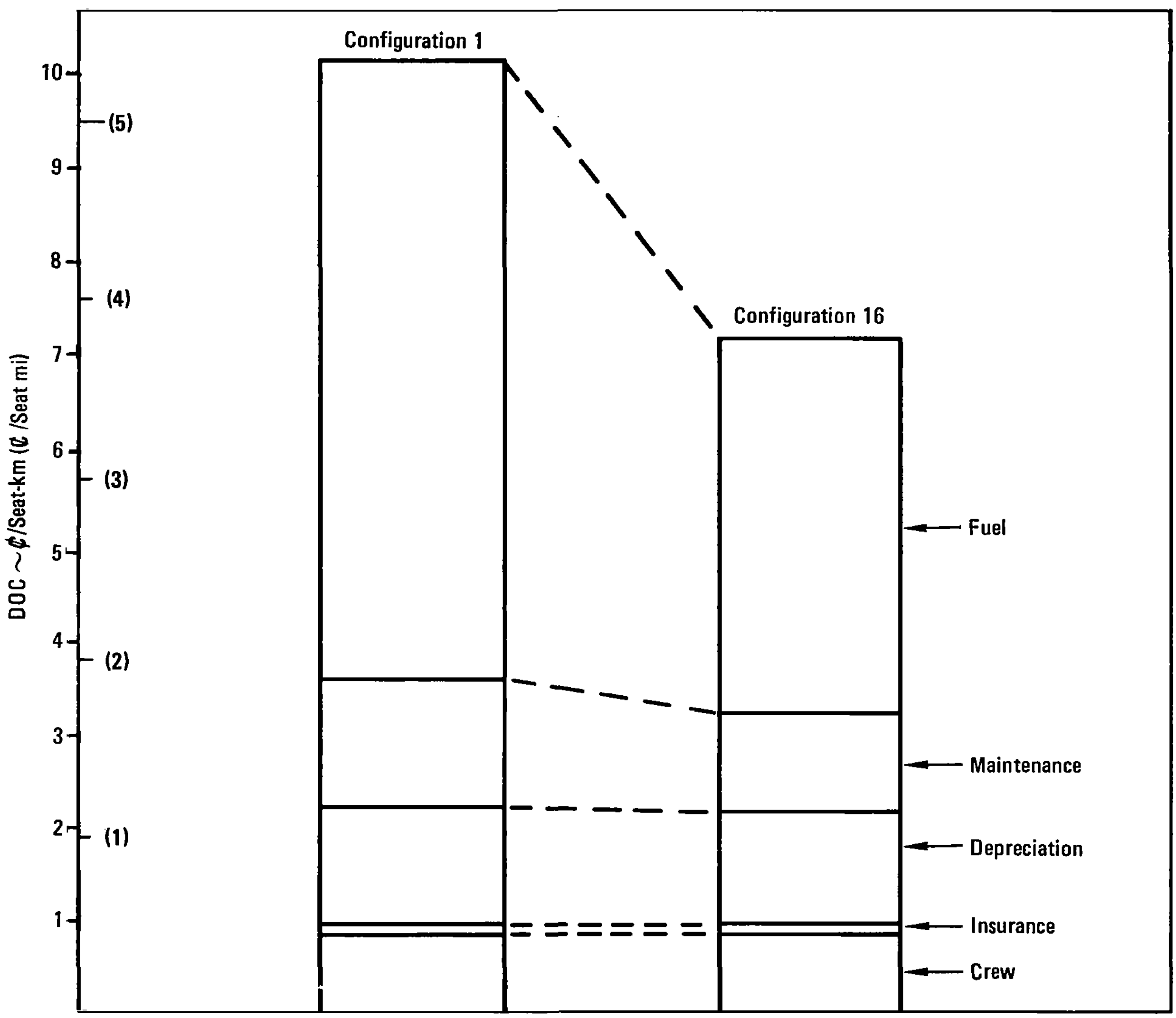


Figure 175. - Direct operating cost comparison.

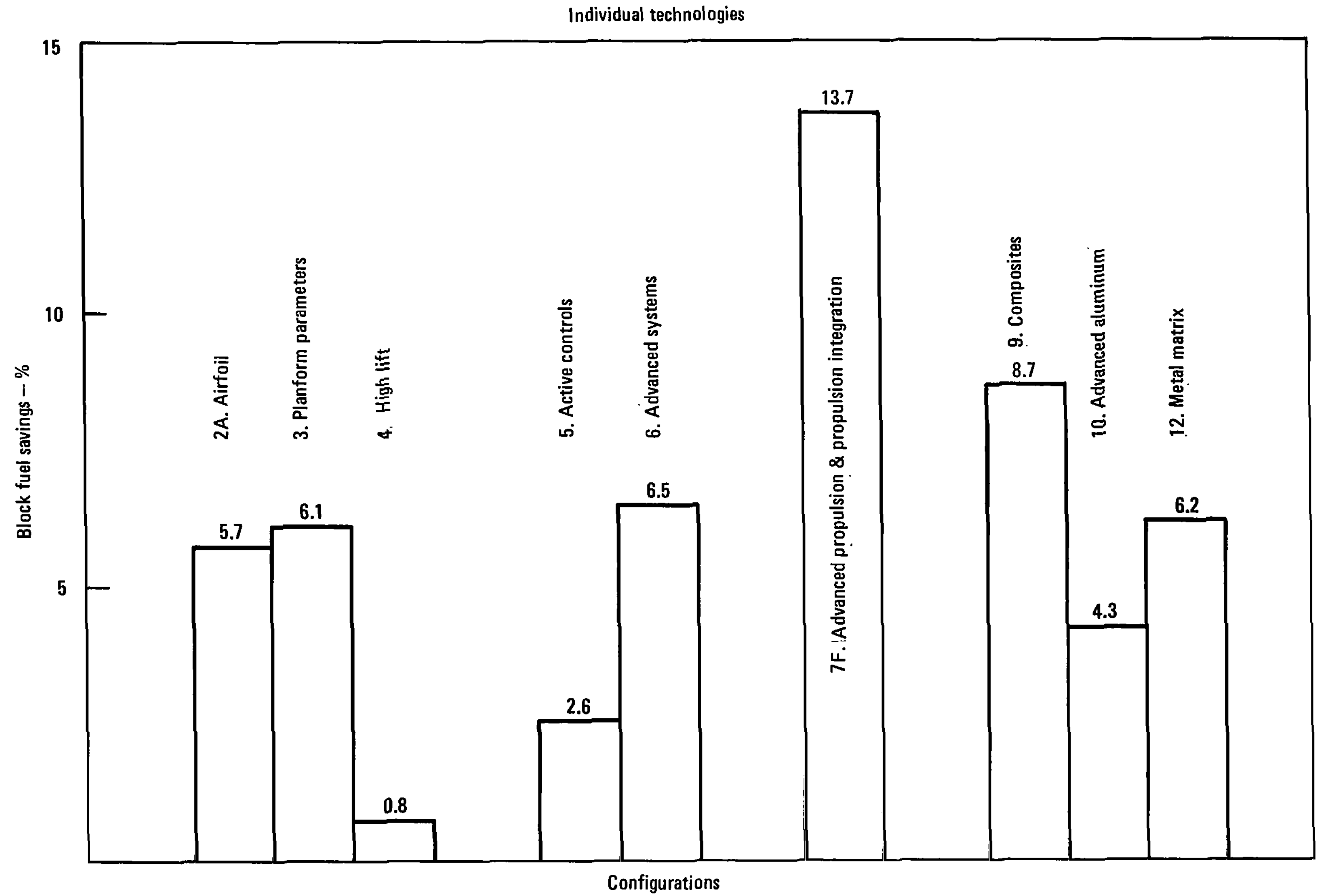


Figure 176. - Block fuel savings - %, individual technologies.

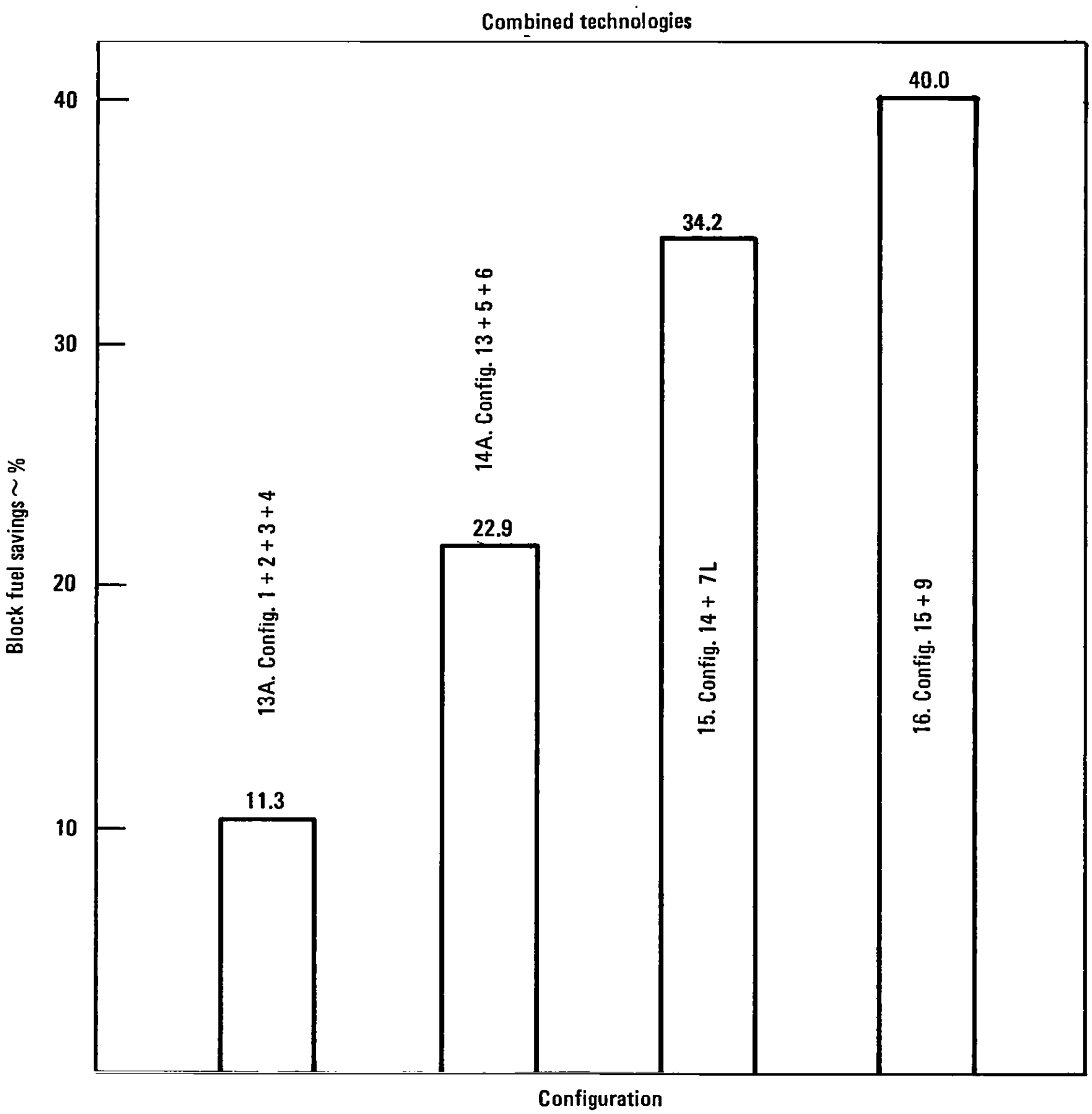


Figure 177. - Block fuel savings ~ %, combined technologies.

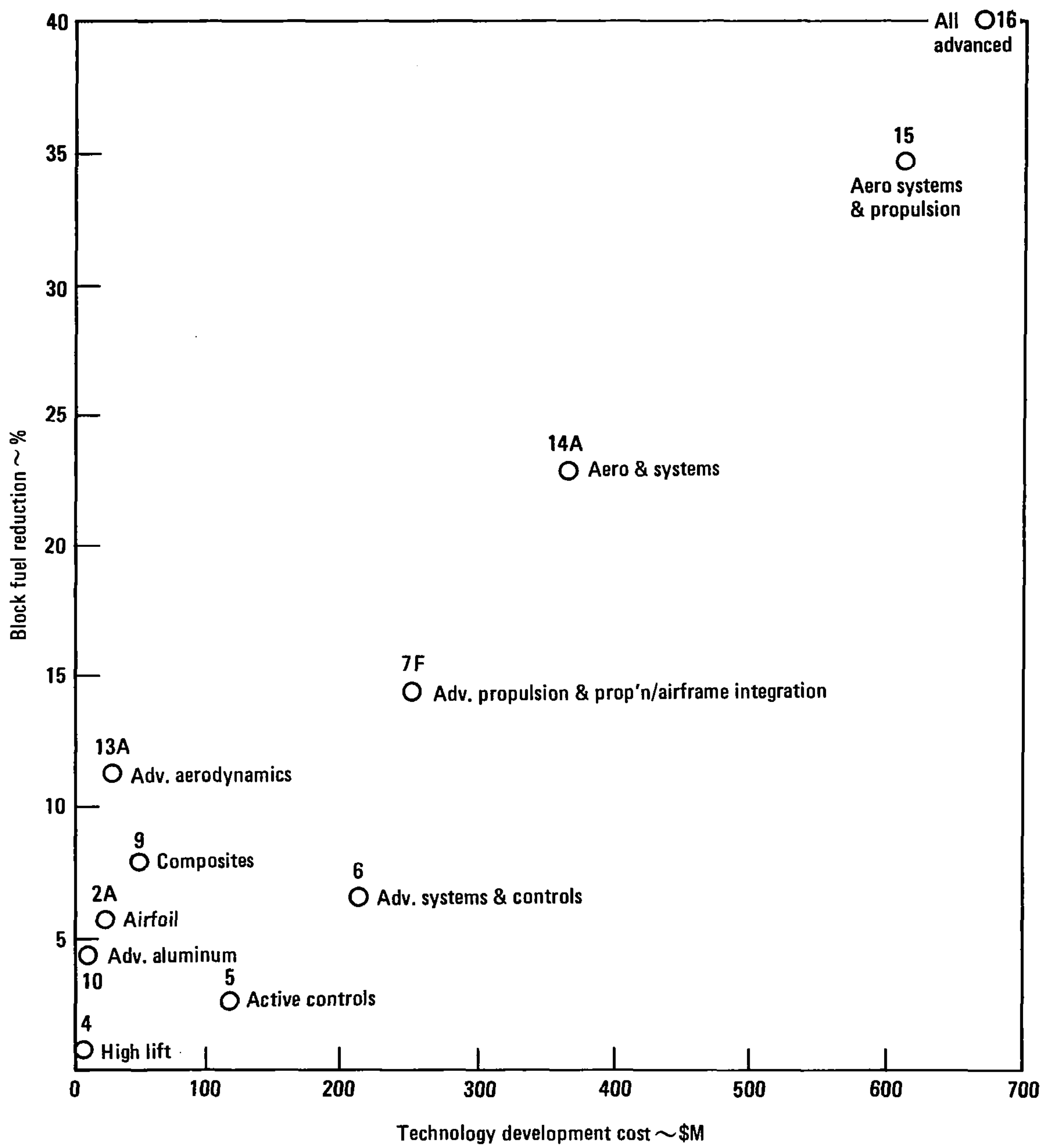


Figure 178. - Block fuel vs technology development cost.

Priorities may be assigned based on the payoff ratio:

$$\frac{\text{Net Value of Technology}}{\text{Technology Development Cost}}$$

Values of this ratio are shown graphically in figure 181.

TABLE XVIII. - FINANCIAL DATA

Configuration	DOC*	IOC*	TOC*	Net value of Technology ~$ B	ROI(%)	Tech. devlpmt.. cost ~$ M	Payoff ratio
1. Ref.	2.90 (5.38)	1.71 (3.17)	4.61 (8.54)	0	15.08	0	–
2A. Ref + airfoil	2.78 (5.15)	1.70 (3.14)	4.48 (8.29)	9.895	17.24	23.7	418
3. Ref + planform	2.81 (5.20)	1.71 (3.17)	4.52 (8.35)	6.791	15.95	–	–
4. Ref + high lift	2.88 (5.34)	1.71 (3.16)	4.59 (8.50)	1.863	15.56	4.5	414
5. Ref + active controls	2.83 (5.24)	1.70 (3.15)	4.53 (8.40)	5.743	16.45	105	55
6. Ref + advanced systems	2.72 (5.04)	1.68 (3.12)	4.41 (8.16)	14.939	18.76	216	69
7F. Ref + adv. propulsion + propulsion integration	2.66 (4.92)	1.68 (3.12)	4.34 (8.04)	19.397	17.56	243	80
9. Ref + composites	2.69 (4.99)	1.69 (3.12)	4.38 (8.11)	16.880	19.05	43	393
10. Ref + advanced aluminum	2.81 (5.20)	1.70 (3.14)	4.50 (8.34)	7.877	16.79	14	563
12. Ref + metal matrix	2.76 (5.12)	1.69 (3.13)	4.45 (8.25)	11.331	17.60	23	493
13A. Config. 1 + 2 + 3 + 4	2.68 (4.97)	1.70 (3.14)	4.37 (8.10)	17.112	18.38	28.2	607
14A. Config. 13A + 5 + 6	2.38 (4.41)	1.65 (3.06)	4.03 (7.47)	41.791	24.89	357	117
15. Config. 14A + 7	2.16 (4.00)	1.63 (3.01)	3.79 (7.02)	59.253	27.39	600	99
16. Config. 15 + 9	2.01 (3.72)	1.61 (2.97)	3.62 (6.70)	71.591	31.16	643	111

*¢/seat-kilometer (¢/seat-n.mi.)

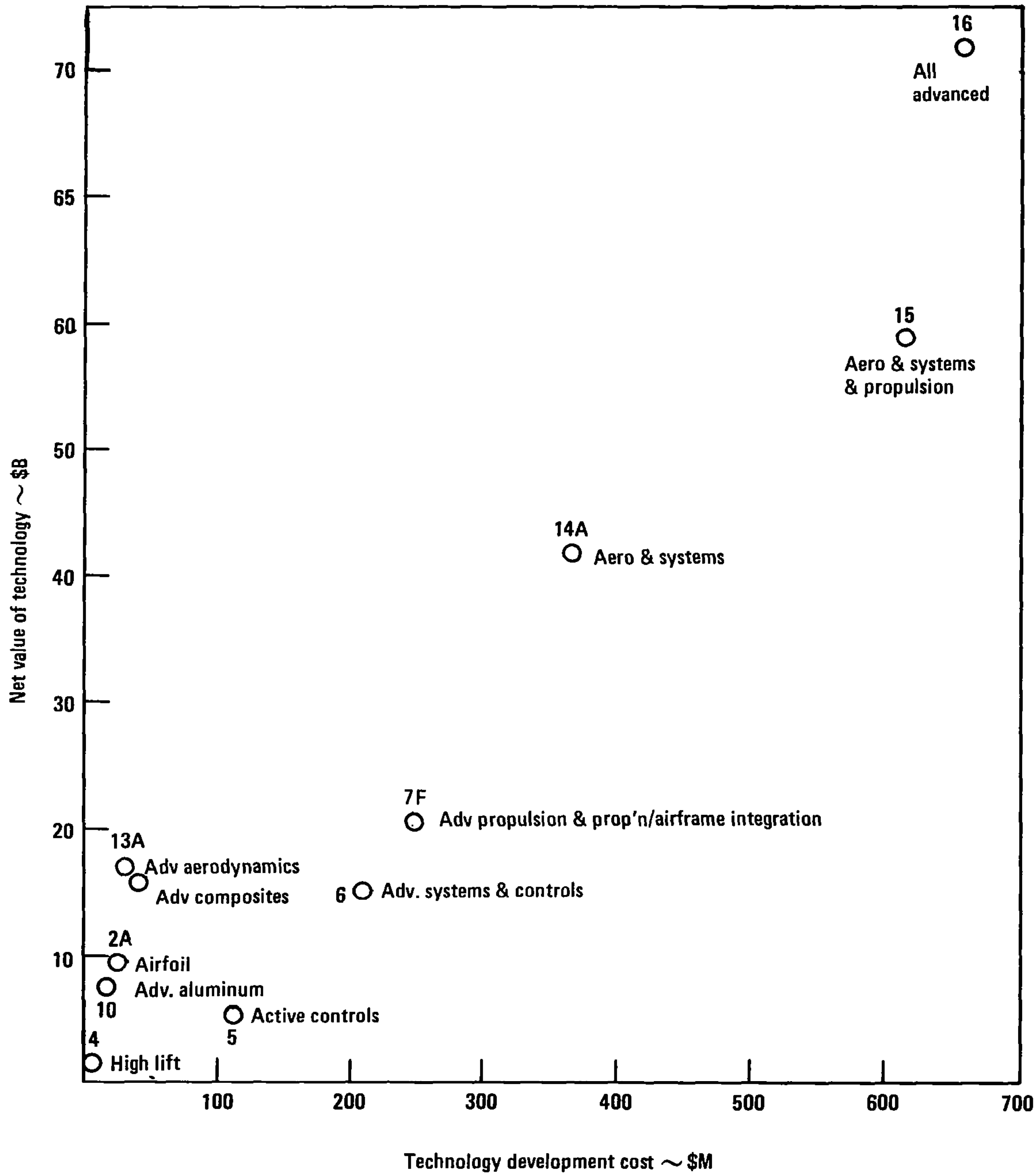


Figure 179. - Net value of technology vs technology development cost.

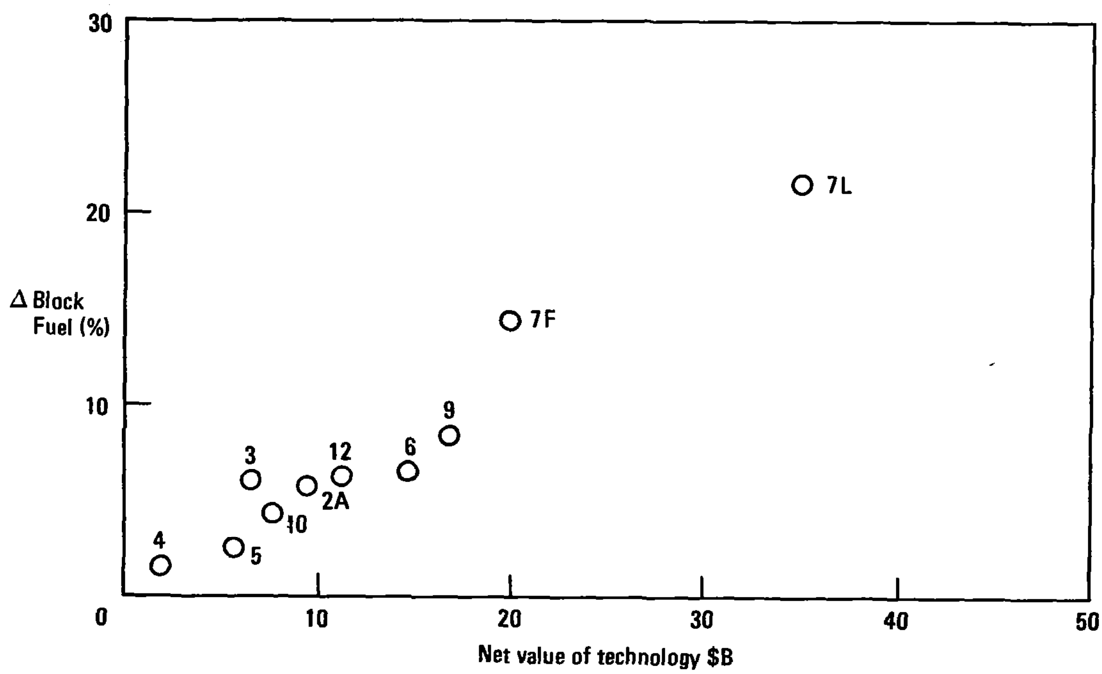


Figure 180. - Change in block fuel vs net value of technology.

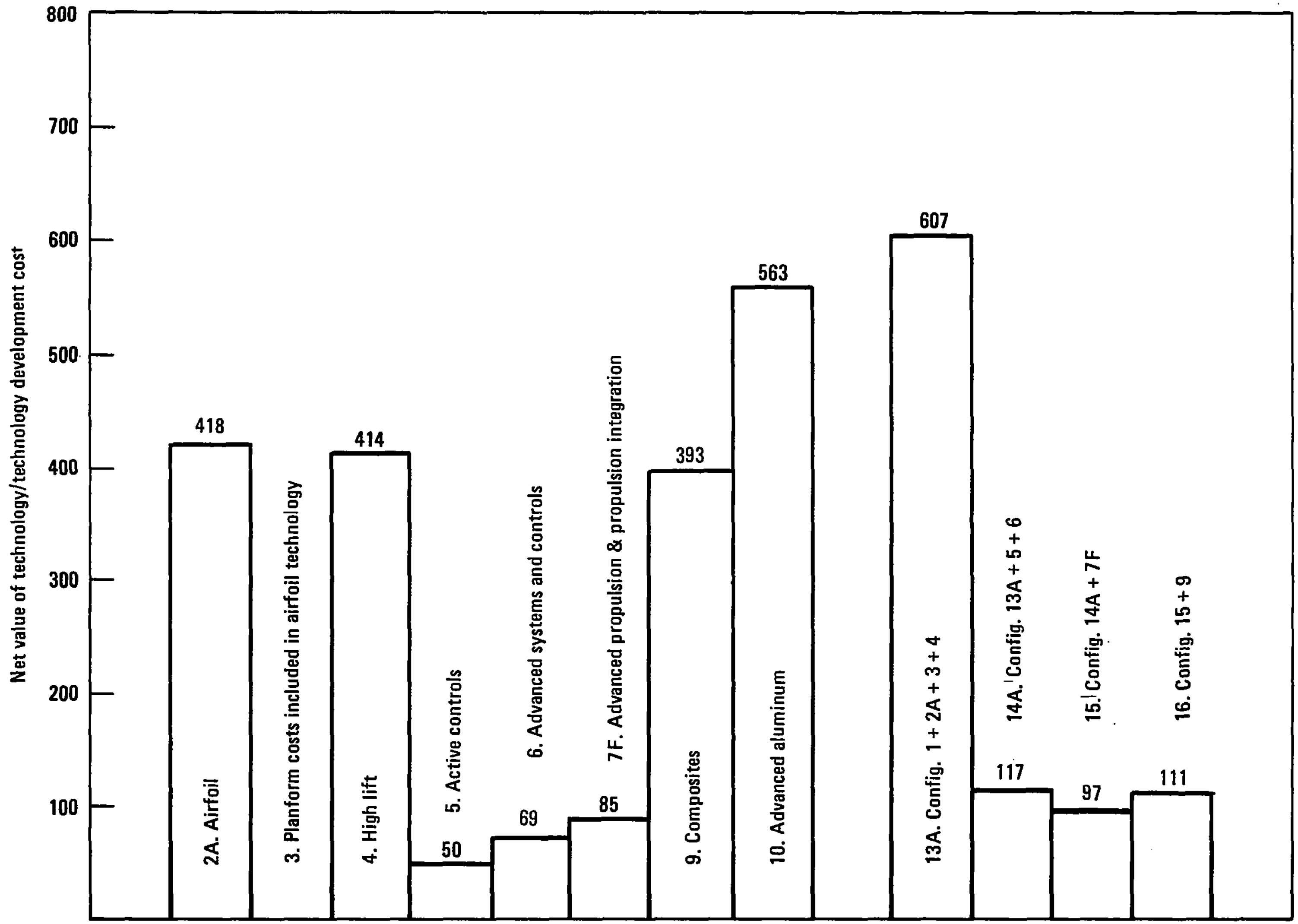


Figure 181. - Payoff ratio.

12.0 CONCLUSIONS AND RECOMMENDATIONS

12.1 Conclusions

The levels of funding for each technology are based on a judgment either to reach a specified technology goal (e.g., all-electric aircraft) or based on extrapolation of past technology improvements (e.g., aerodynamics). It is clear from the results of Section 11 that the net value of technology offers a payback that is considerably greater than the technology development cost.

For a fleet of 400 aircraft, the application of all-advanced technologies yields an NVT of $72 billion (in 1980 dollars), for a total technology development cost of $643 million. Almost all the benefit is achieved through reduction in block fuel, (40 percent reduction for the all-advanced configuration).

In ranking the different technologies, technology development in aerodynamics offers the largest benefit in NVT per unit technology development cost, yielding $17 billion increase in NVT (achieved with 11.3 percent reduction in block fuel) for $28 million technology development cost. However, E^3 propulsion technology with airframe/propulsion integration gives the greatest single benefit in NVT of $19 billion, but with a technology development cost of $249 million.

Based on these results, a large increase in technology development is therefore justified. The question arises as to whether, say, doubling the amount of money spent on technology development cost would produce an equivalent further improvement in net value of technology.

The limitation on technology development is clearly not in the technology development cost itself, but in the nonrecurring aircraft development cost. In this study, the aircraft fuselage and cockpit are unchanged, although for costing purposes each configuration is assumed to be all-new. Nonrecurring aircraft development costs are of the order of two billion dollars, and these costs are reflected in each aircraft price.

The technology development cost for aerodynamics does not include full scale flight test, and thus remains at a higher risk level than other technologies for which full scale testing is included. Use of the National Transonic Facility, permitting full-scale Reynolds number testing, allows this risk to be held to an acceptable level.

Significant benefits in aircraft performance and economics are available from development and future incorporation of advanced materials. The anticipated weight reductions have not been achieved to date on large primary aircraft structural components. However, current data and trends indicate that the projected component weight reductions are reasonable. To fully realize the benefits, the materials and structure development must be systematically carried out prior to the aircraft commitment data. Early initiation of critical and long lead time efforts for developing improved toughness aluminum alloys and toughened-resins for organic composite materials for aerospace applications are recommended as a high-priority technology development effort.

APPENDIX

Table XIX describes the data listed in Table XX, which is a summary of output from the ASSET computer runs. Subsequent pages show significant output data from ASSET for aircraft geometry, weights, material matrix, mission, and costs.

TABLE XIX. ASSET PARAMETRIC ANALYSIS SUMMARY

ASSET PARAMETRIC ANALYSIS SUMMARY

NOTES:	1. COST DATA		Operating cost data are for stage length of 2500 n.mi.
	2. MISSION PARAMETERS		
		26. CRUISE ALT (1)	Initial Cruise Altitude @ Design Mission of 4600 n.mi. ~ ft
		27. BLOCK FUEL (1)	Block Fuel for Design Mission ~ lb
		28. CRUISE ALT (2)	Initial Cruise Altitude @ Alternate Mission of 2500 n.mi. ~ ft
		29. BLOCK FUEL (2)	Block Fuel for Alternate Mission ~ lb
	3. CONSTRAINT OUTPUT		
		30. CEILING (1)	Engine out ceiling at Max Take-off Gross Weight; STD Day + 10°C – Required gradient is .014.
		31. TAKEOFF DST (1)	All-Engine Takeoff Distance @ Max Takeoff Gross Weight, Sea Level, STD + 13.9°C ~ ft.
		32. CLIMB GRAD (1)	All-Engine Climb Gradient
		33. TAKEOFF DST (2)	Engine-Out Take-off Distance @ Max Take-off Sea Level, STD + 13.9°C ~ ft.
		34. CLIMB GRAD (2)	Engine-Out Climb Gradient
		35. CTOL LNDG D(1)	Landing Distance @ End-of-Cruise Gross Weight, Sea Level, STD + 13.9°C ~ ft.
		36. AP SPEED	Landing Approach Speed ~ kt.

TABLE XX. CONFIGURATION SUMMARY

AIRCRAFT DEFINITION	1	2A	3	4	5	6
1 W/S	129.0	130.0	131.0	136.0	129.0	129.0
2 T/W	0.265	0.265	0.235	0.265	0.264	0.260
3 AR	7.78	7.78	11.25	7.78	7.78	7.78
4 T/C	10.30	10.30	10.00	10.30	10.30	10.30
5 SWEEP	35.00	35.00	30.00	35.00	35.00	35.00
6 GROSS WEIGHT	617950	598008	627912	612965	605854	585915
7 FUEL WEIGHT	235197	221942	217804	233720	229403	220174
8 OP. WT. EMPTY	309253	302566	336608	305745	302951	292241
9 ZERO FUEL WT.	382753	376066	410108	379245	376451	365741
10 ENGINE SCALE	1.086	1.051	0.979	1.078	1.061	1.011
11 THRUST/ENGINE	54586	52824	49186	54145	53315	50779
12 WING AREA	4790.	4600.	4793.	4507.	4697.	4542.
13 WING SPAN	193.1	189.2	232.2	187.3	191.2	188.0
14 H. TAIL AREA	1786.2	1672.1	1464.3	1617.5	1729.5	1637.9
15 V. TAIL AREA	855.7	799.0	921.3	772.0	824.0	765.6
16 ENG. LENGTH	14.81	14.59	14.13	14.76	14.66	14.34
17 ENG. DIAMETER	7.53	7.40	7.14	7.49	7.44	7.26
18 BODY LENGTH	201.0	201.0	201.0	201.0	201.0	201.0
19 WING FUEL LIMIT	1.265	1.392	1.108	1.161	1.259	1.247
COST DATA						
20 RDTE - BIL.	2.725	2.687	2.949	2.715	2.714	2.634
21 FLYAWAY - MIL.	62.01	60.88	64.42	61.47	60.75	58.74
22 INVESTMNT - BIL.	29.127	28.591	30.139	28.873	28.528	27.582
23 DOC - ¢/SM	5.38	5.15	5.20	5.33	5.24	5.03
24 IOC - ¢/SM	3.17	3.14	3.17	3.16	3.15	3.12
25 ROI A.T. - %	15.1	17.2	16.00	15.6	16.4	18.8
MISSION PARAMETERS						
26 CRUISE ALT (1)	31000	31000	31000	31000	31000	31000
27 BLOCK FUEL (1)	201552	188899	185761	200468	196472	188712
28 CRUISE ALT (2)	35000	39000	35000	35000	39000	35000
29 BLOCK FUEL (2)	96620	91139	90711	95853	93804	90302
CONSTRAINT OUTPUT						
30 CEILING(1)	14901	14933	15038	14516	15079	15399
31 TAKEOFF DST(1)	9672	9898	9745	9957	9854	9863
32 CLIMB GRAD(1)	0.1143	0.1144	0.1061	0.1170	0.1145	0.1146
33 TAKEOFF DST(2)	10249	10474	10158	10497	10424	10387
34 CLIMB GRAD(2)	0.0419	0.0423	0.0421	0.0442	0.0425	0.0426
35 CTOL LNDG D(1)	5727	5815	5953	5887	5737	5748
36 AP SPEED - KT(1)	130.4	131.9	132.6	130.2	130.6	130.8
37 SEP(1) - FPS	5	8	5	5	5	6

TABLE XX. Continued

AIRCRAFT DEFINITION	7A	7B	7F	7G	7J	7K	7L
1 W/S	129.0	129.0	125.0	129.0	136.0	136.0	136.0
2 T/W	0.265	0.265	0.279	0.265	0.291	0.290	0.289
3 AR	7.78	7.78	7.78	7.78	7.78	7.78	7.78
4 T/C	10.3	10.3	10.3	10.3	10.3	10.3	10.3
5 SWEEP	35.0	35.0	35.0	35.0	35.0	35.0	35.0
6 GROSS WEIGHT	616650	614460	590931	621010	596556	586207	573319
7 FUEL WEIGHT	234294	232771	201408	236797	208431	202012	193681
8 OP. WT. EMPTY	308857	308189	316023	310714	314625	310695	306138
9 ZERO FUEL WT.	382357	381689	389523	384214	388125	384195	379639
10 ENGINE SCALE	1.084	1.08	1.172	1.092	1.234	1.208	1.178
11 THRUST/ENGINE	54471	54277	54957	54856	57866	56667	55230
12 WING AREA	4780	4763	4727	4814	4386	4310	4216
13 WING SPAN	192.8	192.5	191.8	193.5	184.7	183.1	181.1
14 H. TAIL AREA	1780.0	1769.7	1748.1	1800.6	1547.7	1504.5	1451.4
15 V. TAIL AREA	852.7	847.5	886.9	862.9	819.3	792.4	760.4
16 ENG. LENGTH	14.8	14.77	13.00	14.84	13.31	13.18	13.03
17 ENG. DIAMETER	7.52	7.50	8.51	7.54	8.73	8.64	8.53
18 BODY LENGTH	201.0	201.0	201.0	201.0	201.0	201.0	201.0
19 WING FUEL LIMIT	1.266	1.267	1.448	1.399	1.378	1.384	1.395
COST DATA							
20 RDTE - BIL.	2.722	2.717	2.796	2.78	2.835	2.802	2.765
21 FLYAWAY - MIL.	61.94	61.82	67.30	62.47	68.03	67.19	66.27
22 INVESTMNT - BIL.	29.093	29.036	31.838	29.333	32.216	31.815	31.371
23 DOC - ¢/SM	5.35	5.32	4.92	5.40	5.03	4.92	4.77
24 IOC - ¢/SM	3.17	3.16	3.12	3.17	3.13	3.12	3.10
25 ROI A.T. - %	15.3	15.6	17.6	14.8	16.6	17.6	18.9
MISSION PARAMETERS							
26 CRUISE ALT(1)	31000	31000	31000	31000	31000	31000	31000
27 BLOCK FUEL(1)	200745	199407	170915	201913	176422	170869	163734
28 CRUISE ALT(2)	35000	35000	35000	39000	39000	39000	39000
29 BLOCK FUEL(2)	96244	95625	83375	97414	86069	83404	80020
CONSTRAINT OUTPUT							
30 CEILING(1)	14947	15023	16793	14172	16720	16939	17296
31 TAKEOFF DST(1)	9663	9649	9946	9886	9678	9719	9762
32 CLIMB GRAD(1)	0.1143	0.1143	0.1132	0.1146	0.1122	0.1119	0.1119
33 TAKEOFF DST(2)	10235	10213	10497	10512	10282	10305	10414
34 CLIMB GRAD(2)	0.0419	0.0418	0.0432	0.0425	0.0391	0.0391	0.0394
35 CTOL LNDG D(1)	5731	5737	5823	5730	6130	6156	6194
36 AP SPEED - KT(1)	130.5	130.6	131.8	130.5	136.9	137.3	137.9
37 SEP(1) - FPS	5	5	7	5	8	9	10

TABLE XX. Continued

AIRCRAFT DEFINITION	9	10	12	13A	14A	15	16
1 W/S	129.0	129.0	129.0	136.0	136.0	136.0	136.0
2 T/W	0.264	0.264	0.264	0.231	0.222	0.237	0.237
3 AR	7.78	7.78	7.78	12.00	12.00	12.00	12.00
4 T/C	10.30	10.30	10.30	10.00	10.00	10.00	10.00
5 SWEEP	35.00	35.00	35.00	25.00	25.00	25.00	25.00
6 GROSS WEIGHT	564918	591266	579905	601745	545382	513531	463543
7 FUEL WEIGHT	216345	225696	221686	205279	177931	150765	138361
8 OP. WT. EMPTY	275073	292070	284719	322966	293951	289266	251682
9 ZERO FUEL WT.	348573	365570	358219	396466	367451	362766	325182
10 ENGINE SCALE	0.989	1.035	1.016	0.922	0.803	0.865	0.781
11 THRUST/ENGINE	49713	52031	51032	46334	40358	40569	36620
12 WING AREA	4379	4583.	4495.	4425.	4010.	3776.	3408
13 WING SPAN	184.6	188.8	187.0	230.4	219.4	212.9	202.2
14 H. TAIL AREA	1543.6	1662.3	1610.7	1243.5	858.1	780.2	663.8
15 V. TAIL AREA	532.5	790.8	765.4	818.2	663.7	645.6	545.1
16 ENG. LENGTH	14.20	14.50	14.37	13.76	12.93	11.34	10.83
17 ENG. DIAMETER	7.18	7.35	7.28	6.93	6.47	7.31	6.94
18 BODY LENGTH	201.0	201.0	201.0	201.0	201.0	201.0	201.0
19 WING FUEL LIMIT	1.201	1.233	1.219	1.123	1.115	1.200	1.118
COST DATA							
20 RDTE - BIL.	2.753	2.712	2.692	2.837	2.644	2.615	2.642
21 FLYAWAY - MIL.	59.20	61.19	60.59	62.12	57.00	59.38	56.68
22 INVESTMNT - BIL.	27.761	28.717	28.428	29.061	26.643	27.960	26.637
23 DOC - ¢/SM	5.00	5.20	5.12	4.97	4.40	4.00	3.72
24 IOC - ¢/SM	3.12	3.14	3.13	3.14	3.06	3.01	2.97
25 ROI A.T. - %	19.1	16.8	17.6	18.4	24.9	27.4	31.2
MISSION PARAMETERS							
26 CRUISE ALT(1)	31000	31000	31000	31000	35000	35000	35000
27 BLOCK FUEL(1)	185331	193443	190023	174489	150933	126509	116053
28 CRUISE ALT(2)	35000	35000	35000	39000	39000	39000	39000
29 BLOCK FUEL(2)	88181	92420	90648	85828	74722	63554	57928
CONSTRAINT OUTPUT							
30 CEILING(1)	14750	14769	14750	14928	15545	18195	17955
31 TAKEOFF DST(1)	9909	9873	9845	10044	10369	10201	10247
32 CLIMB GRAD(1)	0.1146	0.1145	0.1142	0.1038	0.0996	0.0980	0.0977
33 TAKEOFF DST(2)	10389	10412	10356	10143	10491	10372	10436
34 CLIMB GRAD(2)	0.0427	0.0426	0.0422	0.0411	0.0384	0.0373	0.0370
35 CTOL LNDG D(1)	6714	5720	5717	5845	5915	6094	6068
36 AP SPEED - KT(1)	130.2	130.3	130.2	130.7	131.9	134.6	134.3
37 SEP(1) - FPS	5	5	5	5	6	8	7

ATX-350I, DESIGN RANGE = 4600 NMI, M = 0.80, INTERN. RESRVS MISS

T/C=10.30 AR= 7.78 W/S=129.00 T/W=0.265

Configuration 1

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

BASIC WING--	AREA(SQ FT)	SPAN(FT)	TAPER RATIO	C/4 SWEEP	L.E. SWEEP	MAC(FT)		
	4790.3	193.05	0.246	35.000	37.883	27.84		
WING PANELS--	AREA(SQ FT	EXP. AREA	AVG T/C	L.E. SWEEP	SFLE(SQ FT)	REF L(FT)		
	1138.2	103.9	11.12	37.879	0.0	49.36		
	2316.5	2316.5	10.61	37.879	0.0	39.03		
	422.1	422.1	9.29	37.879	0.0	25.74		
	1458.1	1458.1	9.03	37.879	0.0	18.95		
	156.1	156.1	9.03	37.879	0.0	10.96		
TOTAL WING--	AREA(SQ FT)	EFF AR	AVG T/C	CR(FT)	CT(FT)	MAC(FT)	L(FT)	E SWP
	5491.0	6.79	9.99	57.28	9.81	34.82	84.90	22.988
FUSELAGE--	LENGTH(FT)	S WET(SQ FT)	BWH(FT)	EQUIV D(FT)	SPI(SQ FT)			
	201.00	10804.1	19.32	19.58	301.21			
	BW(FT)	BH(FT)	SBW(SQ FT)					
	19.58	19.58	10538.00					
HORZ. TAIL 1--	SHT1(SQ FT)	SHX1(SQ FT)	REF L1(FT)	L HT1(FT)	HT1 VOL COEF			
	1786.16	1400.05	20.91	71.24	0.9540			
HORZ. TAIL 2--	SHT2(SQ FT)	SHX2(SQ FT)	REF L2(FT)	L HT2(FT)	HT2 VOL COEF			
	0.0	0.0	0.0	201.00	0.0			
VERT. TAIL 1--	SVT1(SQ FT)	SVX1(SQ FT)	REF L1(FT)	L VT1(FT)	VT1 VOL COEF			
	855.71	563.16	22.00	73.75	0.0682			
VERT. TAIL 2--	SVT2(SQ FT)	SVX2(SQ FT)	REF L2(FT)	L VT2(FT)	VT2 VOL COEF			
	0.0	0.0	0.0	201.00	0.0			
PROPULSION--	ENG L(FT)	ENG D(FT)	POD L(FT)	POD D(FT)	POD S WET	NO. PODS	INLET L(FT)	
	14.81	7.53	14.93	9.96	839.29	2.	27.43	
FUEL TANKS--	WING(CU FT)	BOX(CU FT)	FUS(CU FT)					
	4756.36	1189.99	999999.00					
WETTED VOLUMES--	BODY	WING	TAILS	PODS	PYLONS	PONTOONS	TOTAL	
	50706.31	9161.36	3208.69	1969.28	165.00	0.0	65210.64	

ATX-350I, DESIGN RANGE = 4600 NMI, M = 0.80, INTERN. RESRVS MISS

T/C=10.30 AR= 7.78 W/S=129.00 T/W=0.265

Configuration 1

WEIGHT STATEMENT

	WEIGHT(POUNDS)	WEIGHT FRACTION	(PERCENT)
GROSS WEIGHT	(617950.)		
FUEL AVAILABLE	235197.	FUEL	38.06
EXTERNAL	0.		
INTERNAL	235197.		
ZERO FUEL WEIGHT	382753.		
PAYLOAD	73500.	PAYLOAD	11.89
PASSENGERS	57750.		
BAGGAGE	15750.		
CARGO	0.		
STORES	0.		
OPERATIONAL EMPTY WEIGHT	309253.		
OPERATIONAL ITEMS	10396.	OPERATIONAL ITEMS	3.25
STANDARD ITEMS	9672.		
EMPTY WEIGHT	289185.		
STRUCTURE	186041.	STRUCTURE	30.11
WING	64899.		
ROTOR	0.		
TAIL	12887.		
BODY	68152.		
ALIGHTING GEAR	25759.		
ENGINE SECTION AND NACELLE	14344.		
PROPULSION	36106.	PROPULSION	5.84
CRUISE ENGINES	28499.		
LIFT ENGINES	0.		
THRUST REVERSER	5060.		
EXHAUST SYSTEM	0.		
ENGINE CONTROL	234.		
STARTING SYSTEM	467.		
PROPELLERS	0.		
LUBRICATING SYSTEM	0.		
FUEL SYSTEM	1845.		
DRIVE SYSTEM (POWER TRANS)	0.		
SYSTEMS	67038.		
FLIGHT CONTROLS	8044.		
AUXILIARY POWER PLANT	1202.		
INSTRUMENTS	1035.		
HYDRAULIC AND PNEUMATIC	2821.		
ELECTRICAL	5671.		
AVIONICS	3075.	SYSTEMS	10.85
ARMAMENT	0.		
FURNISHINGS AND EQUIPMENT	38504.		
AIR CONDITIONING	6302.		
ANTI-ICING	363.		
PHOTOGRAPHIC	0.		
LOAD AND HANDLING	0.		
		TOTAL	(100.)

Configuration 1

WEIGHTS MATRIX

ELEMENT/ / MATERIAL	AL	TIT.	STEEL	COMP.	OTHER	TOTAL
WING	58409.	1298.	4543.	0.	649.	64899.
ROTOR	0.	0.	0.	0.	0.	0.
TAIL	11598.	258.	902.	0.	129.	12887.
BODY	61337.	2726.	682.	1363.	2045.	68152.
L. G.	5667.	258.	17001.	0.	2834.	25759.
ENG SECT	0.	0.	0.	0.	0.	0.
NACELLE	3776.	4855.	2158.	0.	0.	10790.
AIR INDUCT	3198.	355.	0.	0.	0.	3554.
TOTALS	143986.	9750.	25286.	1363.	5656.	186041.

EXCESS FUEL CAPACITY - BODY	50159536.
EXCESS FUEL CAPACITY - WING	2802.
EXCESS BODY LENGTH - FT	0.0
AIRFRAME WEIGHT (A.M.P.R.) - LB	246253.
GUST LOAD FACTOR	0.0

ALTERNATE MISSION NO. 1 SUMMARY

Configuration 1

ATX-350I, AVRG STAGE L = 2500 NMI, M = 0.80, 60 % LF 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 CL	AVG L/D RATIO	AVG SFC (FF/T)
TAKEOFF POWER 1	0.	0.0	475169.	0.	0.	0.	0.	0.0	0.0	0.	428601.	0.	0.0	0.0	0.934
POWER 2	0.	0.0	475169.	1012.	1012.	0.	0.	1.0	1.0	0.	428501.	0.	0.0	0.0	0.383
CLIMB	0.	0.378	474157.	2462.	3474.	14.	14.	3.2	4.2	0.	428201.	0.	0.464	18.23	0.544
ACCEL	10000.	0.456	471695.	355.	3828.	3.	17.	0.5	4.6	0.	428201.	0.	0.386	17.65	0.574
CLIMB	10000.	0.547	471341.	7690.	11518.	104.	120.	14.3	18.9	0.	428201.	0.	0.341	16.43	0.637
CRUISE	35000.	0.800	463650.	0.	11518.	0.	120.	0.0	18.9	0.	-428101.	0.	0.433	16.84	0.648
ACCEL	35000.	0.800	463650.	0.	11518.	0.	120.	0.0	18.9	0.	428201.	0.	0.433	16.84	0.648
ACCEL	35000.	0.800	463650.	0.	11518.	0.	120.	0.0	18.9	0.	428201.	0.	0.433	16.84	0.648
CRUISE	35000.	0.800	463650.	8469.	19988.	220.	341.	28.7	47.6	0.	-428101.	0.	0.429	16.80	0.648
CLIMB	35000.	0.800	455181.	2576.	22564.	57.	398.	7.4	55.1	0.	428201.	0.	0.476	16.87	0.648
CRUISE	39000.	0.800	452605.	66876.	89439.	1902.	2300.	248.7	303.8	0.	-428101.	0.	0.473	16.78	0.647
CLIMB	39000.	0.800	385730.	0.	89439.	0.	2300.	0.0	303.8	0.	428201.	0.	0.0	0.0	0.0
CRUISE	39000.	0.800	385730.	0.	89439.	0.	2300.	0.0	303.8	0.	-428101.	0.	0.436	16.64	0.650
DESCENT	39000.	0.800	385730.	1903.	91342.	113.	2413.	15.7	319.4	0.	428301.	0.	0.313	15.38	-0.309
DECEL	10000.	0.547	383826.	72.	91415.	4.	2418.	0.8	320.2	0.	428301.	0.	0.318	16.38	-6.998
DESCENT	10000.	0.456	383754.	706.	92121.	28.	2446.	6.2	326.4	0.	428301.	0.	0.378	17.48	-2.632
CRUISE	39000.	0.800	383048.	1774.	93895.	54.	2500.	7.1	333.5	0.	-428101.	0.	0.432	16.61	0.650
LOITER	1500.	0.330	381273.	716.	94611.	0.	2500.	3.0	336.5	0.	-80101.	0.	0.521	18.05	0.679
CRUISE	1500.	0.378	380557.	518.	95129.	0.	2500.	2.0	338.5	0.	-80101.	0.	0.396	17.69	0.723
RESET	0.	0.0	380039.	0.	95129.	-2500.	0.	0.0	338.5	0.	0.	0.	0.0	0.0	0.0
CRUISE	39000.	0.800	380039.	8340.	103469.	0.	0.	33.9	372.4	0.	-428101.	0.	0.425	16.55	0.651
TAKEOFF POWER 1	0.	0.0	371699.	0.	103469.	0.	0.	0.0	372.4	0.	428601.	0.	0.0	0.0	0.934
POWER 2	0.	0.0	371699.	1012.	104481.	0.	0.	1.0	373.4	0.	428501.	0.	0.0	0.0	0.383
CLIMB	0.	0.378	370687.	1790.	106271.	10.	10.	2.3	375.7	0.	428201.	0.	0.360	17.19	0.544
ACCEL	10000.	0.456	368897.	258.	106529.	2.	12.	0.4	376.0	0.	428201.	0.	0.302	16.00	0.574

Configuration 1

CLIMB	10000.	0.547	368639.	3902.	110431.	46.	58.	6.7	382.7	0.	428201.	0.	0.258	14.63	0.626
CRUISE	30000.	0.715	364737.	1451.	111881.	42.	100.	6.0	388.7	0.	-428101.	0.	0.337	16.46	0.654
DESCENT	30000.	0.750	363287.	451.	112333.	49.	149.	7.4	396.0	0.	428301.	0.	0.253	14.53	-1.242
DECEL	10000.	0.547	362835.	70.	112403.	4.	153.	0.8	396.8	0.	428301.	0.	0.300	15.94	-7.021
DESCENT	10000.	0.456	362765.	694.	113097.	27.	181.	6.1	402.9	0.	428301.	0.	0.358	17.15	-2.616
CRUISE	30000.	0.710	362071.	647.	113744.	19.	200.	2.7	405.6	0.	-428101.	0.	0.340	16.53	0.653
CRUISE	1500.	0.378	361424.	8072.	121816.	0.	200.	32.0	437.6	0.	-80101.	0.	0.372	17.36	0.735

COST SUMMARY

Configuration 1

RDT AND E

	TOTAL *
DEVELOPMENT - NONRECURRING	
ENGINEERING	1066.15
TOOLING	564.22
TEST ARTICLES	82.43
DATA	0.0
SYSTEMS ENG/MNGMT	0.0
CRUISE ENGINE	0.0
LIFT ENGINE	0.0
FAN	0.0
AVIONICS	0.0
OTHER SYSTEMS	0.0
FACILITIES	0.0
TOTAL AIR VEHICLE	1712.80
INTEGR LOGISTICS SUPPORT	
PLANNING	12.55
TRAINING	4.27
HANDBOOKS	34.26
SSE	8.92
TOTAL ILS	59.99
TOTAL DVLPMNT-NONREC	1772.79
DEVELOPMENT - RECUR(PROTOTYPES)	
AIR VEHICLE	935.32
SPARES	17.13
TOTAL DVLPMNT-RECUR	952.45
GOVMNT DVLPMNT COST	0.0
TOTAL DVLPMNT COST	2725.24

PRODUCTION

	MATERIAL	LABOR	TOTAL PER PROD A/C**
STRUCTURE	5620.10	12793.38	18413.47
WING	2136.76	3480.71	5617.47
ROTOR	0.0	0.0	0.0
TAIL	318.22	954.83	1273.05
BODY	1262.18	5970.17	7232.35
ALIGHTING GEAR	1033.63	32.75	1066.38
ENG SECT + NACELLE	869.31	2354.92	3224.23
ENG SECTION	0.0	0.0	0.0
NACELLE	843.72	2190.44	3034.16
AIR INDUCTION	25.60	164.48	190.08
PROPULSION	193.74	158.23	351.97
ENGINE INSTALL	0.0	39.63	39.63
THRUST REVERSER	0.0	7.04	7.04
EXHAUST SYSTEM	0.0	0.0	0.0
ENGINE CONTROLS	6.26	6.88	13.15
STARTING SYSTEM	71.65	9.38	81.03
PROPELLER INSTALL	0.0	0.0	0.0
LUBRICATING SYSTEM	0.0	0.0	0.0
FUEL SYSTEM	115.82	95.31	211.13
DRIVE SYS(PWR TRN)	0.0	0.0	0.0
SYSTEMS	4502.39	7629.69	12132.08
FLIGHT CONTROLS	1343.87	562.46	1906.33
AUX POWER PLANT	206.53	26.26	232.80
INSTRUMENTS	131.01	77.52	208.53
HYDRAULIC + PNEUM	214.79	405.14	619.93
ELECTRICAL	585.48	1192.87	1778.35
AVIONIC INSTALL	63.28	516.75	580.02
ARMAMENT	0.0	0.0	0.0
FURN AND EQUIP	1426.21	4352.02	5778.22
AIR CONDITIONING	500.80	468.22	969.01
ANTI-ICING	30.43	28.45	58.88
PHOTOGRAPHIC	0.0	0.0	0.0
LOAD AND HANDLING	0.0	0.0	0.0
SYSTEMS INTEGR	952.12	775.49	1727.61
TOTAL COST	11268.36	21356.77	32625.12
TOTAL HRS **		637.75	637.75
ENG CHANGE ORDERS			1062.04
SUSTAINING ENG COST			1574.22
PROD TOOLING COST			2350.99
QUALITY ASSURANCE			2865.05
MISCELLANEOUS ***			994.29
TOTAL AIRFRAME COST			41471.66
ENGINE COST			12048.11
AVIONICS COST			866.31
TOTAL MANUFACTURING COST			54386.08
WARRANTY			158.85
TOTAL PRODUCTION COST			54544.93

PROCUREMENT

	PER PROD A/C**
TOTAL PRODUCTION	54544.93
INTEGR LOGISTICS SUPPORT	
PLANNING	32.96
TRAINING	11.21
TRAINERS	220.56
HANDBOOKS	42.02
FACILITIES	0.0
SSE - CFE	0.0
SSE - GFE	2563.61
TOTAL ILS	2870.36
INITIAL SPARES COST	7938.34
PRODUCTION DEVELOPMENT	
ENGINEERING	315.44
TOOLING	334.85
ENGINES	0.0
TOTAL PROD DEV	650.29
TOTAL PROCUREMENT	66003.88

* - MILLIONS OF DOLLARS

** -1000 OF DOLLARS OR HOURS PER PROD A/C

*** - INCLUDES PROD DATA, SYSTEMS ENGR AND OTHER SYSTEMS

OPERATIONAL COSTS

DIRECT OPERATIONAL COST (DOC)

	C/SM***	PERCENT
FLIGHT CREW	0.44763	8.32639
FUEL AND OIL	3.53285	65.71509
INSURANCE	0.03068	0.57072
DEPRECIATION	0.64893	12.07092
MAINTENANCE	0.71592	13.31687
TOTAL DOC	5.37601	100.000

INDIRECT OPERATIONAL COST (IOC)

	C/SM***	PERCENT
SYSTEM	0.0	0.0
LOCAL	0.60877	19.21951
AIRCRAFT CONTROL	0.01317	0.41573
CABIN ATTENDANT	0.44053	13.90802
FOOD AND BEVERAGE	0.16701	5.27264
PASSENGER HANDLING	0.63674	20.10258
CARGO HANDLING	0.17677	5.58078
OTHER PASSENGER EXPENSE	0.83200	26.26717
OTHER CARGO EXPENSE	0.00860	0.27139
GENERAL + ADMINISTRATION	0.28388	8.96232
TOTAL IOC	3.16745	100.000

MISC. DATA

FLIGHT DISTANCE (N. MI.)	2500.00
BLOCK FUEL (LBS)	96620.38
BLOCK TIME (HRS)	5.98
FLIGHT TIME (HRS)	5.64
AVG STAGE LENGTH (N. MI.)	2500.00
AVG CARGO PER FLIGHT	13695.72
UTILIZATION (HRS PER YR)	4140.35
FLIGHTS PER A/C PER YEAR	692.92
FARE ($)	374.96
FUEL COST ($/LB)	0.31600

*** - CENTS PER SEAT N. MILE

- -

RATE OF RETURN ON INVESTMENT

YEAR	AVG NO AIRCRAFT DURING YEAR	AIRCRAFT ADDED DURING YEAR	AVERAGE INVESTMENT DURING YEAR	CUMULATIVE DEPRECIATION	AVERAGE BOOK VALUE OF FLEET	REVENUE	INTEREST EXPENSE	OPERATING EXPENSE	CASH FLOW	ROI
			$M	$M	$M	$M	$M	$M	$M	PERCENT
1	5.0	8.0	364.08	20.48	343.60	304.98	43.69	259.00	-141.48	13.05
2	13.0	8.0	946.62	73.73	872.89	792.94	106.60	673.39	-149.99	12.95
3	20.4	7.0	1483.65	157.18	1326.46	1242.79	157.07	1055.41	-137.31	12.98
4	23.0	0.0	1674.79	251.39	1423.40	1402.90	159.91	1191.38	-13.97	13.05
5	23.0	0.0	1674.79	345.60	1329.19	1402.90	139.81	1191.38	-3.92	13.22
6	23.0	0.0	1674.79	439.80	1234.99	1402.90	119.71	1191.38	6.13	13.41
7	23.0	0.0	1674.79	534.01	1140.78	1402.90	99.61	1191.38	16.18	13.64
8	23.0	0.0	1674.79	628.22	1046.57	1402.90	79.52	1191.38	26.23	13.90
9	23.0	0.0	1674.79	722.42	952.37	1402.90	59.42	1191.38	36.28	14.22
10	23.0	0.0	1674.79	816.63	858.16	1402.90	39.32	1191.38	46.32	14.62
11	23.0	0.0	1674.79	910.84	763.95	1402.90	19.22	1191.38	102.98	15.10
12	23.0	0.0	1674.79	1005.04	669.75	1402.90	6.12	1191.38	156.13	16.25
13	23.0	0.0	1674.79	1099.25	575.54	1402.90	-0.00	1191.38	199.97	18.38
14	23.0	0.0	1674.79	1193.46	481.33	1402.90	-0.00	1191.38	199.97	21.97
15	23.0	0.0	1674.79	1287.66	387.13	1402.90	-0.00	1191.38	199.97	27.32
16	23.0	0.0	1674.79	1381.87	292.92	1402.90	-0.00	1191.38	199.97	36.11

AVG ROI OVER THE 16 YEAR PERIOD = 15.08 PERCENT

ATX-350I, DESIGN RANGE = 4600 NMI, M = 0.80, INTERN. RESRVS MISS

T/C=10.30 AR= 7.78 W/S=130.00 T/W=0.265

Configuration 2A

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

BASIC WING--	AREA(SQ FT)	SPAN(FT)	TAPER RATIO	C/4 SWEEP	L.E. SWEEP	MAC(FT)		
	4600.1	189.18	0.246	35.000	37.883	27.29		
WING PANELS--	AREA(SQ FT)	EXP. AREA	AVG T/C	L.E. SWEEP	SFLE(SQ FT)	REF L(FT)		
	1093.0	80.9	12.57	37.879	0.0	48.30		
	2224.5	2224.5	11.64	37.879	0.0	38.25		
	405.3	405.3	9.99	37.879	0.0	25.23		
	1400.2	1400.2	9.86	37.879	0.0	18.57		
	149.9	149.9	9.46	37.879	0.0	10.74		
TOTAL WING--	AREA(SQ FT)	EFF AR	AVG T/C	CR(FT)	CT(FT)	MAC(FT)	L(FT)	E SWP
	5272.9	6.79	11.24	56.13	9.61	34.12	83.19	22.988
FUSELAGE--	LENGTH(FT)	S WET(SQ FT)	BWW(FT)	EQUIV D(FT)	SPI(SQ FT)			
	201.00	10767.3	19.32	19.58	301.21			
	BW(FT)	BH(FT)	SBW(SQ FT)					
	19.58	19.58	10538.00					
HORZ. TAIL 1--	SHT1(SQ FT)	SHX1(SQ FT)	REF L1(FT)	L HT1(FT)	HT1 VOL COEF			
	1672.06	1299.16	20.17	71.62	0.9540			
HORZ. TAIL 2--	SHT2(SQ FT)	SHX2(SQ FT)	REF L2(FT)	L HT2(FT)	HT2 VOL COEF			
	0.0	0.0	0.0	201.00	0.0			
VERT. TAIL 1--	SVT1(SQ FT)	SVX1(SQ FT)	REF L1(FT)	L VT1(FT)	VT1 VOL COEF			
	799.04	517.26	21.13	74.32	0.0682			
VERT. TAIL 2--	SVT2(SQ FT)	SVX2(SQ FT)	REF L2(FT)	L VT2(FT)	VT2 VOL COEF			
	0.0	0.0	0.0	201.00	0.0			
PROPULSION--	ENG L(FT)	ENG D(FT)	POD L(FT)	POD D(FT)	POD S WET	NO. PODS	INLET L(FT)	
	14.59	7.40	14.71	9.80	813.54	2.	26.96	
FUEL TANKS--	WING(CU FT)	BOX(CU FT)	FUS(CU FT)					
	4876.76	1298.24	999999.00					
WETTED VOLUMES--	BODY	WING	TAILS	PODS	PYLONS	PONTOONS	TOTAL	
	50608.75	9378.85	2857.99	1877.81	157.59	0.0	64880.98	

ATX-350I, DESIGN RANGE = 4600 NMI, M = 0.80, INTERN. RESRVS MISS

T/C=10.30 AR= 7.78 W/S=130.00 T/W=0.265

Configuration 2A

W E I G H T   S T A T E M E N T

	WEIGHT(POUNDS)	WEIGHT FRACTION	(PERCENT)
GROSS WEIGHT	(598008.)		
FUEL AVAILABLE	221942.	FUEL	37.11
EXTERNAL	0.		
INTERNAL	221939.		
ZERO FUEL WEIGHT	376066.		
PAYLOAD	73500.	PAYLOAD	12.29
PASSENGERS	57750.		
BAGGAGE	15750.		
CARGO	0.		
STORES	0.		
OPERATIONAL EMPTY WEIGHT	302566.		
OPERATIONAL ITEMS	10387.	OPERATIONAL ITEMS	3.35
STANDARD ITEMS	9656.		
EMPTY WEIGHT	282523.		
STRUCTURE	181015.	STRUCTURE	30.27
WING	62379.		
ROTOR	0.		
TAIL	12057.		
BODY	67818.		
ALIGHTING GEAR	24928.		
ENGINE SECTION AND NACELLE	13833.		
PROPULSION	34914.	PROPULSION	5.84
CRUISE ENGINES	27489.		
LIFT ENGINES	0.		
THRUST REVERSER	4949.		
EXHAUST SYSTEM	0.		
ENGINE CONTROL	227.		
STARTING SYSTEM	451.		
PROPELLERS	0.		
LUBRICATING SYSTEM	0.		
FUEL SYSTEM	1798.		
DRIVE SYSTEM (POWER TRANS)	0.		
SYSTEMS	66594.		
FLIGHT CONTROLS	7715.		
AUXILIARY POWER PLANT	1202.		
INSTRUMENTS	1029.		
HYDRAULIC AND PNEUMATIC	2739.		
ELECTRICAL	5649.	SYSTEMS	11.14
AVIONICS	3075.		
ARMAMENT	0.		
FURNISHINGS AND EQUIPMENT	38504.		
AIR CONDITIONING	6302.		
ANTI-ICING	377.		
PHOTOGRAPHIC	0.		
LOAD AND HANDLING	0.	TOTAL	100.)

Configuration 2A

WEIGHTS MATRIX

ELEMENT/ / MATERIAL	AL	TIT.	STEEL	COMP.	OTHER	TOTAL
WING	56141.	1248.	4367.	0.	624.	62379.
ROTOR	0.	0.	0.	0.	0.	0.
TAIL	10851.	241.	844.	0.	121.	12057.
BODY	61036.	2713.	678.	1356.	2035.	67818.
L. G.	5484.	249.	16452.	0.	2742.	24928.
ENG SECT	0.	0.	0.	0.	0.	0.
NACELLE	3643.	4683.	2081.	0.	0.	10407.
AIR INDUCT	3083.	343.	0.	0.	0.	3426.
TOTALS	140238.	9477.	24423.	1356.	5521.	181015.

EXCESS FUEL CAPACITY - BODY	50164960.
EXCESS FUEL CAPACITY - WING	22109.
EXCESS BODY LENGTH - FT	0.0
AIRFRAME WEIGHT (A.M.P.R.) - LB	240899.
GUST LOAD FACTOR	0.0

A L T E R N A T E   M I S S I O N   N O. 1   S U M M A R Y

Configuration 2A

ATX-350I, AVRG STAGE L = 2500 NMI, M = 0.80, 60 % LF   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 CL	AVG L/D RATIO	AVG SFC (FF/T)
TAKEOFF POWER 1	0.	0.0	462759.	0.	0.	0.	0.	0.0	0.0	0.	428601.	0.	0.0	0.0	0.935
POWER 2	0.	0.0	462759.	980.	980.	0.	0.	1.0	1.0	0.	428501.	0.	0.0	0.0	0.384
CLIMB	0.	0.378	461778.	2424.	3404.	14.	14.	3.2	4.2	0.	428201.	0.	0.470	17.95	0.545
ACCEL	10000.	0.456	459355.	353.	3757.	3.	17.	0.5	4.7	0.	428201.	0.	0.392	17.11	0.574
CLIMB	10000.	0.547	459002.	10322.	14079.	161.	178.	22.0	26.7	0.	428201.	0.	0.386	16.23	0.641
CRUISE	39000.	0.800	448679.	0.	14079.	0.	178.	0.0	26.7	0.	-428101.	0.	0.528	17.82	0.646
ACCEL	39000.	0.800	448679.	0.	14079.	0.	178.	0.0	26.7	0.	428201.	0.	0.528	17.82	0.651
ACCEL	39000.	0.800	448679.	0.	14079.	0.	178.	0.0	26.7	0.	428201.	0.	0.528	17.82	0.651
CRUISE	39000.	0.800	448679.	70072.	84151.	2122.	2300.	277.4	304.1	0.	-428101.	0.	0.486	17.68	0.649
CLIMB	39000.	0.800	378607.	0.	84151.	0.	2300.	0.0	304.1	0.	428201.	0.	0.0	0.0	0.0
CRUISE	39000.	0.800	378607.	1.	84152.	0.	2300.	0.0	304.1	0.	-428101.	0.	0.445	17.38	0.652
CLIMB	39000.	0.800	378607.	0.	84152.	0.	2300.	0.0	304.1	0.	428201.	0.	0.0	0.0	0.0
CRUISE	39000.	0.800	378607.	0.	84152.	0.	2300.	0.0	304.1	0.	-428101.	0.	0.445	17.38	0.652
DESCENT	39000.	0.800	378607.	1967.	86119.	116.	2416.	15.9	320.0	0.	428301.	0.	0.321	15.19	-0.215
DECEL	10000.	0.547	376639.	68.	86187.	4.	2420.	0.8	320.7	0.	428301.	0.	0.325	15.76	-7.031
DESCENT	10000.	0.456	376572.	663.	86849.	27.	2447.	6.0	326.7	0.	428301.	0.	0.387	16.96	-2.654
CRUISE	39000.	0.800	375909.	1638.	88488.	53.	2500.	7.0	333.7	0.	-428101.	0.	0.441	17.33	0.653
LOITER	1500.	0.300	374271.	691.	89178.	0.	2500.	3.0	336.7	0.	-80101.	0.	0.644	17.21	0.636
CRUISE	1500.	0.378	373580.	516.	89695.	0.	2500.	2.0	338.7	0.	-80101.	0.	0.405	17.15	0.712
RESET	0.	0.0	373063.	0.	89695.	-2500.	0.	0.0	338.7	0.	0.	0.	0.0	0.0	0.0
CRUISE	39000.	0.800	373063.	7893.	97588.	0.	0.	33.9	372.5	0.	-428101.	0.	0.434	17.24	0.653
TAKEOFF POWER 1	0.	0.0	365170.	0.	97588.	0.	0.	0.0	372.5	0.	428601.	0.	0.0	0.0	0.935
POWER 2	0.	0.0	365170.	980.	98568.	0.	0.	1.0	373.5	0.	428501.	0.	0.0	0.0	0.384
CLIMB	0.	0.378	364190.	1788.	100356.	11.	11.	2.4	375.9	0.	428201.	0.	0.369	16.69	0.545
ACCEL	10000.	0.456	362402.	261.	100617.	2.	12.	0.4	376.3	0.	428201.	0.	0.309	15.34	0.574

Configuration 2A

CLIMB	10000.	0.547	362141.	4310.	104927.	52.	65.	7.6	383.9	0.	428201.	0.	0.263	13.25	0.628
CRUISE	30000.	0.680	357831.	1192.	106118.	35.	100.	5.2	389.1	0.	-428101.	0.	0.381	16.70	0.640
DESCENT	30000.	0.750	356640.	406.	106524.	46.	145.	6.8	395.9	0.	428301.	0.	0.259	13.38	-1.251
DECEL	10000.	0.547	356233.	66.	106590.	4.	149.	0.7	396.6	0.	428301.	0.	0.307	15.29	-7.061
DESCENT	10000.	0.456	356168.	651.	107240.	27.	176.	5.9	402.5	0.	428301.	0.	0.366	16.63	-2.639
CRUISE	30000.	0.680	355517.	815.	108055.	24.	200.	3.6	406.1	0.	-428101.	0.	0.379	16.66	0.641
CRUISE	1500.	0.378	354702.	8035.	116090.	0.	200.	32.0	438.1	0.	-80101.	0.	0.380	16.84	0.724

COST SUMMARY

Configuration 2A

RDT AND E

	TOTAL *
DEVELOPMENT - NONRECURRING	
ENGINEERING	1055.16
TOOLING	554.82
TEST ARTICLES	81.14
DATA	0.0
SYSTEMS ENG/MNGMT	0.0
CRUISE ENGINE	0.0
LIFT ENGINE	0.0
FAN	0.0
AVIONICS	0.0
OTHER SYSTEMS	0.0
FACILITIES	0.0
TOTAL AIR VEHICLE	1691.12
INTEGR LOGISTICS SUPPORT	
PLANNING	12.30
TRAINING	4.18
HANDBOOKS	33.11
SSE	8.74
TOTAL ILS	58.33
TOTAL DVLPMNT-NONREC	1749.45
DEVELOPMENT - RECUR(PROTOTYPES)	
AIR VEHICLE	920.98
SPARES	16.68
TOTAL DVLPMNT-RECUR	937.66
GOVMNT DVLPMNT COST	0.0
TOTAL DVLPMNT COST	2687.11

PRODUCTION

	MATERIAL	LABOR	TOTAL PER PROD A/C**
STRUCTURE	5448.12	12522.48	17970.59
WING	2054.49	3356.19	5410.68
ROTOR	0.0	0.0	0.0
TAIL	297.83	896.19	1194.02
BODY	1256.41	5959.74	7216.16
ALIGHTING GEAR	1000.62	31.79	1032.41
ENG SECT + NACELLE	838.77	2278.57	3117.34
ENG SECTION	0.0	0.0	0.0
NACELLE	814.09	2119.52	2933.61
AIR INDUCTION	24.68	159.05	183.73
PROPULSION	188.12	154.19	342.30
ENGINE INSTALL	0.0	38.34	38.34
THRUST REVERSER	0.0	6.90	6.90
EXHAUST SYSTEM	0.0	0.0	0.0
ENGINE CONTROLS	6.06	6.68	12.75
STARTING SYSTEM	69.14	9.07	78.21
PROPELLER INSTALL	0.0	0.0	0.0
LUBRICATING SYSTEM	0.0	0.0	0.0
FUEL SYSTEM	112.92	93.18	206.10
DRIVE SYS(PWR TRN)	0.0	0.0	0.0
SYSTEMS	4439.28	7613.70	12052.98
FLIGHT CONTROLS	1289.32	541.16	1830.48
AUX POWER PLANT	206.60	26.35	232.95
INSTRUMENTS	130.29	77.32	207.61
HYDRAULIC + PNEUM	208.61	394.62	603.23
ELECTRICAL	583.50	1192.20	1775.70
AVIONIC INSTALL	63.30	518.39	581.68
ARMAMENT	0.0	0.0	0.0
FURN AND EQUIP	1426.69	4365.84	5792.53
AIR CONDITIONING	500.97	469.70	970.67
ANTI-ICING	29.99	28.12	58.12
PHOTOGRAPHIC	0.0	0.0	0.0
LOAD AND HANDLING	0.0	0.0	0.0
SYSTEMS INTEGR	930.51	760.03	1690.54
TOTAL COST	11006.02	21050.38	32056.40
TOTAL HRS **		628.60	628.60
ENG CHANGE ORDERS			1043.79
SUSTAINING ENG COST			1563.24
PROD TOOLING COST			2317.26
QUALITY ASSURANCE			2823.94
MISCELLANEOUS ***			980.02
TOTAL AIRFRAME COST			40784.62
ENGINE COST			11717.20
AVIONICS COST			866.31
TOTAL MANUFACTURING COST			53368.13
WARRANTY			156.24
TOTAL PRODUCTION COST			53524.37

PROCUREMENT

	PER PROD A/C**
TOTAL PRODUCTION	53524.37
INTEGR LOGISTICS SUPPORT	
PLANNING	32.45
TRAINING	11.03
TRAINERS	220.56
HANDBOOKS	41.19
FACILITIES	0.0
SSE - CFE	0.0
SSE - GFE	2515.64
TOTAL ILS	2820.87
INITIAL SPARES COST	7773.41
PRODUCTION DEVELOPMENT	
ENGINEERING	310.52
TOOLING	330.05
ENGINES	0.0
TOTAL PROD DEV	640.57
TOTAL PROCUREMENT	64759.20

* - MILLIONS OF DOLLARS

** -1000 OF DOLLARS OR HOURS PER PROD A/C

*** - INCLUDES PROD DATA, SYSTEMS ENGR AND OTHER SYSTEMS

Configuration 2A

OPERATIONAL COSTS

DIRECT OPERATIONAL COST (DOC)

	C/SM***	PERCENT
FLIGHT CREW	0.44780	8.69754
FUEL AND OIL	3.33248	64.72623
INSURANCE	0.03013	0.58529
DEPRECIATION	0.63716	12.37546
MAINTENANCE	0.70100	13.61550
TOTAL DOC	5.14857	100.000

INDIRECT OPERATIONAL COST (IOC)

	C/SM***	PERCENT
SYSTEM	0.0	0.0
LOCAL	0.58912	18.76622
AIRCRAFT CONTROL	0.01317	0.41946
CABIN ATTENDANT	0.44070	14.03825
FOOD AND BEVERAGE	0.16707	5.32201
PASSENGER HANDLING	0.63674	20.28304
CARGO HANDLING	0.17677	5.63088
OTHER PASSENGER EXPENSE	0.83200	26.50294
OTHER CARGO EXPENSE	0.00860	0.27383
GENERAL + ADMINISTRATION	0.27511	8.76345
TOTAL IOC	3.13927	100.000

MISC. DATA

FLIGHT DISTANCE (N. MI.)	2500.00
BLOCK FUEL (LBS)	91139.38
BLOCK TIME (HRS)	5.98
FLIGHT TIME (HRS)	5.64
AVG STAGE LENGTH (N. MI.)	2500.00
AVG CARGO PER FLIGHT	13695.72
UTILIZATION (HRS PER YR)	4140.65
FLIGHTS PER A/C PER YEAR	692.70
FARE ($)	374.96
FUEL COST ($/LB)	0.31600

*** - CENTS PER SEAT N. MILE

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RATE OF RETURN ON INVESTMENT

YEAR	AVG NO AIRCRAFT DURING YEAR	AIRCRAFT ADDED DURING YEAR	AVERAGE INVESTMENT DURING YEAR	CUMULATIVE DEPRECIATION	AVERAGE BOOK VALUE OF FLEET	REVENUE	INTEREST EXPENSE	OPERATING EXPENSE	CASH FLOW	ROI
			$M	$M	$M	$M	$M	$M	$M	PERCENT
1	5.0	8.0	357.38	20.10	337.28	304.88	42.89	251.17	-134.59	14.32
2	13.0	8.0	929.20	72.37	856.83	792.70	104.64	653.04	-136.08	14.26
3	20.4	7.0	1456.34	154.29	1302.05	1242.40	154.18	1023.51	-117.31	14.33
4	23.0	0.0	1643.97	246.76	1397.21	1402.47	156.96	1155.37	6.02	14.46
5	23.0	0.0	1643.97	339.24	1304.73	1402.47	137.24	1155.37	15.88	14.73
6	23.0	0.0	1643.97	431.71	1212.26	1402.47	117.51	1155.37	25.75	15.04
7	23.0	0.0	1643.97	524.18	1119.79	1402.47	97.78	1155.37	35.61	15.40
8	23.0	0.0	1643.97	616.65	1027.32	1402.47	78.05	1155.37	45.48	15.82
9	23.0	0.0	1643.97	709.13	934.84	1402.47	58.33	1155.37	55.34	16.34
10	23.0	0.0	1643.97	801.60	842.37	1402.47	38.60	1155.37	65.20	16.96
11	23.0	0.0	1643.97	894.07	749.90	1402.47	18.87	1155.37	120.81	17.73
12	23.0	0.0	1643.97	986.55	657.42	1402.47	6.00	1155.37	172.99	19.25
13	23.0	0.0	1643.97	1079.02	564.95	1402.47	-0.00	1155.37	216.02	21.87
14	23.0	0.0	1643.97	1171.49	472.48	1402.47	-0.00	1155.37	216.02	26.15
15	23.0	0.0	1643.97	1263.96	380.01	1402.47	-0.00	1155.37	216.02	32.51
16	23.0	0.0	1643.97	1356.44	287.53	1402.47	-0.00	1155.37	216.02	42.97

AVG ROI OVER THE 16 YEAR PERIOD = 17.24 PERCENT

ATX-350I, DESIGN RANGE = 4600 NMI, M = 0.80, INTERN. RESRVS MISS

T/C=10.00 AR=11.25 W/S=131.00 T/W=0.235

Configuration 3

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

BASIC WING--	AREA(SQ FT)	SPAN(FT)	TAPER RATIO	C/4 SWEEP	L.E. SWEEP	MAC(FT)		
	4793.2	232.21	0.246	30.000	32.258	23.16		
WING PANELS--	AREA(SQ FT)	EXP. AREA	AVG T/C	L.E. SWEEP	SFLE(SQ FT)	REF L(FT)		
	1138.9	268.3	10.66	33.294	0.0	41.59		
	2317.9	2317.9	10.30	33.204	0.0	32.47		
	422.3	422.3	9.02	33.204	0.0	21.42		
	1459.0	1459.0	8.77	33.204	0.0	15.76		
	156.2	156.2	8.77	33.204	0.0	9.12		
TOTAL WING--	AREA(SQ FT)	EFF AR	AVG T/C	CR(FT)	CT(FT)	MAC(FT)	L(FT)	E SWP
	5494.3	9.81	9.70	47.65	6.16	28.97	84.18	22.375
FUSELAGE--	LENGTH(FT)	S WET(SQ FT)	BWW(FT)	EQUIV D(FT)	SPI(SQ FT)			
	201.00	10691.3	19.32	19.58	301.21			
	BW(FT)	BH(FT)	SBW(SQ FT)					
	19.58	19.58	10538.00					
HORZ. TAIL 1--	SHT1(SQ FT)	SHX1(SQ FT)	REF L1(FT)	L HT1(FT)	HT1 VOL COEF			
	1464.32	1116.67	18.75	72.33	0.9540			
HORZ. TAIL 2--	SHT2(SQ FT)	SHX2(SQ FT)	REF L2(FT)	L HT2(FT)	HT2 VOL COEF			
	0.0	0.0	0.0	201.00	0.0			
VERT. TAIL 1--	SVT1(SQ FT)	SVX1(SQ FT)	REF L1(FT)	L VT1(FT)	VT1 VOL COEF			
	921.32	616.73	22.97	73.11	0.0605			
VERT. TAIL 2--	SVT2(SQ FT)	SVX2(SQ FT)	REF L2(FT)	L VT2(FT)	VT2 VOL COEF			
	0.0	0.0	0.0	201.00	0.0			
PROPULSION--	ENG L(FT)	ENG D(FT)	POD L(FT)	POD D(FT)	POD S WET	NO. PODS	INLET L(FT)	
	14.13	7.14	14.25	9.46	760.22	2.	25.97	
FUEL TANKS--	WING(CU FT)	BOX(CU FT)	FUS(CU FT)					
	4003.13	819.87	999999.00					
WETTED VOLUMES--	BODY	WING	TAILS	PODS	PYLONS	PONTOONS	TOTAL	
	50412.42	7884.07	2696.76	1693.25	142.61	0.0	62829.11	

ATX-350I, DESIGN RANGE = 4600 NMI, M = 0.80, INTERN. RESRVS MISS

T/C=10.00 AR=11.25 W/S=131.00 T/W=0.235

Configuration 3

W E I G H T S T A T E M E N T

	WEIGHT(POUNDS)	WEIGHT FRACTION	(PERCENT)
GROSS WEIGHT	(627912.)		
FUEL AVAILABLE	217804.	FUEL	34.69
EXTERNAL	0.		
INTERNAL	217813.		
ZERO FUEL WEIGHT	410108.		
PAYLOAD	73500.	PAYLOAD	11.71
PASSENGERS	57750.		
BAGGAGE	15750.		
CARGO	0.		
STORES	0.		
OPERATIONAL EMPTY WEIGHT	336608.		
OPERATIONAL ITEMS	10369.	OPERATIONAL ITEMS	3.19
STANDARD ITEMS	9651.		
EMPTY WEIGHT	316588.		
STRUCTURE	216870.	STRUCTURE	34.54
WING	98544.		
ROTOR	0.		
TAIL	11275.		
BODY	68093.		
ALIGHTING GEAR	26175.		
ENGINE SECTION AND NACELLE	12784.		
PROPULSION	32772.	PROPULSION	5.22
CRUISE ENGINES	25414.		
LIFT ENGINES	0.		
THRUST REVERSER	4716.		
EXHAUST SYSTEM	0.		
ENGINE CONTROL	211.		
STARTING SYSTEM	417.		
PROPELLERS	0.		
LUBRICATING SYSTEM	0.		
FUEL SYSTEM	2013.		
DRIVE SYSTEM (POWER TRANS)	0.		
SYSTEMS	66946.		
FLIGHT CONTROLS	7621.		
AUXILIARY POWER PLANT	1202.		
INSTRUMENTS	1096.		
HYDRAULIC AND PNEUMATIC	2862.		
ELECTRICAL	5882.		
AVIONICS	3075.	SYSTEMS	10.66
ARMAMENT	0.		
FURNISHINGS AND EQUIPMENT	38504.		
AIR CONDITIONING	6302.		
ANTI-ICING	402.		
PHOTOGRAPHIC	0.		
LOAD AND HANDLING	0.		
		TOTAL	(100.)

Configuration 3

W E I G H T S   M A T R I X

ELEMENT/ / MATERIAL	AL	TIT.	STEEL	COMP.	OTHER	TOTAL
WING	88689.	1971.	6898.	0.	985.	98544.
ROTOR	0.	0.	0.	0.	0.	0.
TAIL	10148.	226.	789.	0.	113.	11275.
BODY	61283.	2724.	681.	1362.	2043.	68093.
L. G.	5758.	262.	17275.	0.	2879.	26175.
ENG SECT	0.	0.	0.	0.	0.	0.
NACELLE	3368.	4330.	1924.	0.	0.	9622.
AIR INDUCT	2846.	316.	0.	0.	0.	3163.
TOTALS	172093.	9828.	27568.	1362.	6020.	216870.

EXCESS FUEL CAPACITY - BODY	50123456.
EXCESS FUEL CAPACITY - WING	0.
EXCESS BODY LENGTH - FT	0.0
AIRFRAME WEIGHT (A.M.P.R.) - LB	276561.
GUST LOAD FACTOR	0.0

A L T E R N A T E   M I S S I O N   N O. 1   S U M M A R Y

Configuration 3

ATX-350I, AVRG STAGE L = 2500 NMI, M = 0.80, 60 % LF   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 CL	AVG L/D RATIO	AVG SFC (FF/T)
TAKEOFF POWER 1	0.	0.0	495663.	0.	0.	0.	0.	0.0	0.0	0.	428601.	0.	0.0	0.0	0.938
POWER 2	0.	0.0	495663.	916.	916.	0.	0.	1.0	1.0	0.	428501.	0.	0.0	0.0	0.385
CLIMB	0.	0.378	494748.	2599.	3515.	16.	16.	3.7	4.7	0.	428201.	0.	0.485	20.83	0.546
ACCEL	10000.	0.456	492149.	380.	3894.	3.	20.	0.6	5.3	0.	428201.	0.	0.403	19.69	0.576
CLIMB	10000.	0.547	491769.	8690.	12584.	130.	150.	17.9	23.2	0.	428201.	0.	0.356	18.07	0.640
CRUISE	35000.	0.800	483079.	0.	12584.	0.	150.	0.0	23.2	0.	-428101.	0.	0.451	18.97	0.649
ACCEL	35000.	0.800	483079.	0.	12584.	0.	150.	0.0	23.2	0.	428201.	0.	0.451	18.97	0.651
ACCEL	35000.	0.800	483079.	0.	12584.	0.	150.	0.0	23.2	0.	428201.	0.	0.451	18.97	0.651
CRUISE	35000.	0.800	483079.	9538.	22122.	268.	417.	34.8	58.0	0.	-428101.	0.	0.446	18.91	0.649
CLIMB	35000.	0.800	473541.	3024.	25145.	74.	491.	9.7	67.7	0.	428201.	0.	0.496	19.10	0.651
CRUISE	39000.	0.800	470518.	59164.	84309.	1808.	2300.	236.4	304.1	0.	-428101.	0.	0.497	19.03	0.649
CLIMB	39000.	0.800	411354.	0.	84309.	0.	2300.	0.0	304.1	0.	428201.	0.	0.0	0.0	0.0
CRUISE	39000.	0.800	411354.	6.	84316.	0.	2300.	0.0	304.2	0.	-428101.	0.	0.464	18.86	0.651
DESCENT	39000.	0.800	411347.	1343.	85659.	106.	2406.	14.8	319.0	0.	428301.	0.	0.329	16.95	-0.536
DECEL	10000.	0.547	410004.	73.	85732.	5.	2411.	0.9	319.9	0.	428301.	0.	0.339	18.14	-7.060
DESCENT	10000.	0.456	409931.	716.	86448.	31.	2442.	6.9	326.8	0.	428301.	0.	0.404	19.64	-2.666
CRUISE	39000.	0.800	409215.	1778.	88226.	58.	2500.	7.6	334.3	0.	-428101.	0.	0.461	18.82	0.651
LOITER	1500.	0.325	407437.	654.	88880.	0.	2500.	3.0	337.3	0.	-80101.	0.	0.573	20.83	0.670
CRUISE	1500.	0.378	406783.	481.	89362.	0.	2500.	2.0	339.3	0.	-80101.	0.	0.423	19.96	0.713
RESET	0.	0.0	406301.	0.	89362.	-2500.	0.	0.0	339.3	0.	0.	0.	0.0	0.0	0.0
CRUISE	39000.	0.800	406301.	7907.	97269.	0.	0.	33.9	373.2	0.	-428101.	0.	0.454	18.75	0.651
TAKEOFF POWER 1	0.	0.0	398394.	0.	97269.	0.	0.	0.0	373.2	0.	428601.	0.	0.0	0.0	0.938
POWER 2	0.	0.0	398394.	916.	98184.	0.	0.	1.0	374.2	0.	428501.	0.	0.0	0.0	0.385
CLIMB	0.	0.378	397478.	1969.	100153.	12.	12.	2.8	377.0	0.	428201.	0.	0.388	19.30	0.546
ACCEL	10000.	0.456	395509.	288.	100441.	2.	15.	0.4	377.5	0.	428201.	0.	0.323	17.67	0.576

Configuration 3

CLIMB	10000.	0.547	395221.	4531.	104973.	59.	74.	8.6	386.0	0.	428201.	0.	0.276	16.00	0.629
CRUISE	30000.	0.700	390690.	854.	105826.	26.	100.	3.8	389.8	0.	-428101.	0.	0.377	18.78	0.647
DESCENT	30000.	0.750	389836.	450.	106277.	55.	154.	8.1	397.9	0.	428301.	0.	0.272	15.88	-1.247
DECEL	10000.	0.547	389386.	71.	106347.	5.	159.	0.9	398.8	0.	428301.	0.	0.322	17.62	-7.080
DESCENT	10000.	0.456	389315.	701.	107048.	31.	190.	6.8	405.6	0.	428301.	0.	0.384	19.21	-2.654
CRUISE	30000.	0.700	388614.	338.	107386.	10.	200.	1.5	407.1	0.	-428101.	0.	0.375	18.74	0.647
CRUISE	1500.	0.378	388276.	7577.	114963.	0.	200.	32.0	439.1	0.	-80101.	0.	0.400	19.53	0.722

Configuration 3

COST SUMMARY

RDT AND E

	TOTAL *
DEVELOPMENT - NONRECURRING	
ENGINEERING	1184.21
TOOLING	616.54
TEST ARTICLES	87.61
DATA	0.0
SYSTEMS ENG/MNGMT	0.0
CRUISE ENGINE	0.0
LIFT ENGINE	0.0
FAN	0.0
AVIONICS	0.0
OTHER SYSTEMS	0.0
FACILITIES	0.0
TOTAL AIR VEHICLE	1888.35
INTEGR LOGISTICS SUPPORT	
PLANNING	12.91
TRAINING	4.39
HANDBOOKS	33.13
SSE	9.17
TOTAL ILS	59.61
TOTAL DVLPMNT-NONREC	1947.96
DEVELOPMENT - RECUR(PROTOTYPES)	
AIR VEHICLE	984.95
SPARES	15.75
TOTAL DVLPMNT-RECUR	1000.71
GOVMNT DVLPMNT COST	0.0
TOTAL DVLPMNT COST	2948.66

PRODUCTION

	MATERIAL	LABOR	TOTAL PER PROD A/C**
STRUCTURE	6600.78	14044.43	20645.20
WING	3240.24	5220.46	8460.70
ROTOR	0.0	0.0	0.0
TAIL	278.06	825.20	1103.26
BODY	1259.42	5891.89	7151.31
ALIGHTING GEAR	1048.92	32.87	1081.79
ENG SECT + NACELLE	774.15	2074.00	2848.14
ENG SECTION	0.0	0.0	0.0
NACELLE	751.40	1929.42	2680.82
AIR INDUCTION	22.75	144.58	167.33
PROPULSION	195.65	158.48	354.14
ENGINE INSTALL	0.0	34.91	34.91
THRUST REVERSER	0.0	6.48	6.48
EXHAUST SYSTEM	0.0	0.0	0.0
ENGINE CONTROLS	5.64	6.13	11.76
STARTING SYSTEM	63.81	8.26	72.07
PROPELLER INSTALL	0.0	0.0	0.0
LUBRICATING SYSTEM	0.0	0.0	0.0
FUEL SYSTEM	126.20	102.71	228.92
DRIVE SYS(PWR TRN)	0.0	0.0	0.0
SYSTEMS	4459.87	7562.65	12022.53
FLIGHT CONTROLS	1271.42	526.32	1797.74
AUX POWER PLANT	206.26	25.94	232.20
INSTRUMENTS	138.49	81.05	219.54
HYDRAULIC + PNEUM	217.62	406.00	623.61
ELECTRICAL	606.54	1222.23	1828.77
AVIONIC INSTALL	63.19	510.42	573.61
ARMAMENT	0.0	0.0	0.0
FURN AND EQUIP	1424.34	4298.73	5723.07
AIR CONDITIONING	500.14	462.48	962.62
ANTI-ICING	31.88	29.48	61.35
PHOTOGRAPHIC	0.0	0.0	0.0
LOAD AND HANDLING	0.0	0.0	0.0
SYSTEMS INTEGR	1040.98	838.58	1879.56
TOTAL COST	12297.29	22604.11	34901.39
TOTAL HRS **		674.99	674.99
ENG CHANGE ORDERS			1135.20
SUSTAINING ENG COST			1694.31
PROD TOOLING COST			2488.30
QUALITY ASSURANCE			3032.38
MISCELLANEOUS ***			1052.36
TOTAL AIRFRAME COST			44303.90
ENGINE COST			11028.50
AVIONICS COST			866.31
TOTAL MANUFACTURING COST			56198.70
WARRANTY			169.61
TOTAL PRODUCTION COST			56368.30

PROCUREMENT

	PER PROD A/C**
TOTAL PRODUCTION	56368.30
INTEGR LOGISTICS SUPPORT	
PLANNING	33.70
TRAINING	11.46
TRAINERS	220.56
HANDBOOKS	41.30
FACILITIES	0.0
SSE - CFE	0.0
SSE - GFE	2649.31
TOTAL ILS	2956.33
INITIAL SPARES COST	7974.59
PRODUCTION DEVELOPMENT	
ENGINEERING	322.51
TOOLING	354.41
ENGINES	0.0
TOTAL PROD DEV	676.92
TOTAL PROCUREMENT	67976.06

* - MILLIONS OF DOLLARS

** -1000 OF DOLLARS OR HOURS PER PROD A/C

*** - INCLUDES PROD DATA, SYSTEMS ENGR AND OTHER SYSTEMS

Configuration 3

OPERATIONAL COSTS

DIRECT OPERATIONAL COST (DOC)

	C/SM***	PERCENT
FLIGHT CREW	0.44862	8.63282
FUEL AND OIL	3.31682	63.82576
INSURANCE	0.03193	0.61445
DEPRECIATION	0.67282	12.94713
MAINTENANCE	0.72648	13.97979
TOTAL DOC	5.19667	100.000

INDIRECT OPERATIONAL COST (IOC)

	C/SM***	PERCENT
SYSTEM	0.0	0.0
LOCAL	0.61858	19.50473
AIRCRAFT CONTROL	0.01317	0.41520
CABIN ATTENDANT	0.44151	13.92129
FOOD AND BEVERAGE	0.16738	5.27767
PASSENGER HANDLING	0.63674	20.07726
CARGO HANDLING	0.17677	5.57375
OTHER PASSENGER EXPENSE	0.83200	26.23405
OTHER CARGO EXPENSE	0.00860	0.27105
GENERAL + ADMINISTRATION	0.27671	8.72514
TOTAL IOC	3.17145	100.000

MISC. DATA

FLIGHT DISTANCE (N. MI.)	2500.00
BLOCK FUEL (LBS)	90711.13
BLOCK TIME (HRS)	5.99
FLIGHT TIME (HRS)	5.66
AVG STAGE LENGTH (N. MI.)	2500.00
AVG CARGO PER FLIGHT	13695.72
UTILIZATION (HRS PER YR)	4142.10
FLIGHTS PER A/C PER YEAR	691.68
FARE ($)	374.96
FUEL COST ($/LB)	0.31600

*** - CENTS PER SEAT N. MILE

- -

RATE OF RETURN ON INVESTMENT

YEAR	AVG NO AIRCRAFT DURING YEAR	AIRCRAFT ADDED DURING YEAR	AVERAGE INVESTMENT DURING YEAR $M	CUMULATIVE DEPRECIATION $M	AVERAGE BOOK VALUE OF FLEET $M	REVENUE $M	INTEREST EXPENSE $M	OPERATING EXPENSE $M	CASH FLOW $M	ROI PERCENT
1	5.0	8.0	376.74	21.19	355.55	304.43	45.21	253.23	-144.59	13.56
2	13.0	8.0	979.52	76.29	903.23	791.52	110.31	658.39	-150.49	13.48
3	20.4	7.0	1535.21	162.65	1372.57	1240.56	162.52	1031.90	-134.70	13.52
4	23.0	0.0	1733.00	260.13	1472.87	1400.39	165.46	1164.84	-6.12	13.61
5	23.0	0.0	1733.00	357.61	1375.39	1400.39	144.67	1164.84	4.28	13.82
6	23.0	0.0	1733.00	455.09	1277.91	1400.39	123.87	1164.84	14.68	14.06
7	23.0	0.0	1733.00	552.57	1180.43	1400.39	103.08	1164.84	25.08	14.34
8	23.0	0.0	1733.00	650.05	1082.95	1400.39	82.28	1164.84	35.48	14.67
9	23.0	0.0	1733.00	747.53	985.47	1400.39	61.48	1164.84	45.87	15.07
10	23.0	0.0	1733.00	845.01	887.99	1400.39	40.69	1164.84	56.27	15.55
11	23.0	0.0	1733.00	942.49	790.51	1400.39	19.89	1164.84	114.89	16.16
12	23.0	0.0	1733.00	1039.97	693.03	1400.39	6.33	1164.84	169.90	17.45
13	23.0	0.0	1733.00	1137.45	595.55	1400.39	-0.00	1164.84	215.26	19.78
14	23.0	0.0	1733.00	1234.93	498.06	1400.39	-0.00	1164.84	215.26	23.65
15	23.0	0.0	1733.00	1332.41	400.58	1400.39	-0.00	1164.84	215.26	29.40
16	23.0	0.0	1733.00	1429.89	303.10	1400.39	-0.00	1164.84	215.26	38.86

AVG ROI OVER THE 16 YEAR PERIOD = 15.95 PERCENT

ATX-350I, DESIGN RANGE = 4600 NMI, M = 0.80, INTERN. RESRVS MISS

T/C=10.30 AR= 7.78 W/S=136.00 T/W=0.265

Configuration 4

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

BASIC WING--	AREA(SQ FT)	SPAN(FT)	TAPER RATIO	C/4 SWEEP	L.E. SWEEP	MAC(FT)		
	4507.1	187.26	0.246	35.000	37.883	27.01		
WING PANELS--	AREA(SQ FT)	EXP. AREA	AVG T/C	L.E. SWEEP	SFLE(SQ FT)	REF L(FT)		
	1070.9	69.8	11.14	37.879	0.0	47.77		
	2179.6	2179.6	10.61	37.879	0.0	37.86		
	397.1	397.1	9.29	37.879	0.0	24.97		
	1371.9	1371.9	9.03	37.879	0.0	18.38		
	146.8	146.8	9.03	37.879	0.0	10.63		
TOTAL WING--	AREA(SQ FT)	EFF AR	AVG T/C	CR(FT)	CT(FT)	MAC(FT)	L(FT)	E SWP
	5166.3	6.79	9.99	55.56	9.51	33.78	82.35	22.988
FUSELAGE--	LENGTH(FT)	S WET(SQ FT)	BWH(FT)	EQUIV D(FT)	SPI(SQ FT)			
	201.00	10794.9	19.32	19.58	301.21			
	BW(FT)	BH(FT)	SBW(SQ FT)					
	19.58	19.58	10538.00					
HORZ. TAIL 1--	SHT1(SQ FT)	SHX1(SQ FT)	REF L1(FT)	L HT1(FT)	HT1 VOL COEF			
	1617.50	1251.07	19.81	71.80	0.9540			
HORZ. TAIL 2--	SHT2(SQ FT)	SHX2(SQ FT)	REF L2(FT)	L HT2(FT)	HT2 VOL COEF			
	0.0	0.0	0.0	201.00	0.0			
VERT. TAIL 1--	SVT1(SQ FT)	SVX1(SQ FT)	REF L1(FT)	L VT1(FT)	VT1 VOL COEF			
	772.04	495.52	20.71	74.60	0.0682			
VERT. TAIL 2--	SVT2(SQ FT)	SVX2(SQ FT)	REF L2(FT)	L VT2(FT)	VT2 VOL COEF			
	0.0	0.0	0.0	201.00	0.0			
PROPULSION--	ENG L(FT)	ENG D(FT)	POD L(FT)	POD D(FT)	POD S WET	NO. PODS	INLET L(FT)	
	14.76	7.49	14.88	9.92	832.85	2.	27.32	
FUEL TANKS--	WING(CU FT)	BOX(CU FT)	FUS(CU FT)					
	4308.28	1114.39	999999.00					
WETTED VOLUMES--	BODY	WING	TAILS	PODS	PYLONS	PONTOONS	TOTAL	
	50681.78	8262.92	2695.96	1946.29	163.14	0.0	63750.09	

ATX-350I, DESIGN RANGE = 4600 NMI, M = 0.80, INTERN. RESRVS MISS

T/C=10.30 AR= 7.78 W/S=136.00 T/W=0.265

Configuration 4

W E I G H T   S T A T E M E N T

	WEIGHT(POUNDS)		WEIGHT FRACTION	(PERCENT)
GROSS WEIGHT	(612965.)			
FUEL AVAILABLE		233720.	FUEL	38.13
EXTERNAL	0.			
INTERNAL	233720.			
ZERO FUEL WEIGHT		379245.		
PAYLOAD		73500.	PAYLOAD	11.99
PASSENGERS	57750.			
BAGGAGE	15750.			
CARGO	0.			
STORES	0.			
OPERATIONAL EMPTY WEIGHT		305745.		
OPERATIONAL ITEMS	10394.		OPERATIONAL ITEMS	3.27
STANDARD ITEMS	9671.			
EMPTY WEIGHT		285681.		
STRUCTURE	183084.		STRUCTURE	29.87
WING	63652.			
ROTOR	0.			
TAIL	11661.			
BODY	68004.			
ALIGHTING GEAR	25551.			
ENGINE SECTION AND NACELLE	14216.			
PROPULSION	36092.		PROPULSION	5.89
CRUISE ENGINES	28246.			
LIFT ENGINES	0.			
THRUST REVERSER	5032.			
EXHAUST SYSTEM	0.			
ENGINE CONTROL	232.			
STARTING SYSTEM	463.			
PROPELLERS	0.			
LUBRICATING SYSTEM	0.			
FUEL SYSTEM	2118.			
DRIVE SYSTEM (POWER TRANS)	0.			
SYSTEMS	66504.			
FLIGHT CONTROLS	7576.			
AUXILIARY POWER PLANT	1202.			
INSTRUMENTS	1026.			
HYDRAULIC AND PNEUMATIC	2801.			
ELECTRICAL	5639.			
AVIONICS	3075.		SYSTEMS	10.85
ARMAMENT	0.			
FURNISHINGS AND EQUIPMENT	38504.			
AIR CONDITIONING	6302.			
ANTI-ICING	378.			
PHOTOGRAPHIC	0.			
LOAD AND HANDLING	0.			
			TOTAL	(100.)

Configuration 4

WEIGHTS MATRIX

ELEMENT/ / MATERIAL	AL	TIT.	STEEL	COMP.	OTHER	TOTAL
WING	57287.	1273.	4456.	0.	637.	63652.
ROTOR	0.	0.	0.	0.	0.	0.
TAIL	10495.	233.	816.	0.	117.	11661.
BODY	61204.	2720.	680.	1360.	2040.	68004.
L. G.	5621.	256.	16864.	0.	2811.	25551.
ENG SECT	0.	0.	0.	0.	0.	0.
NACELLE	3743.	4812.	2139.	0.	0.	10694.
AIR INDUCT	3170.	352.	0.	0.	0.	3522.
TOTALS	141519.	9646.	24955.	1360.	5604.	183084.

EXCESS FUEL CAPACITY - BODY	50137584.
EXCESS FUEL CAPACITY - WING	0.
EXCESS BODY LENGTH - FT	0.0
AIRFRAME WEIGHT (A.M.P.R.) - LB	243087.
GUST LOAD FACTOR	0.0

ALTERNATE MISSION NO. 1 SUMMARY

Configuration 4

ATX-350I, AVRG STAGE L = 2500 NMI, M = 0.80, 60 % LF 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 CL	AVG L/D RATIO	AVG SFC (FF/T)
TAKEOFF POWER 1	0.	0.0	470500.	0.	0.	0.	0.	0.0	0.0	0.	428601.	0.	0.0	0.0	0.934
POWER 2	0.	0.0	470500.	1004.	1004.	0.	0.	1.0	1.0	0.	428501.	0.	0.0	0.0	0.383
CLIMB	0.	0.378	469497.	2440.	3444.	14.	14.	3.1	4.1	0.	428201.	0.	0.488	18.17	0.544
ACCEL	10000.	0.456	467056.	350.	3794.	3.	17.	0.5	4.6	0.	428201.	0.	0.407	17.75	0.574
CLIMB	10000.	0.547	466707.	7482.	11276.	101.	118.	14.0	18.7	0.	428201.	0.	0.359	16.63	0.637
CRUISE	35000.	0.800	459224.	0.	11276.	0.	118.	0.0	18.7	0.	-428101.	0.	0.455	16.86	0.648
ACCEL	35000.	0.800	459224.	0.	11276.	0.	118.	0.0	18.7	0.	428201.	0.	0.455	16.86	0.648
ACCEL	35000.	0.800	459224.	0.	11276.	0.	118.	0.0	18.7	0.	428201.	0.	0.455	16.86	0.648
CRUISE	35000.	0.800	459224.	27187.	38463.	727.	845.	94.6	113.3	0.	-428101.	0.	0.442	16.78	0.649
CLIMB	35000.	0.800	432037.	2018.	40481.	45.	890.	5.9	119.1	0.	428201.	0.	0.479	16.77	0.648
CRUISE	39000.	0.800	430019.	48296.	88777.	1410.	2300.	184.3	303.4	0.	-428101.	0.	0.487	16.71	0.648
CLIMB	39000.	0.800	381723.	0.	88777.	0.	2300.	0.0	303.4	0.	428201.	0.	0.0	0.0	0.0
CRUISE	39000.	0.800	381723.	0.	88777.	0.	2300.	0.0	303.4	0.	-428101.	0.	0.458	16.66	0.650
DESCENT	39000.	0.800	381723.	1824.	90602.	113.	2413.	15.6	319.0	0.	428301.	0.	0.328	15.61	-0.335
DECEL	10000.	0.547	379898.	73.	90675.	4.	2417.	0.8	319.8	0.	428301.	0.	0.334	16.60	-6.984
DESCENT	10000.	0.456	379825.	706.	91380.	28.	2445.	6.2	326.0	0.	428301.	0.	0.398	17.60	-2.629
CRUISE	39000.	0.800	379120.	1764.	93144.	55.	2500.	7.2	333.2	0.	-428101.	0.	0.454	16.64	0.651
LOITER	1500.	0.335	377356.	718.	93861.	0.	2500.	3.0	336.2	0.	-80101.	0.	0.531	17.93	0.683
CRUISE	1500.	0.378	376639.	512.	94373.	0.	2500.	2.0	338.2	0.	-80101.	0.	0.417	17.77	0.725
RESET	0.	0.0	376127.	0.	94373.	-2500.	0.	0.0	338.2	0.	0.	0.	0.0	0.0	0.0
CRUISE	39000.	0.800	376127.	8228.	102601.	0.	0.	33.8	372.0	0.	-428101.	0.	0.447	16.60	0.651
TAKEOFF POWER 1	0.	0.0	367899.	0.	102601.	0.	0.	0.0	372.0	0.	428601.	0.	0.0	0.0	0.934
POWER 2	0.	0.0	367899.	1004.	103605.	0.	0.	1.0	373.0	0.	428501.	0.	0.0	0.0	0.383
CLIMB	0.	0.378	366895.	1766.	105370.	10.	10.	2.3	375.3	0.	428201.	0.	0.379	17.35	0.544
ACCEL	10000.	0.456	365129.	254.	105624.	2.	12.	0.4	375.6	0.	428201.	0.	0.318	16.25	0.574

CLIMB	10000.	0.547	364876.	3791.	109415.	45.	57.	6.5	382.2	0.	428201.	0.	0.271	14.94	0.626
CRUISE	30000.	0.725	361084.	1463.	110878.	43.	100.	6.1	388.2	0.	-428101.	0.	0.345	16.45	0.659
DESCENT	30000.	0.750	359621.	457.	111335.	50.	150.	7.5	395.7	0.	428301.	0.	0.267	14.85	-1.243
DECEL	10000.	0.547	359165.	71.	111406.	4.	155.	0.8	396.5	0.	428301.	0.	0.316	16.19	-7.009
DESCENT	10000.	0.456	359094.	695.	112101.	28.	182.	6.1	402.6	0.	428301.	0.	0.376	17.31	-2.612
CRUISE	30000.	0.720	358399.	593.	112693.	18.	200.	2.5	405.1	0.	-428101.	0.	0.348	16.52	0.658
CRUISE	1500.	0.378	357806.	7962.	120656.	0.	200.	32.0	437.1	0.	-80101.	0.	0.392	17.49	0.738

Configuration 4

COST SUMMARY

Configuration 4

RDT AND E

	TOTAL *
DEVELOPMENT - NONRECURRING	
ENGINEERING	1070.06
TOOLING	558.67
TEST ARTICLES	81.61
DATA	0.0
SYSTEMS ENG/MNGMT	0.0
CRUISE ENGINE	0.0
LIFT ENGINE	0.0
FAN	0.0
AVIONICS	0.0
OTHER SYSTEMS	0.0
FACILITIES	0.0
TOTAL AIR VEHICLE	1710.33
INTEGR LOGISTICS SUPPORT	
PLANNING	12.44
TRAINING	4.23
HANDBOOKS	34.13
SSE	8.84
TOTAL ILS	59.65
TOTAL DVLPMNT-NONREC	1769.98
DEVELOPMENT - RECUR(PROTOTYPES)	
AIR VEHICLE	927.99
SPARES	17.02
TOTAL DVLPMNT-RECUR	945.01
GOVMNT DVLPMNT COST	0.0
TOTAL DVLPMNT COST	2714.99

PRODUCTION

	MATERIAL	LABOR	TOTAL PER PROD A/C**
STRUCTURE	5530.96	12622.43	18153.38
WING	2096.08	3419.50	5515.58
ROTOR	0.0	0.0	0.0
TAIL	287.99	865.41	1153.40
BODY	1259.66	5967.09	7226.76
ALIGHTING GEAR	1025.48	32.54	1058.01
ENG SECT + NACELLE	861.75	2337.88	3199.63
ENG SECTION	0.0	0.0	0.0
NACELLE	836.38	2174.62	3011.00
AIR INDUCTION	25.37	163.27	188.63
PROPULSION	210.22	172.08	382.30
ENGINE INSTALL	0.0	39.34	39.34
THRUST REVERSER	0.0	7.01	7.01
EXHAUST SYSTEM	0.0	0.0	0.0
ENGINE CONTROLS	6.21	6.84	13.06
STARTING SYSTEM	71.03	9.31	80.34
PROPELLER INSTALL	0.0	0.0	0.0
LUBRICATING SYSTEM	0.0	0.0	0.0
FUEL SYSTEM	132.97	109.58	242.56
DRIVE SYS(PWR TRN)	0.0	0.0	0.0
SYSTEMS	4418.64	7598.94	12017.59
FLIGHT CONTROLS	1265.91	530.62	1796.53
AUX POWER PLANT	206.57	26.31	232.88
INSTRUMENTS	129.90	76.98	206.88
HYDRAULIC + PNEUM	213.26	402.87	616.13
ELECTRICAL	582.33	1188.19	1770.52
AVIONIC INSTALL	63.29	517.60	580.89
ARMAMENT	0.0	0.0	0.0
FURN AND EQUIP	1426.46	4359.24	5785.70
AIR CONDITIONING	500.89	468.99	969.88
ANTI-ICING	30.05	28.14	58.19
PHOTOGRAPHIC	0.0	0.0	0.0
LOAD AND HANDLING	0.0	0.0	0.0
SYSTEMS INTEGR	940.75	767.36	1708.12
TOTAL COST	11100.58	21160.80	32261.38
TOTAL HRS **		631.89	631.89
ENG CHANGE ORDERS			1050.37
SUSTAINING ENG COST			1581.66
PROD TOOLING COST			2329.42
QUALITY ASSURANCE			2838.76
MISCELLANEOUS ***			985.16
TOTAL AIRFRAME COST			41046.72
ENGINE COST			11965.55
AVIONICS COST			866.31
TOTAL MANUFACTURING COST			53878.56
WARRANTY			157.24
TOTAL PRODUCTION COST			54035.79

PROCUREMENT

	PER PROD A/C**
TOTAL PRODUCTION	54035.79
INTEGR LOGISTICS SUPPORT	
PLANNING	32.74
TRAINING	11.13
TRAINERS	220.56
HANDBOOKS	41.97
FACILITIES	0.0
SSE - CFE	0.0
SSE - GFE	2539.68
TOTAL ILS	2846.08
INITIAL SPARES COST	7869.30
PRODUCTION DEVELOPMENT	
ENGINEERING	313.34
TOOLING	331.78
ENGINES	0.0
TOTAL PROD DEV	645.11
TOTAL PROCUREMENT	65396.27

* - MILLIONS OF DOLLARS

** -1000 OF DOLLARS OR HOURS PER PROD A/C

*** - INCLUDES PROD DATA, SYSTEMS ENGR AND OTHER SYSTEMS

Configuration 4

OPERATIONAL COSTS

DIRECT OPERATIONAL COST (DOC)	C/SM***	PERCENT	INDIRECT OPERATIONAL COST (IOC)	C/SM***	PERCENT	MISC. DATA	
FLIGHT CREW	0.44723	8.38351	SYSTEM	0.0	0.0	FLIGHT DISTANCE (N. MI.)	2500.00
FUEL AND OIL	3.50479	65.69844	LOCAL	0.60386	19.10648	BLOCK FUEL (LBS)	95852.81
INSURANCE	0.03039	0.56973	AIRCRAFT CONTROL	0.01317	0.41664	BLOCK TIME (HRS)	5.97
DEPRECIATION	0.64282	12.04996	CABIN ATTENDANT	0.44014	13.92634	FLIGHT TIME (HRS)	5.64
MAINTENANCE	0.70942	13.29837	FOOD AND BEVERAGE	0.16686	5.27958	AVG STAGE LENGTH (N. MI.)	2500.00
			PASSENGER HANDLING	0.63674	20.14688	AVG CARGO PER FLIGHT	13695.72
TOTAL DOC	5.33466	100.000	CARGO HANDLING	0.17677	5.59308	UTILIZATION (HRS PER YR)	4139.65
			OTHER PASSENGER EXPENSE	0.83200	26.32504	FLIGHTS PER A/C PER YEAR	693.41
			OTHER CARGO EXPENSE	0.00860	0.27199	FARE ($)	374.96
			GENERAL + ADMINISTRATION	0.28236	8.93404	FUEL COST ($/LB)	0.31600
			TOTAL IOC	3.16049	100.000	*** - CENTS PER SEAT N. MILE	

RATE OF RETURN ON INVESTMENT

YEAR	AVG NO AIRCRAFT DURING YEAR	AIRCRAFT ADDED DURING YEAR	AVERAGE INVESTMENT DURING YEAR $M	CUMULATIVE DEPRECIATION $M	AVERAGE BOOK VALUE OF FLEET $M	REVENUE $M	INTEREST EXPENSE $M	OPERATING EXPENSE $M	CASH FLOW $M	ROI PERCENT
1	5.0	8.0	360.92	20.30	340.62	305.20	43.31	257.72	-139.30	13.33
2	13.0	8.0	938.39	73.09	865.30	793.51	105.68	670.06	-146.22	13.24
3	20.4	7.0	1470.74	155.82	1314.93	1243.68	155.70	1050.19	-132.25	13.28
4	23.0	0.0	1660.23	249.20	1411.02	1403.91	158.52	1185.49	-9.48	13.36
5	23.0	0.0	1660.23	342.59	1317.64	1403.91	138.59	1185.49	0.48	13.55
6	23.0	0.0	1660.23	435.98	1224.25	1403.91	118.67	1185.49	10.44	13.77
7	23.0	0.0	1660.23	529.36	1130.86	1403.91	98.75	1185.49	20.40	14.02
8	23.0	0.0	1660.23	622.75	1037.47	1403.91	78.82	1185.49	30.37	14.33
9	23.0	0.0	1660.23	716.14	944.09	1403.91	58.90	1185.49	40.33	14.69
10	23.0	0.0	1660.23	809.53	850.70	1403.91	38.98	1185.49	50.29	15.13
11	23.0	0.0	1660.23	902.91	757.31	1403.91	19.06	1185.49	106.45	15.68
12	23.0	0.0	1660.23	996.30	663.92	1403.91	6.06	1185.49	159.14	16.91
13	23.0	0.0	1660.23	1089.69	570.54	1403.91	-0.00	1185.49	202.60	19.14
14	23.0	0.0	1660.23	1183.08	477.15	1403.91	-0.00	1185.49	202.60	22.89
15	23.0	0.0	1660.23	1276.46	383.76	1403.91	-0.00	1185.49	202.60	28.46
16	23.0	0.0	1660.23	1369.85	290.38	1403.91	-0.00	1185.49	202.60	37.61

AVG ROI OVER THE 16 YEAR PERIOD = 15.56 PERCENT

ATX-350I, DESIGN RANGE = 4600 NMI, M = 0.30, INTERN. RESRVS MISS

T/C=10.30 AR= 7.78 W/S=129.00 T/W=0.264

Configuration 5

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

BASIC WING--	AREA(SQ FT)	SPAN(FT)	TAPER RATIO	C/4 SWEEP	L.E. SWEEP	MAC(FT)			
	4696.5	191.15	0.246	35.000	37.883	27.57			
WING PANELS--	AREA(SQ FT)	EXP. AREA	AVG T/C	L.E. SWEEP	SFLE(SQ FT)	REF L(FT)			
	1115.9	92.5	11.12	37.879	0.0	48.84			
	2271.2	2271.2	10.61	37.879	0.0	38.65			
	413.8	413.8	9.29	37.879	0.0	25.49			
	1429.6	1429.6	9.03	37.879	0.0	18.76			
	153.0	153.0	9.03	37.879	0.0	10.86			
TOTAL WING--	AREA(SQ FT)	EFF AR	AVG T/C	CR(FT)	CT(FT)	MAC(FT)	L(FT)	E SWP	
	5383.5	6.79	9.99	56.72	9.71	34.48	84.06	22.988	
FUSELAGE--	LENGTH(FT)	S WET(SQ FT)	BWW(FT)	EQUIV D(FT)	SPI(SQ FT)				
	201.00	10777.6	19.32	19.58	301.21				
	BW(FT)	BH(FT)	SBW(SQ FT)						
	19.58	19.58	10538.00						
HORZ. TAIL 1--	SHT1(SQ FT)	SHX1(SQ FT)	REF L1(FT)	L HT1(FT)	HT1 VOL COEF				
	1729.51	1349.91	20.55	71.43	0.9540				
HORZ. TAIL 2--	SHT2(SQ FT)	SHX2(SQ FT)	REF L2(FT)	L HT2(FT)	HT2 VOL COEF				
	0.0	0.0	0.0	201.00	0.0				
VERT. TAIL 1--	SVT1(SQ FT)	SVX1(SQ FT)	REF L1(FT)	L VT1(FT)	VT1 VOL COEF				
	824.03	537.45	21.52	74.07	0.0680				
VERT. TAIL 2--	SVT2(SQ FT)	SVX2(SQ FT)	REF L2(FT)	L VT2(FT)	VT2 VOL COEF				
	0.0	0.0	0.0	201.00	0.0				
PROPULSION--	ENG L(FT)	ENG D(FT)	POD L(FT)	POD D(FT)	POD S WET	NO. PODS	INLET L(FT)		
	14.66	7.44	14.78	9.84	820.72	2.	27.10		
FUEL TANKS--	WING(CU FT)	BOX(CU FT)	FUS(CU FT)						
	4606.25	1164.95	999999.00						
WETTED VOLUMES--	BODY	WING	TAILS	PODS	PYLONS	PONTOONS	TOTAL		
	50635.79	8860.13	3025.66	1903.18	159.65	0.0	64584.40		

ATX-350I, DESIGN RANGE = 4600 NMI, M = 0.80, INTERN. RESRVS MISS

T/C=10.30 AR= 7.78 W/S=129.00 T/W=0.264

Configuration 5

WEIGHT STATEMENT

	WEIGHT(POUNDS)	WEIGHT FRACTION	(PERCENT)
GROSS WEIGHT	(605854.)		
FUEL AVAILABLE	229403.	FUEL	37.86
EXTERNAL	0.		
INTERNAL	229403.		
ZERO FUEL WEIGHT	376451.		
PAYLOAD	73500.	PAYLOAD	12.13
PASSENGERS	57750.		
BAGGAGE	15750.		
CARGO	0.		
STORES	0.		
OPERATIONAL EMPTY WEIGHT	302951.		
OPERATIONAL ITEMS	10390.	OPERATIONAL ITEMS	3.31
STANDARD ITEMS	9665.		
EMPTY WEIGHT	282896.		
STRUCTURE	182947.	STRUCTURE	30.20
WING	63360.		
ROTOR	0.		
TAIL	12464.		
BODY	67893.		
ALIGHTING GEAR	25255.		
ENGINE SECTION AND NACELLE	13975.		
PROPULSION	35253.	PROPULSION	5.82
CRUISE ENGINES	27771.		
LIFT ENGINES	0.		
THRUST REVERSER	4980.		
EXHAUST SYSTEM	0.		
ENGINE CONTROL	229.		
STARTING SYSTEM	455.		
PROPELLERS	0.		
LUBRICATING SYSTEM	0.		
FUEL SYSTEM	1818.		
DRIVE SYSTEM (POWER TRANS)	0.		
SYSTEMS	64697.		
FLIGHT CONTROLS	5769.		
AUXILIARY POWER PLANT	1202.		
INSTRUMENTS	1032.		
HYDRAULIC AND PNEUMATIC	2771.		
ELECTRICAL	5660.		
AVIONICS	3075.	SYSTEMS	10.68
ARMAMENT	0.		
FURNISHINGS AND EQUIPMENT	38504.		
AIR CONDITIONING	6302.		
ANTI-ICING	380.		
PHOTOGRAPHIC	0.		
LOAD AND HANDLING	0.		
		TOTAL	(100.)

Configuration 5

WEIGHTS MATRIX

ELEMENT/ / MATERIAL	AL	TIT.	STEEL	COMP.	OTHER	TOTAL
WING	57024.	1267.	4435.	0.	634.	63360.
ROTOR	0.	0.	0.	0.	0.	0.
TAIL	11217.	249.	872.	0.	125.	12464.
BODY	61104.	2716.	679.	1358.	2037.	67893.
L. G.	5556.	253.	16668.	0.	2778.	25255.
ENG SECT	0.	0.	0.	0.	0.	0.
NACELLE	3680.	4731.	2103.	0.	0.	10514.
AIR INDUCT	3115.	346.	0.	0.	0.	3461.
TOTALS	141696.	9562.	24758.	1358.	5573.	182946.

EXCESS FUEL CAPACITY - BODY	50158288.
EXCESS FUEL CAPACITY - WING	1083.
EXCESS BODY LENGTH - FT	0.0
AIRFRAME WEIGHT (A.M.P.R.) - LB	240874.
GUST LOAD FACTOR	0.0

Configuration 5

ALTERNATE MISSION NO. 1 SUMMARY

ATX-350I, AVRG STAGE L = 2500 NMI, M = 0.80, 60 % LF 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 CL	AVG L/D RATIO	AVG SFC (FF/T)
TAKEOFF POWER 1	0.	0.0	465729.	0.	0.	0.	0.	0.0	0.0	0.	428601.	0.	0.0	0.0	0.934
POWER 2	0.	0.0	465729.	989.	989.	0.	0.	1.0	1.0	0.	428501.	0.	0.0	0.0	0.384
CLIMB	0.	0.378	464740.	2412.	3401.	14.	14.	3.2	4.2	0.	428201.	0.	0.464	18.35	0.545
ACCEL	10000.	0.456	462327.	348.	3749.	3.	17.	0.5	4.6	0.	428201.	0.	0.386	17.73	0.574
CLIMB	10000.	0.547	461980.	7541.	11290.	104.	121.	14.3	19.0	0.	428201.	0.	0.341	16.49	0.638
CRUISE	39000.	0.800	454439.	0.	11290.	0.	121.	0.0	19.0	0.	-428101.	0.	0.524	16.94	0.645
ACCEL	39000.	0.800	454439.	0.	11290.	0.	121.	0.0	19.0	0.	428201.	0.	0.524	16.94	0.651
ACCEL	39000.	0.800	454439.	0.	11290.	0.	121.	0.0	19.0	0.	428201.	0.	0.524	16.94	0.651
CRUISE	39000.	0.800	454438.	75507.	86797.	2179.	2300.	285.0	304.0	0.	-428101.	0.	0.479	16.92	0.647
CLIMB	39000.	0.800	378931.	0.	86797.	0.	2300.	0.0	304.0	0.	428201.	0.	0.0	0.0	0.0
CRUISE	39000.	0.800	378931.	0.	86797.	0.	2300.	0.0	304.0	0.	-428101.	0.	0.437	16.75	0.651
CLIMB	39000.	0.800	378931.	0.	86797.	0.	2300.	0.0	304.0	0.	428201.	0.	0.0	0.0	0.0
CRUISE	39000.	0.800	378931.	0.	86797.	0.	2300.	0.0	304.0	0.	-428101.	0.	0.437	16.75	0.651
DESCENT	39000.	0.800	378931.	1844.	88642.	113.	2413.	15.6	319.6	0.	428301.	0.	0.313	15.45	-0.316
DECEL	10000.	0.547	377086.	71.	88713.	4.	2417.	0.8	320.4	0.	428301.	0.	0.318	16.45	-7.005
DESCENT	10000.	0.456	377015.	694.	89406.	28.	2445.	6.2	326.6	0.	428301.	0.	0.379	17.57	-2.635
CRUISE	39000.	0.800	376322.	1738.	91144.	55.	2500.	7.1	333.7	0.	-428101.	0.	0.433	16.72	0.651
LOITER	1500.	0.325	374584.	695.	91839.	0.	2500.	3.0	336.7	0.	-80101.	0.	0.538	18.14	0.674
CRUISE	1500.	0.378	373889.	507.	92346.	0.	2500.	2.0	338.7	0.	-80101.	0.	0.397	17.78	0.723
RESET	0.	0.0	373382.	0.	92346.	-2500.	0.	0.0	338.7	0.	0.	0.	0.0	0.0	0.0
CRUISE	39000.	0.800	373382.	8155.	100501.	0.	0.	33.9	372.6	0.	-428101.	0.	0.426	16.65	0.652
TAKEOFF POWER 1	0.	0.0	365227.	0.	100501.	0.	0.	0.0	372.6	0.	428601.	0.	0.0	0.0	0.934
POWER 2	0.	0.0	365227.	989.	101490.	0.	0.	1.0	373.6	0.	428501.	0.	0.0	0.0	0.384
CLIMB	0.	0.378	364238.	1761.	103251.	10.	10.	2.3	375.9	0.	428201.	0.	0.361	17.27	0.545
ACCEL	10000.	0.456	362476.	254.	103506.	2.	12.	0.4	376.2	0.	428201.	0.	0.303	16.06	0.574

Configuration 5

CLIMB	10000.	0.547	362222.	3848.	107353.	46.	58.	6.7	382.9	0.	428201.	0.	0.258	14.67	0.627
CRUISE	30000.	0.715	358374.	1394.	108748.	42.	100.	5.9	388.9	0.	-428101.	0.	0.340	16.59	0.654
DESCENT	30000.	0.750	356980.	443.	109190.	50.	149.	7.4	396.2	0.	428301.	0.	0.254	14.57	-1.243
DECEL	10000.	0.547	356537.	69.	109259.	4.	153.	0.8	397.0	0.	428301.	0.	0.301	16.00	-7.029
DESCENT	10000.	0.456	356468.	681.	109940.	28.	181.	6.1	403.1	0.	428301.	0.	0.358	17.23	-2.619
CRUISE	30000.	0.710	355787.	632.	110572.	19.	200.	2.7	405.8	0.	-428101.	0.	0.341	16.60	0.653
CRUISE	1500.	0.378	355155.	7897.	118469.	0.	200.	32.0	437.8	0.	-80101.	0.	0.373	17.44	0.735

C O S T   S U M M A R Y

RDT AND E

	TOTAL *
DEVELOPMENT - NONRECURRING	
ENGINEERING	1078.13
TOOLING	554.78
TEST ARTICLES	80.63
DATA	0.0
SYSTEMS ENG/MNGMT	0.0
CRUISE ENGINE	0.0
LIFT ENGINE	0.0
FAN	0.0
AVIONICS	0.0
OTHER SYSTEMS	0.0
FACILITIES	0.0
TOTAL AIR VEHICLE	1713.54
INTEGR LOGISTICS SUPPORT	
PLANNING	12.96
TRAINING	4.41
HANDBOOKS	32.73
SSE	9.21
TOTAL ILS	59.31
TOTAL DVLPMNT-NONREC	1772.85
DEVELOPMENT - RECUR(PROTOTYPES)	
AIR VEHICLE	923.91
SPARES	16.81
TOTAL DVLPMNT-RECUR	940.72
GOVMNT DVLPMNT COST	0.0
TOTAL DVLPMNT COST	2713.57

PRODUCTION

	MATERIAL	LABOR	TOTAL PER PROD A/C**
STRUCTURE	5513.46	12633.55	18147.01
WING	2086.76	3408.36	5495.11
ROTOR	0.0	0.0	0.0
TAIL	307.86	926.22	1234.08
BODY	1257.78	5965.26	7223.04
ALIGHTING GEAR	1013.72	32.20	1045.93
ENG SECT + NACELLE	847.34	2301.50	3148.84
ENG SECTION	0.0	0.0	0.0
NACELLE	822.40	2140.82	2963.22
AIR INDUCTION	24.94	160.68	185.62
PROPULSION	190.12	155.78	345.90
ENGINE INSTALL	0.0	38.73	38.73
THRUST REVERSER	0.0	6.95	6.95
EXHAUST SYSTEM	0.0	0.0	0.0
ENGINE CONTROLS	6.12	6.74	12.86
STARTING SYSTEM	69.84	9.16	79.01
PROPELLER INSTALL	0.0	0.0	0.0
LUBRICATING SYSTEM	0.0	0.0	0.0
FUEL SYSTEM	114.16	94.19	208.35
DRIVE SYS(PWR TRN)	0.0	0.0	0.0
SYSTEMS	4080.95	7432.62	11513.57
FLIGHT CONTROLS	926.93	354.04	1280.97
AUX POWER PLANT	206.60	26.34	232.94
INSTRUMENTS	130.68	77.54	208.21
HYDRAULIC + PNEUM	211.07	399.19	610.26
ELECTRICAL	584.60	1194.26	1778.86
AVIONIC INSTALL	63.30	518.29	581.59
ARMAMENT	0.0	0.0	0.0
FURN AND EQUIP	1426.66	4365.05	5791.71
AIR CONDITIONING	500.96	469.62	970.57
ANTI-ICING	30.17	28.28	58.45
PHOTOGRAPHIC	0.0	0.0	0.0
LOAD AND HANDLING	0.0	0.0	0.0
SYSTEMS INTEGR	931.72	760.90	1692.61
TOTAL COST	10716.25	20982.81	31699.07
TOTAL HRS **		626.58	626.58
ENG CHANGE ORDERS			1032.81
SUSTAINING ENG COST			1590.00
PROD TOOLING COST			2309.82
QUALITY ASSURANCE			2814.88
MISCELLANEOUS ***			976.88
TOTAL AIRFRAME COST			40423.44
ENGINE COST			11809.63
AVIONICS COST			866.31
TOTAL MANUFACTURING COST			53099.38
WARRANTY			216.00
TOTAL PRODUCTION COST			53315.36

PROCUREMENT

	PER PROD A/C**
TOTAL PRODUCTION	53315.36
INTEGR LOGISTICS SUPPORT	
PLANNING	33.54
TRAINING	11.40
TRAINERS	220.56
HANDBOOKS	41.10
FACILITIES	0.0
SSE - CFE	0.0
SSE - GFE	2505.82
TOTAL ILS	2812.42
INITIAL SPARES COST	7758.64
PRODUCTION DEVELOPMENT	
ENGINEERING	320.99
TOOLING	328.99
ENGINES	0.0
TOTAL PROD DEV	649.98
TOTAL PROCUREMENT	64536.38

* - MILLIONS OF DOLLARS

** -1000 OF DOLLARS OR HOURS PER PROD A/C

*** - INCLUDES PROD DATA, SYSTEMS ENGR AND OTHER SYSTEMS

Configuration 5

OPERATIONAL COSTS

DIRECT OPERATIONAL COST (DOC)

	C/SM***	PERCENT
FLIGHT CREW	0.44784	8.54011
FUEL AND OIL	3.42988	65.40569
INSURANCE	0.03308	0.63077
DEPRECIATION	0.63583	12.12499
MAINTENANCE	0.69737	13.29849
TOTAL DOC	5.24400	100.000

INDIRECT OPERATIONAL COST (IOC)

	C/SM***	PERCENT
SYSTEM	0.0	0.0
LOCAL	0.59685	18.94191
AIRCRAFT CONTROL	0.01317	0.41790
CABIN ATTENDANT	0.44074	13.98757
FOOD AND BEVERAGE	0.16709	5.30279
PASSENGER HANDLING	0.63674	20.20778
CARGO HANDLING	0.17677	5.60999
OTHER PASSENGER EXPENSE	0.83200	26.40463
OTHER CARGO EXPENSE	0.00860	0.27281
GENERAL + ADMINISTRATION	0.27901	8.85471
TOTAL IOC	3.15096	100.000

MISC. DATA

FLIGHT DISTANCE (N. MI.)	2500.00
BLOCK FUEL (LBS)	93803.81
BLOCK TIME (HRS)	5.98
FLIGHT TIME (HRS)	5.64
AVG STAGE LENGTH (N. MI.)	2500.00
AVG CARGO PER FLIGHT	13695.72
UTILIZATION (HRS PER YR)	4140.73
FLIGHTS PER A/C PER YEAR	692.65
FARE ($)	374.96
FUEL COST ($/LB)	0.31600

*** - CENTS PER SEAT N. MILE

- -

RATE OF RETURN ON INVESTMENT

YEAR	AVG NO AIRCRAFT DURING YEAR	AIRCRAFT ADDED DURING YEAR	AVERAGE INVESTMENT DURING YEAR	CUMULATIVE DEPRECIATION	AVERAGE BOOK VALUE OF FLEET	REVENUE	INTEREST EXPENSE	OPERATING EXPENSE	CASH FLOW	ROI
			$M	$M	$M	$M	$M	$M	$M	PERCENT
1	5.0	8.0	356.60	20.06	336.54	304.86	42.79	254.39	-135.86	13.86
2	13.0	8.0	927.16	72.21	854.95	792.63	104.41	661.43	-139.85	13.78
3	20.4	7.0	1453.15	153.95	1299.20	1242.30	153.84	1036.66	-123.43	13.83
4	23.0	0.0	1640.37	246.22	1394.14	1402.35	156.62	1170.21	-1.20	13.94
5	23.0	0.0	1640.37	338.49	1301.87	1402.35	136.93	1170.21	8.64	14.17
6	23.0	0.0	1640.37	430.76	1209.60	1402.35	117.25	1170.21	18.49	14.44
7	23.0	0.0	1640.37	523.03	1117.33	1402.35	97.57	1170.21	28.33	14.75
8	23.0	0.0	1640.37	615.30	1025.06	1402.35	77.88	1170.21	38.17	15.12
9	23.0	0.0	1640.37	707.57	932.79	1402.35	58.20	1170.21	48.01	15.56
10	23.0	0.0	1640.37	799.84	840.52	1402.35	38.51	1170.21	57.85	16.10
11	23.0	0.0	1640.37	892.11	748.25	1402.35	18.83	1170.21	113.34	16.77
12	23.0	0.0	1640.37	984.39	655.98	1402.35	5.99	1170.21	165.40	18.15
13	23.0	0.0	1640.37	1076.66	563.71	1402.35	-0.00	1170.21	208.34	20.59
14	23.0	0.0	1640.37	1168.93	471.44	1402.35	-0.00	1170.21	208.34	24.62
15	23.0	0.0	1640.37	1261.20	379.17	1402.35	-0.00	1170.21	208.34	30.61
16	23.0	0.0	1640.37	1353.47	286.90	1402.35	-0.00	1170.21	208.34	40.46

AVG ROI OVER THE 16 YEAR PERIOD = 16.45 PERCENT

ATX-350I, DESIGN RANGE = 4600 NMI, M = 0.80, INTERN. RESRVS MISS

T/C=10.30 AR= 7.78 W/S=129.00 T/W=0.260

Configuration 6

CONFIGURATION GEOMETRY

BASIC WING--	AREA(SQ FT)	SPAN(FT)	TAPER RATIO	C/4 SWEEP	L.E. SWEEP	MAC(FT)		
	4542.0	187.98	0.246	35.000	37.883	27.11		
WING PANELS--	AREA(SQ FT)	EXP. AREA	AVG T/C	L.E. SWEEP	SFLE(SQ FT)	REF L(FT)		
	1079.2	73.9	11.14	37.879	0.0	47.97		
	2196.4	2196.4	10.61	37.879	0.0	38.01		
	400.2	400.2	9.29	37.879	0.0	25.07		
	1382.5	1382.5	9.03	37.879	0.0	18.45		
	148.0	148.0	9.03	37.879	0.0	10.68		
TOTAL WING--	AREA(SQ FT)	EFF AR	AVG T/C	CR(FT)	CT(FT)	MAC(FT)	L(FT)	E SWP
	5206.3	6.79	9.99	55.78	9.55	33.91	82.67	22.988
FUSELAGE--	LENGTH(FT)	S WET(SQ FT)	BWW(FT)	EQUIV D(FT)	SPI(SQ FT)			
	201.00	10724.6	19.32	19.58	301.21			
	BW(FT)	BH(FT)	SBW(SQ FT)					
	19.58	19.58	10538.00					
HORZ. TAIL 1--	SHT1(SQ FT)	SHX1(SQ FT)	REF L1(FT)	L HT1(FT)	HT1 VOL COEF			
	1637.88	1269.02	19.94	71.73	0.9540			
HORZ. TAIL 2--	SHT2(SQ FT)	SHX2(SQ FT)	REF L2(FT)	L HT2(FT)	HT2 VOL COEF			
	0.0	0.0	0.0	201.00	0.0			
VERT. TAIL 1--	SVT1(SQ FT)	SVX1(SQ FT)	REF L1(FT)	L VT1(FT)	VT1 VOL COEF			
	765.59	490.34	20.60	74.67	0.0670			
VERT. TAIL 2--	SVT2(SQ FT)	SVX2(SQ FT)	REF L2(FT)	L VT2(FT)	VT2 VOL COEF			
	0.0	0.0	0.0	201.00	0.0			
PROPULSION--	ENG L(FT)	ENG D(FT)	POD L(FT)	POD D(FT)	POD S WET	NO. PODS	INLET L(FT)	
	14.34	7.26	14.46	9.61	783.59	2.	26.41	
FUEL TANKS--	WING(CU FT)	BOX(CU FT)	FUS(CU FT)					
	4362.61	1123.70	999999.00					
WETTED VOLUMES--	BODY	WING	TAILS	PODS	PYLONS	PONTOONS	TOTAL	
	50497.53	8371.74	2725.01	1773.34	149.12	0.0	63516.73	

ATX-350I, DESIGN RANGE = 4600 NMI, M = 0.80, INTERN. RESRVS MISS

T/C=10.30 AR= 7.78 W/S=129.00 T/W=0.260

Configuration 6

W E I G H T   S T A T E M E N T

	WEIGHT(POUNDS)	WEIGHT FRACTION	(PERCENT)
GROSS WEIGHT	(585915.)		
FUEL AVAILABLE	220174.	FUEL	37.58
EXTERNAL	0.		
INTERNAL	220173.		
ZERO FUEL WEIGHT	365741.		
PAYLOAD	73500.	PAYLOAD	12.54
PASSENGERS	57750.		
BAGGAGE	15750.		
CARGO	0.		
STORES	0.		
OPERATIONAL EMPTY WEIGHT	292241.		
OPERATIONAL ITEMS	10377.	OPERATIONAL ITEMS	3.42
STANDARD ITEMS	9654.		
EMPTY WEIGHT	272210.		
STRUCTURE	177789.	STRUCTURE	30.34
WING	61046.		
ROTOR	0.		
TAIL	11755.		
BODY	67298.		
ALIGHTING GEAR	24448.		
ENGINE SECTION AND NACELLE	13243.		
PROPULSION	33274.	PROPULSION	5.68
CRUISE ENGINES	26321.		
LIFT ENGINES	0.		
THRUST REVERSER	4938.		
EXHAUST SYSTEM	0.		
ENGINE CONTROL	218.		
STARTING SYSTEM	0.		
PROPELLERS	0.		
LUBRICATING SYSTEM	0.		
FUEL SYSTEM	1797.		
DRIVE SYSTEM (POWER TRANS)	0.		
SYSTEMS	61148.		
FLIGHT CONTROLS	7790.		
AUXILIARY POWER PLANT	1000.		
INSTRUMENTS	1047.		
HYDRAULIC AND PNEUMATIC	0.		
ELECTRICAL	5718.		
AVIONICS	2921.	SYSTEMS	10.44
ARMAMENT	0.		
FURNISHINGS AND EQUIPMENT	38504.		
AIR CONDITIONING	4053.		
ANTI-ICING	114.		
PHOTOGRAPHIC	0.		
LOAD AND HANDLING	0.		
		TOTAL	(100.)

Configuration 6

WEIGHTS MATRIX

ELEMENT/ / MATERIAL	AL	TIT.	STEEL	COMP.	OTHER	TOTAL
WING	54941.	1221.	4273.	0.	610.	61046.
ROTOR	0.	0.	0.	0.	0.	0.
TAIL	10580.	235.	823.	0.	118.	11755.
BODY	60568.	2692.	673.	1346.	2019.	67298.
L. G.	5379.	244.	16136.	0.	2689.	24448.
ENG SECT	0.	0.	0.	0.	0.	0.
NACELLE	3488.	4484.	1993.	0.	0.	9965.
AIR INDUCT	2950.	328.	0.	0.	0.	3277.
TOTALS	137905.	9204.	23898.	1346.	5436.	177789.

EXCESS FUEL CAPACITY - BODY	50154336.
EXCESS FUEL CAPACITY - WING	0.
EXCESS BODY LENGTH - FT	0.0
AIRFRAME WEIGHT (A.M.P.R.) - LB	232655.
GUST LOAD FACTOR	0.0

Configuration 6

ALTERNATE MISSION NO. 1 SUMMARY

ATX-350I, AVRG STAGE L = 2500 NMI, M = 0.80, 60 % LF 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 CL	AVG L/D RATIO	AVG SFC (FF/T)
TAKEOFF POWER 1	0.	0.0	450177.	0.	0.	0.	0.	0.0	0.0	0.	428601.	0.	0.0	0.0	0.936
POWER 2	0.	0.0	450177.	953.	953.	0.	0.	1.0	1.0	0.	428501.	0.	0.0	0.0	0.382
CLIMB	0.	0.378	449224.	2282.	3236.	14.	14.	3.1	4.1	0.	428201.	0.	0.463	18.19	0.536
ACCEL	10000.	0.456	446941.	328.	3564.	3.	16.	0.5	4.5	0.	428201.	0.	0.386	17.60	0.566
CLIMB	10000.	0.547	446613.	7022.	10586.	99.	115.	13.7	18.2	0.	428201.	0.	0.341	16.39	0.628
CRUISE	35000.	0.800	439591.	0.	10586.	0.	115.	0.0	18.2	0.	-428101.	0.	0.433	16.80	0.637
ACCEL	35000.	0.800	439591.	0.	10586.	0.	115.	0.0	18.2	0.	428201.	0.	0.433	16.80	0.639
ACCEL	35000.	0.800	439591.	0.	10586.	0.	115.	0.0	18.2	0.	428201.	0.	0.433	16.80	0.639
CRUISE	35000.	0.800	439591.	8127.	18712.	227.	342.	29.5	47.7	0.	-428101.	0.	0.429	16.77	0.637
CLIMB	35000.	0.800	431464.	2195.	20907.	51.	393.	6.6	54.4	0.	428201.	0.	0.475	16.84	0.639
CRUISE	39000.	0.800	429269.	62694.	83601.	1907.	2300.	249.4	303.7	0.	-428101.	0.	0.473	16.75	0.636
CLIMB	39000.	0.800	366575.	0.	83601.	0.	2300.	0.0	303.7	0.	428201.	0.	0.0	0.0	0.0
CRUISE	39000.	0.800	366575.	0.	83601.	0.	2300.	0.0	303.7	0.	-428101.	0.	0.437	16.62	0.639
DESCENT	39000.	0.800	366575.	1780.	85381.	114.	2414.	15.7	319.4	0.	428301.	0.	0.313	15.36	-0.316
DECEL	10000.	0.547	364795.	68.	85449.	4.	2418.	0.8	320.2	0.	428301.	0.	0.318	16.35	-7.015
DESCENT	10000.	0.456	364728.	657.	86105.	28.	2446.	6.1	326.3	0.	428301.	0.	0.379	17.45	-2.650
CRUISE	39000.	0.800	364071.	1658.	87764.	54.	2500.	7.1	333.4	0.	-428101.	0.	0.433	16.59	0.639
LOITER	1500.	0.330	362413.	666.	88429.	0.	2500.	3.0	336.4	0.	-80101.	0.	0.522	18.01	0.662
CRUISE	1500.	0.378	361747.	481.	88911.	0.	2500.	2.0	338.4	0.	-80101.	0.	0.397	17.66	0.705
RESET	0.	0.0	361266.	0.	88911.	-2500.	0.	0.0	338.4	0.	0.	0.	0.0	0.0	0.0
CRUISE	39000.	0.800	361266.	7802.	96712.	0.	0.	33.8	372.3	0.	-428101.	0.	0.426	16.53	0.640
TAKEOFF POWER 1	0.	0.0	353464.	0.	96712.	0.	0.	0.0	372.3	0.	428601.	0.	0.0	0.0	0.936
POWER 2	0.	0.0	353464.	953.	97665.	0.	0.	1.0	373.3	0.	428501.	0.	0.0	0.0	0.382
CLIMB	0.	0.378	352511.	1671.	99336.	10.	10.	2.2	375.5	0.	428201.	0.	0.361	17.17	0.536
ACCEL	10000.	0.456	350840.	241.	99577.	2.	12.	0.3	375.9	0.	428201.	0.	0.303	15.98	0.566

Configuration 6

CLIMB	10000.	0.547	350600.	3617.	103193.	44.	56.	6.5	382.4	0.	428201.	0.	0.258	14.61	0.617
CRUISE	30000.	0.715	346983.	1404.	104597.	44.	100.	6.2	388.6	0.	-428101.	0.	0.338	16.44	0.642
DESCENT	30000.	0.750	345579.	422.	105019.	49.	149.	7.4	396.0	0.	428301.	0.	0.254	14.51	-1.246
DECEL	10000.	0.547	345157.	66.	105084.	4.	154.	0.8	396.7	0.	428301.	0.	0.301	15.92	-7.038
DESCENT	10000.	0.456	345092.	646.	105730.	27.	181.	6.0	402.8	0.	428301.	0.	0.359	17.12	-2.634
CRUISE	30000.	0.710	344446.	604.	106334.	19.	200.	2.7	405.5	0.	-428101.	0.	0.341	16.51	0.641
CRUISE	1500.	0.378	343842.	7502.	113836.	0.	200.	32.0	437.5	0.	-80101.	0.	0.374	17.33	0.717

COST SUMMARY

Configuration 6

RDT AND E

	TOTAL *
DEVELOPMENT - NONRECURRING	
ENGINEERING	1054.53
TOOLING	540.26
TEST ARTICLES	76.82
DATA	0.0
SYSTEMS ENG/MNGMT	0.0
CRUISE ENGINE	0.0
LIFT ENGINE	0.0
FAN	0.0
AVIONICS	0.0
OTHER SYSTEMS	0.0
FACILITIES	0.0
TOTAL AIR VEHICLE	1671.60
INTEGR LOGISTICS SUPPORT	
PLANNING	12.96
TRAINING	4.41
HANDBOOKS	29.55
SSE	9.21
TOTAL ILS	56.12
TOTAL DVLPMNT-NONREC	1727.72
DEVELOPMENT - RECUR(PROTOTYPES)	
AIR VEHICLE	890.07
SPARES	16.41
TOTAL DVLPMNT-RECUR	906.47
GOVMNT DVLPMNT COST	0.0
TOTAL DVLPMNT COST	2634.20

PRODUCTION

	MATERIAL	LABOR	TOTAL PER PROD A/C**
STRUCTURE	5335.05	12347.34	17682.38
WING	2011.67	3301.13	5312.80
ROTOR	0.0	0.0	0.0
TAIL	290.53	878.18	1168.72
BODY	1247.44	5944.00	7191.45
ALIGHTING GEAR	981.87	31.34	1013.21
ENG SECT + NACELLE	803.54	2192.69	2996.23
ENG SECTION	0.0	0.0	0.0
NACELLE	779.91	2039.74	2819.66
AIR INDUCTION	23.63	152.94	176.57
PROPULSION	118.72	143.86	262.58
ENGINE INSTALL	0.0	36.90	36.90
THRUST REVERSER	0.0	6.92	6.92
EXHAUST SYSTEM	0.0	0.0	0.0
ENGINE CONTROLS	5.83	6.46	12.29
STARTING SYSTEM	0.0	0.0	0.0
PROPELLER INSTALL	0.0	0.0	0.0
LUBRICATING SYSTEM	0.0	0.0	0.0
FUEL SYSTEM	112.89	93.58	206.47
DRIVE SYS(PWR TRN)	0.0	0.0	0.0
SYSTEMS	4254.60	6645.66	10900.25
FLIGHT CONTROLS	1214.59	326.09	1540.68
AUX POWER PLANT	171.98	22.03	194.01
INSTRUMENTS	132.66	79.08	211.75
HYDRAULIC + PNEUM	0.0	0.0	0.0
ELECTRICAL	887.57	1030.65	1918.22
AVIONIC INSTALL	57.12	523.59	580.72
ARMAMENT	0.0	0.0	0.0
FURN AND EQUIP	1427.46	4387.98	5815.44
AIR CONDITIONING	353.28	268.66	621.94
ANTI-ICING	9.95	7.56	17.51
PHOTOGRAPHIC	0.0	0.0	0.0
LOAD AND HANDLING	0.0	0.0	0.0
SYSTEMS INTEGR	897.02	736.00	1633.03
TOTAL COST	10605.40	19872.85	30478.24
TOTAL HRS **		593.43	593.43
ENG CHANGE ORDERS			991.85
SUSTAINING ENG COST			1569.38
PROD TOOLING COST			2187.64
QUALITY ASSURANCE			2665.98
MISCELLANEOUS ***			925.20
TOTAL AIRFRAME COST			38818.25
ENGINE COST			11331.00
AVIONICS COST			1111.01
TOTAL MANUFACTURING COST			51260.25
WARRANTY			267.85
TOTAL PRODUCTION COST			51528.09

PROCUREMENT

	PER PROD A/C**
TOTAL PRODUCTION	51528.09
INTEGR LOGISTICS SUPPORT	
PLANNING	33.28
TRAINING	11.32
TRAINERS	220.56
HANDBOOKS	38.93
FACILITIES	0.0
SSE - CFE	0.0
SSE - GFE	2421.82
TOTAL ILS	2725.91
INITIAL SPARES COST	7484.83
PRODUCTION DEVELOPMENT	
ENGINEERING	318.50
TOOLING	311.58
ENGINES	0.0
TOTAL PROD DEV	630.08
TOTAL PROCUREMENT	62368.91

* - MILLIONS OF DOLLARS

** -1000 OF DOLLARS OR HOURS PER PROD A/C

*** - INCLUDES PROD DATA, SYSTEMS ENGR AND OTHER SYSTEMS

Configuration 6

OPERATIONAL COSTS

DIRECT OPERATIONAL COST (DOC)

	C/SM***	PERCENT
FLIGHT CREW	0.44754	8.88919
FUEL AND OIL	3.30185	65.58313
INSURANCE	0.03391	0.67345
DEPRECIATION	0.61434	12.20230
MAINTENANCE	0.63698	12.65195
TOTAL DOC	5.03460	100.000

INDIRECT OPERATIONAL COST (IOC)

	C/SM***	PERCENT
SYSTEM	0.0	0.0
LOCAL	0.57721	18.48169
AIRCRAFT CONTROL	0.01317	0.42163
CABIN ATTENDANT	0.44044	14.10244
FOOD AND BEVERAGE	0.16697	5.34634
PASSENGER HANDLING	0.63674	20.38780
CARGO HANDLING	0.17677	5.65997
OTHER PASSENGER EXPENSE	0.83200	26.63983
OTHER CARGO EXPENSE	0.00860	0.27524
GENERAL + ADMINISTRATION	0.27125	8.68520
TOTAL IOC	3.12314	100.000

MISC. DATA

FLIGHT DISTANCE (N. MI.)	2500.00
BLOCK FUEL (LBS)	90301.69
BLOCK TIME (HRS)	5.97
FLIGHT TIME (HRS)	5.64
AVG STAGE LENGTH (N. MI.)	2500.00
AVG CARGO PER FLIGHT	13695.72
UTILIZATION (HRS PER YR)	4140.19
FLIGHTS PER A/C PER YEAR	693.03
FARE ($)	374.96
FUEL COST ($/LB)	0.31600

*** - CENTS PER SEAT N. MILE

RATE OF RETURN ON INVESTMENT

YEAR	AVG NO AIRCRAFT DURING YEAR	AIRCRAFT ADDED DURING YEAR	AVERAGE INVESTMENT DURING YEAR	CUMULATIVE DEPRECIATION	AVERAGE BOOK VALUE OF FLEET	REVENUE	INTEREST EXPENSE	OPERATING EXPENSE	CASH FLOW	ROI
			$M	$M	$M	$M	$M	$M	$M	PERCENT
1	5.0	8.0	344.77	19.39	325.38	305.03	41.37	247.34	-126.91	15.22
2	13.0	8.0	896.41	69.82	826.59	793.08	100.95	643.09	-123.65	15.18
3	20.4	7.0	1404.95	148.84	1256.10	1242.99	148.73	1007.92	-101.22	15.28
4	23.0	0.0	1585.95	238.05	1347.90	1403.13	151.42	1137.78	19.30	15.46
5	23.0	0.0	1585.95	327.26	1258.69	1403.13	132.39	1137.78	28.81	15.80
6	23.0	0.0	1585.95	416.47	1169.48	1403.13	113.36	1137.78	38.33	16.19
7	23.0	0.0	1585.95	505.68	1080.27	1403.13	94.33	1137.78	47.85	16.65
8	23.0	0.0	1585.95	594.89	991.06	1403.13	75.30	1137.78	57.36	17.19
9	23.0	0.0	1585.95	684.10	901.85	1403.13	56.27	1137.78	66.88	17.83
10	23.0	0.0	1585.95	773.31	812.64	1403.13	37.24	1137.78	76.39	18.62
11	23.0	0.0	1585.95	862.52	723.43	1403.13	18.20	1137.78	130.04	19.60
12	23.0	0.0	1585.95	951.73	634.22	1403.13	5.79	1137.78	180.38	21.38
13	23.0	0.0	1585.95	1040.94	545.01	1403.13	-0.00	1137.78	221.89	24.34
14	23.0	0.0	1585.95	1130.15	455.80	1403.13	-0.00	1137.78	221.89	29.11
15	23.0	0.0	1585.95	1219.36	366.59	1403.13	-0.00	1137.78	221.89	36.19
16	23.0	0.0	1585.95	1308.57	277.38	1403.13	-0.00	1137.78	221.89	47.83

AVG ROI OVER THE 16 YEAR PERIOD = 18.76 PERCENT

Configuration 7A

ATX-350I, DESIGN RANGE = 4600 NMI, M = 0.80, INTERN. RESRVS MISS

T/C=10.30 AR= 7.78 W/S=129.00 T/W=0.265

CONFIGURATION GEOMETRY

BASIC WING--	AREA(SQ FT)	SPAN(FT)	TAPER RATIO	C/4 SWEEP	L.E. SWEEP	MAC(FT)		
	4780.2	192.85	0.246	35.000	37.883	27.81		
WING PANELS--	AREA(SQ FT)	EXP. AREA	AVG T/C	L.E. SWEEP	SFLE(SQ FT)	REF L(FT)		
	1135.8	102.6	11.12	37.879	0.0	49.31		
	2311.7	2311.7	10.61	37.879	0.0	38.99		
	421.2	421.2	9.29	37.879	0.0	25.72		
	1455.1	1455.1	9.03	37.879	0.0	18.93		
	155.7	155.7	9.03	37.879	0.0	10.95		
TOTAL WING--	AREA(SQ FT)	EFF AR	AVG T/C	CR(FT)	CT(FT)	MAC(FT)	L(FT)	E SWP
	5479.4	6.79	9.99	57.22	9.80	34.79	84.81	22.988
FUSELAGE--	LENGTH(FT)	S WET(SQ FT)	BWW(FT)	EQUIV D(FT)	SPI(SQ FT)			
	201.00	10801.7	19.32	19.58	301.21			
	BW(FT)	BH(FT)	SBW(SQ FT)					
	19.58	19.58	10538.00					
HORZ. TAIL 1--	SHT1(SQ FT)	SHX1(SQ FT)	REF L1(FT)	L HT1(FT)	HT1 VOL COEF			
	1780.04	1394.63	20.87	71.26	0.9540			
HORZ. TAIL 2--	SHT2(SQ FT)	SHX2(SQ FT)	REF L2(FT)	L HT2(FT)	HT2 VOL COEF			
	0.0	0.0	0.0	201.00	0.0			
VERT. TAIL 1--	SVT1(SQ FT)	SVX1(SQ FT)	REF L1(FT)	L VT1(FT)	VT1 VOL COEF			
	852.66	560.68	21.96	73.78	0.0682			
VERT. TAIL 2--	SVT2(SQ FT)	SVX2(SQ FT)	REF L2(FT)	L VT2(FT)	VT2 VOL COEF			
	0.0	0.0	0.0	201.00	0.0			
PROPULSION--	ENG L(FT)	ENG D(FT)	POD L(FT)	POD D(FT)	POD S WET	NO. PODS	INLET L(FT)	
	14.80	7.52	14.92	9.95	837.61	2.	27.40	
FUEL TANKS--	WING(CU FT)	BOX(CU FT)	FUS(CU FT)					
	4740.15	1187.30	999999.00					
WETTED VOLUMES--	BODY	WING	TAILS	PODS	PYLONS	PONTOONS	TOTAL	
	50699.91	9128.82	3189.46	1963.28	164.51	0.0	65145.98	

ATX-350I, DESIGN RANGE = 4600 NMI, M = 0.80, INTERN. RESRVS MISS

T/C=10.30 AR= 7.78 W/S=129.00 T/W=0.265

Configuration 7A

WEIGHT STATEMENT

	WEIGHT(POUNDS)	WEIGHT FRACTION	(PERCENT)
GROSS WEIGHT	(616650.)		
FUEL AVAILABLE	234294.	FUEL	37.99
EXTERNAL	0.		
INTERNAL	234293.		
ZERO FUEL WEIGHT	382357.		
PAYLOAD	73500.	PAYLOAD	11.92
PASSENGERS	57750.		
BAGGAGE	15750.		
CARGO	0.		
STORES	0.		
OPERATIONAL EMPTY WEIGHT	308857.		
OPERATIONAL ITEMS	10395.	OPERATIONAL ITEMS	3.25
STANDARD ITEMS	9671.		
EMPTY WEIGHT	288790.		
STRUCTURE	185749.	STRUCTURE	30.12
WING	64760.		
ROTOR	0.		
TAIL	12842.		
BODY	68132.		
ALIGHTING GEAR	25705.		
ENGINE SECTION AND NACELLE	14310.		
PROPULSION	36028.	PROPULSION	5.84
CRUISE ENGINES	28433.		
LIFT ENGINES	0.		
THRUST REVERSER	5052.		
EXHAUST SYSTEM	0.		
ENGINE CONTROL	234.		
STARTING SYSTEM	466.		
PROPELLERS	0.		
LUBRICATING SYSTEM	0.		
FUEL SYSTEM	1842.		
DRIVE SYSTEM (POWER TRANS)	0.		
SYSTEMS	67013.		
FLIGHT CONTROLS	8026.		
AUXILIARY POWER PLANT	1202.		
INSTRUMENTS	1035.		
HYDRAULIC AND PNEUMATIC	2816.		
ELECTRICAL	5670.		
AVIONICS	3075.	SYSTEMS	10.87
ARMAMENT	0.		
FURNISHINGS AND EQUIPMENT	38504.		
AIR CONDITIONING	6302.		
ANTI-ICING	383.		
PHOTOGRAPHIC	0.		
LOAD AND HANDLING	0.		
		TOTAL	(100.)

Configuration 7A

W E I G H T S   M A T R I X

ELEMENT/ / MATERIAL	AL	TIT.	STEEL	COMP.	OTHER	TOTAL
WING	58284.	1295.	4533.	0.	648.	64760.
ROTOR	0.	0.	0.	0.	0.	0.
TAIL	11558.	257.	899.	0.	128.	12842.
BODY	61318.	2725.	681.	1363.	2044.	68132.
L. G.	5655.	257.	16965.	0.	2828.	25705.
ENG SECT	0.	0.	0.	0.	0.	0.
NACELLE	3768.	4844.	2153.	0.	0.	10765.
AIR INDUCT	3191.	355.	0.	0.	0.	3545.
TOTALS	143774.	9733.	25232.	1363.	5648.	185749.

EXCESS FUEL CAPACITY - BODY	50159392.
EXCESS FUEL CAPACITY - WING	2895.
EXCESS BODY LENGTH - FT	0.0
AIRFRAME WEIGHT (A.M.P.R.) - LB	245944.
GUST LOAD FACTOR	0.0

Configuration 7A

ALTERNATE MISSION NO. 1 SUMMARY

ATX-350I, AVRG STAGE L = 2500 NMI, M = 0.80, 60 % LF 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 CL	AVG L/D RATIO	AVG SFC (FF/T)
TAKEOFF POWER 1	0.	0.0	474301.	0.	0.	0.	0.	0.0	0.0	0.	428601.	0.	0.0	0.0	0.934
POWER 2	0.	0.0	474301.	1010.	1010.	0.	0.	1.0	1.0	0.	428501.	0.	0.0	0.0	0.383
CLIMB	0.	0.378	473291.	2455.	3465.	14.	14.	3.1	4.1	0.	428201.	0.	0.464	18.28	0.544
ACCEL	10000.	0.456	470836.	353.	3818.	3.	17.	0.5	4.6	0.	428201.	0.	0.387	17.70	0.574
CLIMB	10000.	0.547	470483.	7642.	11460.	103.	120.	14.2	18.9	0.	428201.	0.	0.341	16.49	0.637
CRUISE	35000.	0.800	462841.	0.	11460.	0.	120.	0.0	18.9	0.	-428101.	0.	0.433	16.88	0.648
ACCEL	35000.	0.800	462841.	0.	11460.	0.	120.	0.0	18.9	0.	428201.	0.	0.433	16.88	0.648
ACCEL	35000.	0.800	462841.	0.	11460.	0.	120.	0.0	18.9	0.	428201.	0.	0.433	16.88	0.648
CRUISE	35000.	0.800	462841.	8929.	20389.	234.	353.	30.4	49.3	0.	-428101.	0.	0.429	16.85	0.648
CLIMB	35000.	0.800	453912.	2524.	22913.	56.	409.	7.3	56.6	0.	428201.	0.	0.476	16.91	0.648
CRUISE	39000.	0.800	451388.	66182.	89095.	1891.	2300.	247.2	303.8	0.	-428101.	0.	0.473	16.82	0.647
CLIMB	39000.	0.800	385206.	0.	89095.	0.	2300.	0.0	303.8	0.	428201.	0.	0.0	0.0	0.0
CRUISE	39000.	0.800	385206.	0.	89095.	0.	2300.	0.0	303.8	0.	-428101.	0.	0.436	16.69	0.650
DESCENT	39000.	0.800	385206.	1881.	90975.	113.	2413.	15.6	319.4	0.	428301.	0.	0.313	15.44	-0.316
DECEL	10000.	0.547	383325.	73.	91048.	4.	2417.	0.8	320.2	0.	428301.	0.	0.318	16.44	-6.997
DESCENT	10000.	0.456	383253.	707.	91755.	28.	2445.	6.2	326.4	0.	428301.	0.	0.379	17.54	-2.631
CRUISE	39000.	0.800	382546.	1771.	93526.	55.	2500.	7.1	333.5	0.	-428101.	0.	0.432	16.66	0.650
LOITER	1500.	0.330	380775.	714.	94240.	0.	2500.	3.0	336.5	0.	-80101.	0.	0.521	18.09	0.679
CRUISE	1500.	0.378	380061.	516.	94756.	0.	2500.	2.0	338.5	0.	-80101.	0.	0.396	17.74	0.724
RESET	0.	0.0	379545.	0.	94756.	-2500.	0.	0.0	338.5	0.	0.	0.	0.0	0.0	0.0
CRUISE	39000.	0.800	379545.	8307.	103063.	0.	0.	33.9	372.4	0.	-428101.	0.	0.425	16.60	0.651
TAKEOFF POWER 1	0.	0.0	371237.	0.	103063.	0.	0.	0.0	372.4	0.	428601.	0.	0.0	0.0	0.934
POWER 2	0.	0.0	371237.	1010.	104073.	0.	0.	1.0	373.4	0.	428501.	0.	0.0	0.0	0.383
CLIMB	0.	0.378	370228.	1786.	105859.	10.	10.	2.3	375.7	0.	428201.	0.	0.360	17.26	0.544
ACCEL	10000.	0.456	368441.	257.	106116.	2.	12.	0.4	376.0	0.	428201.	0.	0.302	16.06	0.574

CLIMB	10000.	0.547	368184.	3886.	110002.	46.	58.	6.6	382.7	0.	428201.	0.	0.258	14.69	0.626
CRUISE	30000.	0.715	364298.	1448.	111450.	42.	100.	6.0	388.7	0.	-428101.	0.	0.338	16.53	0.654
DESCENT	30000.	0.750	362850.	452.	111902.	50.	150.	7.4	396.1	0.	428301.	0.	0.254	14.59	-1.243
DECEL	10000.	0.547	362398.	71.	111973.	4.	154.	0.8	396.8	0.	428301.	0.	0.301	16.01	-7.021
DESCENT	10000.	0.456	362327.	695.	112667.	28.	181.	6.1	402.9	0.	428301.	0.	0.358	17.21	-2.615
CRUISE	30000.	0.715	361632.	634.	113301.	19.	200.	2.7	405.6	0.	-428101.	0.	0.338	16.54	0.654
CRUISE	1500.	0.378	360998.	8043.	121344.	0.	200.	32.0	437.6	0.	-80101.	0.	0.373	17.42	0.736

Configuration 7A

Configuration 7A

COST SUMMARY

RDT AND E

	TOTAL *
DEVELOPMENT - NONRECURRING	
ENGINEERING	1064.66
TOOLING	563.68
TEST ARTICLES	82.35
DATA	0.0
SYSTEMS ENG/MNGMT	0.0
CRUISE ENGINE	0.0
LIFT ENGINE	0.0
FAN	0.0
AVIONICS	0.0
OTHER SYSTEMS	0.0
FACILITIES	0.0
TOTAL AIR VEHICLE	1710.69
INTEGR LOGISTICS SUPPORT	
PLANNING	12.54
TRAINING	4.26
HANDBOOKS	34.20
SSE	8.91
TOTAL ILS	59.90
TOTAL DVLPMNT-NONREC	1770.59
DEVELOPMENT - RECUR(PROTOTYPES)	
AIR VEHICLE	934.42
SPARES	17.10
TOTAL DVLPMNT-RECUR	951.52
GOVMNT DVLPMNT COST	0.0
TOTAL DVLPMNT COST	2722.11

PRODUCTION

	MATERIAL	LABOR	TOTAL PER PROD A/C**
STRUCTURE	5609.97	12777.64	18387.61
WING	2132.23	3473.91	5606.14
ROTOR	0.0	0.0	0.0
TAIL	317.13	951.70	1268.83
BODY	1261.82	5969.45	7231.27
ALIGHTING GEAR	1031.48	32.68	1064.16
ENG SECT + NACELLE	867.32	2349.90	3217.22
ENG SECTION	0.0	0.0	0.0
NACELLE	841.78	2185.78	3027.56
AIR INDUCTION	25.54	164.12	189.66
PROPULSION	193.37	157.96	351.33
ENGINE INSTALL	0.0	39.54	39.54
THRUST REVERSER	0.0	7.03	7.03
EXHAUST SYSTEM	0.0	0.0	0.0
ENGINE CONTROLS	6.25	6.87	13.12
STARTING SYSTEM	71.49	9.36	80.85
PROPELLER INSTALL	0.0	0.0	0.0
LUBRICATING SYSTEM	0.0	0.0	0.0
FUEL SYSTEM	115.63	95.16	210.79
DRIVE SYS(PWR TRN)	0.0	0.0	0.0
SYSTEMS	4498.93	7628.82	12127.75
FLIGHT CONTROLS	1340.93	561.33	1902.26
AUX POWER PLANT	206.54	26.27	232.81
INSTRUMENTS	130.97	77.51	208.49
HYDRAULIC + PNEUM	214.38	404.45	618.83
ELECTRICAL	585.38	1192.86	1778.24
AVIONIC INSTALL	63.28	516.84	580.12
ARMAMENT	0.0	0.0	0.0
FURN AND EQUIP	1426.23	4352.82	5779.06
AIR CONDITIONING	500.81	468.30	969.11
ANTI-ICING	30.40	28.43	58.83
PHOTOGRAPHIC	0.0	0.0	0.0
LOAD AND HANDLING	0.0	0.0	0.0
SYSTEMS INTEGR	950.84	774.58	1725.42
TOTAL COST	11253.11	21338.97	32592.08
TOTAL HRS **		637.21	637.21
ENG CHANGE ORDERS			1060.98
SUSTAINING ENG COST			1572.67
PROD TOOLING COST			2349.03
QUALITY ASSURANCE			2862.66
MISCELLANEOUS ***			993.46
TOTAL AIRFRAME COST			41430.86
ENGINE COST			12026.59
AVIONICS COST			866.31
TOTAL MANUFACTURING COST			54323.76
WARRANTY			158.70
TOTAL PRODUCTION COST			54482.45

PROCUREMENT

	PER PROD A/C**
TOTAL PRODUCTION	54482.45
INTEGR LOGISTICS SUPPORT	
PLANNING	32.93
TRAINING	11.20
TRAINERS	220.56
HANDBOOKS	41.98
FACILITIES	0.0
SSE - CFE	0.0
SSE - GFE	2560.67
TOTAL ILS	2867.33
INITIAL SPARES COST	7928.04
PRODUCTION DEVELOPMENT	
ENGINEERING	315.14
TOOLING	334.57
ENGINES	0.0
TOTAL PROD DEV	649.72
TOTAL PROCUREMENT	65927.50

* - MILLIONS OF DOLLARS

** -1000 OF DOLLARS OR HOURS PER PROD A/C

*** - INCLUDES PROD DATA, SYSTEMS ENGR AND OTHER SYSTEMS

Configuration 7A

OPERATIONAL COSTS

DIRECT OPERATIONAL COST (DOC)

	C/SM***	PERCENT
FLIGHT CREW	0.44763	8.37107
FUEL AND OIL	3.51909	65.80997
INSURANCE	0.03065	0.57313
DEPRECIATION	0.64819	12.12161
MAINTENANCE	0.70180	13.12432
TOTAL DOC	5.34735	100.000

INDIRECT OPERATIONAL COST (IOC)

	C/SM***	PERCENT
SYSTEM	0.0	0.0
LOCAL	0.60749	19.19341
AIRCRAFT CONTROL	0.01317	0.41604
CABIN ATTENDANT	0.44053	13.91851
FOOD AND BEVERAGE	0.16701	5.27661
PASSENGER HANDLING	0.63674	20.11758
CARGO HANDLING	0.17677	5.58495
OTHER PASSENGER EXPENSE	0.83200	26.28677
OTHER CARGO EXPENSE	0.00860	0.27159
GENERAL + ADMINISTRATION	0.28279	8.93462
TOTAL IOC	3.16509	100.000

MISC. DATA

FLIGHT DISTANCE (N. MI.)	2500.00
BLOCK FUEL (LBS)	96244.06
BLOCK TIME (HRS)	5.98
FLIGHT TIME (HRS)	5.64
AVG STAGE LENGTH (N. MI.)	2500.00
AVG CARGO PER FLIGHT	13695.72
UTILIZATION (HRS PER YR)	4140.36
FLIGHTS PER A/C PER YEAR	692.91
FARE ($)	374.96
FUEL COST ($/LB)	0.31600

*** - CENTS PER SEAT N. MILE

- -

RATE OF RETURN ON INVESTMENT

YEAR	AVG NO AIRCRAFT DURING YEAR	AIRCRAFT ADDED DURING YEAR	AVERAGE INVESTMENT DURING YEAR	CUMULATIVE DEPRECIATION	AVERAGE BOOK VALUE OF FLEET	REVENUE	INTEREST EXPENSE	OPERATING EXPENSE	CASH FLOW	ROI
			$M	$M	$M	$M	$M	$M	$M	PERCENT
1	5.0	8.0	363.66	20.46	343.21	304.98	43.64	258.05	-140.82	13.19
2	13.0	8.0	945.53	73.64	871.88	792.94	106.48	670.94	-148.53	13.10
3	20.4	7.0	1481.93	157.00	1324.93	1242.78	156.88	1051.57	-135.13	13.14
4	23.0	0.0	1672.85	251.10	1421.76	1402.89	159.72	1187.05	-11.67	13.21
5	23.0	0.0	1672.85	345.20	1327.66	1402.89	139.65	1187.05	-1.63	13.39
6	23.0	0.0	1672.85	439.29	1233.56	1402.89	119.57	1187.05	8.41	13.60
7	23.0	0.0	1672.85	533.39	1139.46	1402.89	99.50	1187.05	18.44	13.84
8	23.0	0.0	1672.85	627.49	1045.36	1402.89	79.42	1187.05	28.48	14.12
9	23.0	0.0	1672.85	721.59	951.27	1402.89	59.35	1187.05	38.52	14.46
10	23.0	0.0	1672.85	815.68	857.17	1402.89	39.28	1187.05	48.55	14.88
11	23.0	0.0	1672.85	909.78	763.07	1402.89	19.20	1187.05	105.14	15.40
12	23.0	0.0	1672.85	1003.88	668.97	1402.89	6.11	1187.05	158.24	16.59
13	23.0	0.0	1672.85	1097.98	574.88	1402.89	-0.00	1187.05	202.02	18.77
14	23.0	0.0	1672.85	1192.08	480.78	1402.89	-0.00	1187.05	202.02	22.45
15	23.0	0.0	1672.85	1286.17	386.68	1402.89	-0.00	1187.05	202.02	27.91
16	23.0	0.0	1672.85	1380.27	292.58	1402.89	-0.00	1187.05	202.02	36.89

AVG ROI OVER THE 16 YEAR PERIOD = 15.33 PERCENT

ATX-350I, DESIGN RANGE = 4600 NMI, M = 0.80, INTERN. RESRVS MISS

T/C=10.30 AR= 7.78 W/S=129.00 T/W=0.265

Configuration 7B

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

BASIC WING--	AREA(SQ FT)	SPAN(FT)	TAPER RATIO	C/4 SWEEP	L.E. SWEEP	MAC(FT)		
	4763.3	192.50	0.246	35.000	37.883	27.77		
WING PANELS--	AREA(SQ FT)	EXP. AREA	AVG T/C	L.E. SWEEP	SFLE(SQ FT)	REF L(FT)		
	1131.8	100.6	11.12	37.879	0.0	49.21		
	2303.4	2303.4	10.61	37.879	0.0	38.92		
	419.7	419.7	9.29	37.879	0.0	25.67		
	1449.9	1449.9	9.03	37.879	0.0	18.89		
	155.2	155.2	9.03	37.879	0.0	10.93		
TOTAL WING--	AREA(SQ FT)	EFF AR	AVG T/C	CR(FT)	CT(FT)	MAC(FT)	L(FT)	E SWP
	5460.0	6.79	9.99	57.12	9.78	34.72	84.66	22.988
FUSELAGE--	LENGTH(FT)	S WET(SQ FT)	BWW(FT)	EQUIV D(FT)	SPI(SQ FT)			
	201.00	10797.7	19.32	19.58	301.21			
	BW(FT)	BH(FT)	SBW(SQ FT)					
	19.58	19.58	10538.00					
HORZ. TAIL 1--	SHT1(SQ FT)	SHX1(SQ FT)	REF L1(FT)	L HT1(FT)	HT1 VOL COEF			
	1769.74	1385.50	20.81	71.30	0.9540			
HORZ. TAIL 2--	SHT2(SQ FT)	SHX2(SQ FT)	REF L2(FT)	L HT2(FT)	HT2 VOL COEF			
	0.0	0.0	0.0	201.00	0.0			
VERT. TAIL 1--	SVT1(SQ FT)	SVX1(SQ FT)	REF L1(FT)	L VT1(FT)	VT1 VOL COEF			
	847.54	556.51	21.88	73.83	0.0682			
VERT. TAIL 2--	SVT2(SQ FT)	SVX2(SQ FT)	REF L2(FT)	L VT2(FT)	VT2 VOL COEF			
	0.0	0.0	0.0	201.00	0.0			
PROPULSION--	ENG L(FT)	ENG D(FT)	POD L(FT)	POD D(FT)	POD S WET	NO. PODS	INLET L(FT)	
	14.77	7.50	14.90	9.93	834.78	2.	27.35	
FUEL TANKS--	WING(CU FT)	BOX(CU FT)	FUS(CU FT)					
	4712.88	1182.76	999999.00					
WETTED VOLUMES--	BODY	WING	TAILS	PODS	PYLONS	PONTOONS	TOTAL	
	50689.13	9074.07	3157.22	1953.18	163.70	0.0	65037.29	

ATX-350I, DESIGN RANGE = 4600 NMI, M = 0.80, INTERN. RESRVS MISS

T/C=10.30 AR= 7.78 W/S=129.00 T/W=0.265

Configuration 7B

W E I G H T   S T A T E M E N T

	WEIGHT(POUNDS)	WEIGHT FRACTION	(PERCENT)
GROSS WEIGHT	(614460.)		
FUEL AVAILABLE	232771.	FUEL	37.88
EXTERNAL	0.		
INTERNAL	232770.		
ZERO FUEL WEIGHT	381689.		
PAYLOAD	73500.	PAYLOAD	11.96
PASSENGERS	57750.		
BAGGAGE	15750.		
CARGO	0.		
STORES	0.		
OPERATIONAL EMPTY WEIGHT	308189.		
OPERATIONAL ITEMS	10394.	OPERATIONAL ITEMS	3.27
STANDARD ITEMS	9669.		
EMPTY WEIGHT	288126.		
STRUCTURE	185258.	STRUCTURE	30.15
WING	64526.		
ROTOR	0.		
TAIL	12767.		
BODY	68096.		
ALIGHTING GEAR	25614.		
ENGINE SECTION AND NACELLE	14254.		
PROPULSION	35897.	PROPULSION	5.84
CRUISE ENGINES	28322.		
LIFT ENGINES	0.		
THRUST REVERSER	5040.		
EXHAUST SYSTEM	0.		
ENGINE CONTROL	233.		
STARTING SYSTEM	464.		
PROPELLERS	0.		
LUBRICATING SYSTEM	0.		
FUEL SYSTEM	1837.		
DRIVE SYSTEM (POWER TRANS)	0.		
SYSTEMS	66971.		
FLIGHT CONTROLS	7997.		
AUXILIARY POWER PLANT	1202.		
INSTRUMENTS	1034.		
HYDRAULIC AND PNEUMATIC	2807.		
ELECTRICAL	5668.		
AVIONICS	3075.	SYSTEMS	10.90
ARMAMENT	0.		
FURNISHINGS AND EQUIPMENT	38504.		
AIR CONDITIONING	6302.		
ANTI-ICING	382.		
PHOTOGRAPHIC	0.		
LOAD AND HANDLING	0.		
		TOTAL	(100.)

Configuration 7B

WEIGHTS MATRIX

ELEMENT/ / MATERIAL	AL	TIT.	STEEL	COMP.	OTHER	TOTAL
WING	58074.	1291.	4517.	0.	645.	64526.
ROTOR	0.	0.	0.	0.	0.	0.
TAIL	11491.	255.	894.	0.	128.	12767.
BODY	61287.	2724.	681.	1362.	2043.	68096.
L. G.	5635.	256.	16905.	0.	2818.	25614.
ENG SECT	0.	0.	0.	0.	0.	0.
NACELLE	3753.	4825.	2145.	0.	0.	10723.
AIR INDUCT	3178.	353.	0.	0.	0.	3531.
TOTALS	143417.	9704.	25141.	1362.	5633.	185257.

EXCESS FUEL CAPACITY - BODY	50159168.
EXCESS FUEL CAPACITY - WING	3053.
EXCESS BODY LENGTH - FT	0.0
AIRFRAME WEIGHT (A.M.P.R.) - LB	245423.
GUST LOAD FACTOR	0.0

Configuration 7B

ALTERNATE MISSION NO. 1 SUMMARY

ATX-350I, AVRG STAGE L = 2500 NMI, M = 0.80, 60 % LF 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 CL	AVG L/D RATIO	AVG SFC (FF/T)
TAKEOFF POWER 1	0.	0.0	472856.	0.	0.	0.	0.	0.0	0.0	0.	428601.	0.	0.0	0.0	0.934
POWER 2	0.	0.0	472856.	1006.	1006.	0.	0.	1.0	1.0	0.	428501.	0.	0.0	0.0	0.383
CLIMB	0.	0.378	471849.	2444.	3450.	14.	14.	3.1	4.1	0.	428201.	0.	0.464	18.36	0.544
ACCEL	10000.	0.456	469406.	351.	3801.	3.	17.	0.5	4.6	0.	428201.	0.	0.387	17.80	0.574
CLIMB	10000.	0.547	469054.	7565.	11366.	102.	119.	14.1	18.8	0.	428201.	0.	0.341	16.59	0.637
CRUISE	35000.	0.800	461489.	0.	11366.	0.	119.	0.0	18.8	0.	-428101.	0.	0.433	16.96	0.648
ACCEL	35000.	0.800	461489.	0.	11366.	0.	119.	0.0	18.8	0.	428201.	0.	0.433	16.96	0.648
ACCEL	35000.	0.800	461489.	0.	11366.	0.	119.	0.0	18.8	0.	428201.	0.	0.433	16.96	0.648
CRUISE	35000.	0.800	461489.	9758.	21124.	257.	376.	33.5	52.2	0.	-428101.	0.	0.429	16.92	0.649
CLIMB	35000.	0.800	451731.	2440.	23564.	54.	430.	7.1	59.3	0.	428201.	0.	0.475	16.98	0.648
CRUISE	39000.	0.800	449291.	64963.	88527.	1870.	2300.	244.4	303.8	0.	-428101.	0.	0.473	16.89	0.647
CLIMB	39000.	0.800	384328.	0.	88527.	0.	2300.	0.0	303.8	0.	428201.	0.	0.0	0.0	0.0
CRUISE	39000.	0.800	384328.	0.	88527.	0.	2300.	0.0	303.8	0.	-428101.	0.	0.437	16.77	0.650
DESCENT	39000.	0.800	384328.	1844.	90371.	113.	2413.	15.6	319.3	0.	428301.	0.	0.313	15.54	-0.328
DECEL	10000.	0.547	382484.	73.	90444.	4.	2417.	0.8	320.1	0.	428301.	0.	0.318	16.55	-6.996
DESCENT	10000.	0.456	382411.	709.	91153.	28.	2445.	6.2	326.4	0.	428301.	0.	0.379	17.64	-2.630
CRUISE	39000.	0.800	381702.	1765.	92918.	55.	2500.	7.2	333.5	0.	-428101.	0.	0.433	16.74	0.651
LOITER	1500.	0.330	379937.	710.	93628.	0.	2500.	3.0	336.5	0.	-80101.	0.	0.522	18.16	0.680
CRUISE	1500.	0.378	379227.	513.	94141.	0.	2500.	2.0	338.5	0.	-80101.	0.	0.397	17.84	0.725
RESET	0.	0.0	378713.	0.	94141.	-2500.	0.	0.0	338.5	0.	0.	0.	0.0	0.0	0.0
CRUISE	39000.	0.800	378713.	8253.	102395.	0.	0.	33.9	372.4	0.	-428101.	0.	0.426	16.68	0.651
TAKEOFF POWER 1	0.	0.0	370460.	0.	102395.	0.	0.	0.0	372.4	0.	428601.	0.	0.0	0.0	0.934
POWER 2	0.	0.0	370460.	1006.	103401.	0.	0.	1.0	373.4	0.	428501.	0.	0.0	0.0	0.383
CLIMB	0.	0.378	369454.	1780.	105181.	10.	10.	2.3	375.7	0.	428201.	0.	0.361	17.36	0.544
ACCEL	10000.	0.456	367674.	256.	105437.	2.	12.	0.4	376.0	0.	428201.	0.	0.303	16.18	0.574

CLIMB	10000.	0.547	367417.	3859.	109297.	45.	57.	6.6	382.6	0.	428201.	0.	0.258	14.80	0.626
CRUISE	30000.	0.715	363558.	1443.	110739.	43.	100.	6.1	388.7	0.	-428101.	0.	0.338	16.63	0.655
DESCENT	30000.	0.750	362115.	454.	111193.	50.	150.	7.4	396.1	0.	428301.	0.	0.254	14.71	-1.243
DECEL	10000.	0.547	361661.	71.	111264.	4.	154.	0.8	396.9	0.	428301.	0.	0.301	16.12	-7.020
DESCENT	10000.	0.456	361591.	697.	111961.	28.	182.	6.1	403.0	0.	428301.	0.	0.358	17.32	-2.613
CRUISE	30000.	0.715	360894.	611.	112572.	18.	200.	2.6	405.6	0.	-428101.	0.	0.336	16.59	0.655
CRUISE	1500.	0.378	360283.	7995.	120566.	0.	200.	32.0	437.6	0.	-80101.	0.	0.373	17.52	0.737

Configuration 7B

...iguration 7B

Development

ENGINEERING	1062.14
TOOLING	562.77
TEST ARTICLES	82.23
DATA	0.0
SYSTEMS ENG/MNGMT	0.0
CRUISE ENGINE	0.0
LIFT ENGINE	0.0
FAN	0.0
AVIONICS	0.0
OTHER SYSTEMS	0.0
FACILITIES	0.0
TOTAL AIR VEHICLE	1707.13
INTEGR LOGISTICS SUPPORT	
PLANNING	12.51
TRAINING	4.25
HANDBOOKS	34.10
SSE	8.89
TOTAL ILS	59.75
TOTAL DVLPMNT-NONREC	1766.88
DEVELOPMENT - RECUR(PROTOTYPES)	
AIR VEHICLE	932.91
SPARES	17.05
TOTAL DVLPMNT-RECUR	949.96
GOVMNT DVLPMNT COST	0.0
TOTAL DVLPMNT COST	2716.84

Production

	MATERIAL	LABOR	TOTAL PER PROD A/C**
STRUCTURE	5592.90	12751.14	18344.03
WING	2124.60	3462.45	5587.05
ROTOR	0.0	0.0	0.0
TAIL	315.29	946.45	1261.73
BODY	1261.21	5968.21	7229.42
ALIGHTING GEAR	1027.85	32.58	1060.43
ENG SECT + NACELLE	863.96	2341.45	3205.40
ENG SECTION	0.0	0.0	0.0
NACELLE	838.52	2177.92	3016.45
AIR INDUCTION	25.43	163.52	188.96
PROPULSION	192.74	157.51	350.25
ENGINE INSTALL	0.0	39.40	39.40
THRUST REVERSER	0.0	7.01	7.01
EXHAUST SYSTEM	0.0	0.0	0.0
ENGINE CONTROLS	6.23	6.85	13.08
STARTING SYSTEM	71.21	9.32	80.53
PROPELLER INSTALL	0.0	0.0	0.0
LUBRICATING SYSTEM	0.0	0.0	0.0
FUEL SYSTEM	115.30	94.92	210.22
DRIVE SYS(PWR TRN)	0.0	0.0	0.0
SYSTEMS	4493.10	7627.35	12120.45
FLIGHT CONTROLS	1335.99	559.41	1895.40
AUX POWER PLANT	206.54	26.28	232.82
INSTRUMENTS	130.91	77.50	208.41
HYDRAULIC + PNEUM	213.70	403.28	616.99
ELECTRICAL	585.21	1192.84	1778.05
AVIONIC INSTALL	63.28	517.00	580.28
ARMAMENT	0.0	0.0	0.0
FURN AND EQUIP	1426.28	4354.19	5780.47
AIR CONDITIONING	500.82	468.45	969.27
ANTI-ICING	30.36	28.40	58.76
PHOTOGRAPHIC	0.0	0.0	0.0
LOAD AND HANDLING	0.0	0.0	0.0
SYSTEMS INTEGR	948.69	773.04	1721.72
TOTAL COST	11227.43	21309.01	32536.43
TOTAL HRS **		636.32	636.32

ENG CHANGE ORDERS	1059.20
SUSTAINING ENG COST	1570.06
PROD TOOLING COST	2345.73
QUALITY ASSURANCE	2858.64
MISCELLANEOUS ***	992.06
TOTAL AIRFRAME COST	41362.09
ENGINE COST	11990.32
AVIONICS COST	866.31
TOTAL MANUFACTURING COST	54218.72
WARRANTY	158.43
TOTAL PRODUCTION COST	54377.15

PROCUREMENT

	PER PROD A/C**
TOTAL PRODUCTION	54377.15
INTEGR LOGISTICS SUPPORT	
PLANNING	32.88
TRAINING	11.18
TRAINERS	220.56
HANDBOOKS	41.90
FACILITIES	0.0
SSE - CFE	0.0
SSE - GFE	2555.73
TOTAL ILS	2862.24
INITIAL SPARES COST	7910.68
PRODUCTION DEVELOPMENT	
ENGINEERING	314.64
TOOLING	334.10
ENGINES	0.0
TOTAL PROD DEV	648.74
TOTAL PROCUREMENT	65798.75

* - MILLIONS OF DOLLARS

** -1000 OF DOLLARS OR HOURS PER PROD A/C

*** - INCLUDES PROD DATA, SYSTEMS ENGR AND OTHER SYSTEMS

Configuration 7B

OPERATIONAL COSTS

DIRECT OPERATIONAL COST (DOC)

	C/SM***	PERCENT
FLIGHT CREW	0.44763	8.41127
FUEL AND OIL	3.49644	65.69989
INSURANCE	0.03059	0.57477
DEPRECIATION	0.64692	12.15595
MAINTENANCE	0.70026	13.15826
TOTAL DOC	5.32184	100.000

INDIRECT OPERATIONAL COST (IOC)

	C/SM***	PERCENT
SYSTEM	0.0	0.0
LOCAL	0.60533	19.14421
AIRCRAFT CONTROL	0.01317	0.41645
CABIN ATTENDANT	0.44054	13.93244
FOOD AND BEVERAGE	0.16701	5.28189
PASSENGER HANDLING	0.63674	20.13756
CARGO HANDLING	0.17677	5.59049
OTHER PASSENGER EXPENSE	0.83200	26.31285
OTHER CARGO EXPENSE	0.00860	0.27186
GENERAL + ADMINISTRATION	0.28180	8.91234
TOTAL IOC	3.16195	100.000

MISC. DATA

FLIGHT DISTANCE (N. MI.)	2500.00
BLOCK FUEL (LBS)	95624.50
BLOCK TIME (HRS)	5.98
FLIGHT TIME (HRS)	5.64
AVG STAGE LENGTH (N. MI.)	2500.00
AVG CARGO PER FLIGHT	13695.72
UTILIZATION (HRS PER YR)	4140.36
FLIGHTS PER A/C PER YEAR	692.91
FARE ($)	374.96
FUEL COST ($/LB)	0.31600

*** - CENTS PER SEAT N. MILE

RATE OF RETURN ON INVESTMENT

YEAR	AVG NO AIRCRAFT DURING YEAR	AIRCRAFT ADDED DURING YEAR	AVERAGE INVESTMENT DURING YEAR	CUMULATIVE DEPRECIATION	AVERAGE BOOK VALUE OF FLEET	REVENUE	INTEREST EXPENSE	OPERATING EXPENSE	CASH FLOW	ROI
			$M	$M	$M	$M	$M	$M	$M	PERCENT
1	5.0	8.0	362.95	20.42	342.54	304.97	43.55	257.18	-140.07	13.33
2	13.0	8.0	943.68	73.50	870.18	792.93	106.27	668.68	-146.99	13.25
3	20.4	7.0	1479.04	156.69	1322.34	1242.77	156.58	1048.02	-132.91	13.28
4	23.0	0.0	1669.59	250.61	1418.98	1402.88	159.41	1183.04	-9.44	13.36
5	23.0	0.0	1669.59	344.52	1325.07	1402.88	139.37	1183.04	0.58	13.55
6	23.0	0.0	1669.59	438.44	1231.15	1402.88	119.34	1183.04	10.60	13.77
7	23.0	0.0	1669.59	532.35	1137.24	1402.88	99.30	1183.04	20.62	14.03
8	23.0	0.0	1669.59	626.26	1043.32	1402.88	79.27	1183.04	30.63	14.33
9	23.0	0.0	1669.59	720.18	949.41	1402.88	59.23	1183.04	40.65	14.70
10	23.0	0.0	1669.59	814.09	855.50	1402.88	39.20	1183.04	50.67	15.14
11	23.0	0.0	1669.59	908.01	761.58	1402.88	19.16	1183.04	107.14	15.69
12	23.0	0.0	1669.59	1001.92	667.67	1402.88	6.10	1183.04	160.13	16.92
13	23.0	0.0	1669.59	1095.84	573.75	1402.88	-0.00	1183.04	203.83	19.16
14	23.0	0.0	1669.59	1189.75	479.84	1402.88	-0.00	1183.04	203.83	22.91
15	23.0	0.0	1669.59	1283.66	385.93	1402.88	-0.00	1183.04	203.83	28.48
16	23.0	0.0	1669.59	1377.58	292.01	1402.88	-0.00	1183.04	203.83	37.64

AVG ROI OVER THE 16 YEAR PERIOD = 15.57 PERCENT

Configuration 7F

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ATX-350I, DESIGN RANGE = 4600 NMI, M = 0.80, INTERN. RESRVS   MISS

T/C=10.30        AR= 7.78        W/S=125.00        T/W=0.279

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

BASIC WING--     AREA(SQ FT)   SPAN(FT)  TAPER RATIO  C/4 SWEEP  L.E. SWEEP   MAC(FT)
                   4727.4      191.78       0.246      35.000      37.883      27.66

WING PANELS--    AREA(SQ FT)   EXP. AREA   AVG T/C   L.E. SWEEP  SFLE(SQ FT)  REF L(FT)
                   1123.2        96.2       11.12      37.879       0.0        49.01
                   2286.1      2286.1       10.61      37.879       0.0        38.78
                    416.5       416.5        9.29      37.879       0.0        25.58
                   1439.0      1439.0        9.03      37.879       0.0        18.82
                    154.0       154.0        9.03      37.879       0.0        10.89

TOTAL WING--     AREA(SQ FT)    EFF AR     AVG T/C     CR(FT)      CT(FT)     MAC(FT)     L(FT)    E SWP
                   5418.9        6.79        9.99       56.90        9.74       34.59      84.34    22.988

FUSELAGE--       LENGTH(FT)  S WET(SQ FT)  BWW(FT)   EQUIV D(FT)  SPI(SQ FT)
                   201.00      11121.0      19.32       19.58      301.21

                    BW(FT)      BH(FT)    SBW(SQ FT)
                    19.58       19.58     10538.00

HORZ. TAIL 1--   SHT1(SQ FT) SHX1(SQ FT)  REF L1(FT)   L HT1(FT)  HT1 VOL COEF
                   1748.10     1366.35      20.67       71.37      0.9540

HORZ. TAIL 2--   SHT2(SQ FT) SHX2(SQ FT)  REF L2(FT)   L HT2(FT)  HT2 VOL COEF
                    0.0         0.0          0.0       201.00      0.0

VERT. TAIL 1--   SVT1(SQ FT) SVX1(SQ FT)  REF L1(FT)   L VT1(FT)  VT1 VOL COEF
                   886.94      588.60       22.47       73.44      0.0718

VERT. TAIL 2--   SVT2(SQ FT) SVX2(SQ FT)  REF L2(FT)   L VT2(FT)  VT2 VOL COEF
                    0.0         0.0          0.0       201.00      0.0

PROPULSION--       ENG L(FT)   ENG D(FT)   POD L(FT)   POD D(FT)   POD S WET    NO. PODS  INLET L(FT)
                    13.00        8.51       13.11       11.26      832.90        2.        34.75

FUEL TANKS--     WING(CU FT)  BOX(CU FT)  FUS(CU FT)
                   4655.54     1173.20    999999.00

WETTED VOLUMES-- BODY           WING       TAILS        PODS       PYLONS      PONTOONS    TOTAL
                   51609.30    8959.01     3191.79     2209.12     143.75        0.0      66112.94
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ATX-350I, DESIGN RANGE = 4600 NMI, M = 0.80, INTERN. RESRVS MISS

T/C=10.30 AR= 7.78 W/S=125.00 T/W=0.279

Configuration 7F

W E I G H T   S T A T E M E N T

	WEIGHT(POUNDS)	WEIGHT FRACTION	(PERCENT)
GROSS WEIGHT	(590931.)		
FUEL AVAILABLE	201408.	FUEL	34.08
EXTERNAL	0.		
INTERNAL	201408.		
ZERO FUEL WEIGHT	389523.		
PAYLOAD	73500.	PAYLOAD	12.44
PASSENGERS	57750.		
BAGGAGE	15750.		
CARGO	0.		
STORES	0.		
OPERATIONAL EMPTY WEIGHT	316023.		
OPERATIONAL ITEMS	10398.	OPERATIONAL ITEMS	3.39
STANDARD ITEMS	9630.		
EMPTY WEIGHT	295995.		
STRUCTURE	186702.	STRUCTURE	31.59
WING	63992.		
ROTOR	0.		
TAIL	12772.		
BODY	67982.		
ALIGHTING GEAR	24633.		
ENGINE SECTION AND NACELLE	17323.		
PROPULSION	42480.	PROPULSION	7.19
CRUISE ENGINES	35630.		
LIFT ENGINES	0.		
THRUST REVERSER	4240.		
EXHAUST SYSTEM	0.		
ENGINE CONTROL	236.		
STARTING SYSTEM	584.		
PROPELLERS	0.		
LUBRICATING SYSTEM	0.		
FUEL SYSTEM	1790.		
DRIVE SYSTEM (POWER TRANS)	0.		
SYSTEMS	66814.		
FLIGHT CONTROLS	7918.		
AUXILIARY POWER PLANT	1202.		
INSTRUMENTS	1033.		
HYDRAULIC AND PNEUMATIC	2710.		
ELECTRICAL	5664.		
AVIONICS	3075.	SYSTEMS	11.31
ARMAMENT	0.		
FURNISHINGS AND EQUIPMENT	38504.		
AIR CONDITIONING	6302.		
ANTI-ICING	405.		
PHOTOGRAPHIC	0.		
LOAD AND HANDLING	0.		
		TOTAL	(100.)

Configuration 7F

W E I G H T S   M A T R I X

ELEMENT/ / MATERIAL	AL	TIT.	STEEL	COMP.	OTHER	TOTAL
WING	57593.	1280.	4479.	0.	640.	63992.
ROTOR	0.	0.	0.	0.	0.	0.
TAIL	11495.	255.	894.	0.	128.	12772.
BODY	61183.	2719.	680.	1360.	2039.	67982.
L. G.	5419.	246.	16258.	0.	2710.	24633.
ENG SECT	0.	0.	0.	0.	0.	0.
NACELLE	3163.	6464.	2888.	1238.	0.	13753.
AIR INDUCT	2463.	357.	0.	750.	0.	3570.
TOTALS	141317.	11322.	25199.	3347.	5517.	186701.

EXCESS FUEL CAPACITY - BODY	50158688.
EXCESS FUEL CAPACITY - WING	31583.
EXCESS BODY LENGTH - FT	0.0
AIRFRAME WEIGHT (A.M.P.R.) - LB	246236.
GUST LOAD FACTOR	0.0

Configuration 7F

ALTERNATE MISSION NO. 1 SUMMARY

ATX-350I, AVRG STAGE L = 2500 NMI, M = 0.80, 60 % LF 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 CL	AVG L/D RATIO	AVG SFC (FF/T)
TAKEOFF POWER 1	0.	0.0	466652.	0.	0.	0.	0.	0.0	0.0	0.	429601.	0.	0.0	0.0	0.929
POWER 2	0.	0.0	466652.	773.	773.	0.	0.	1.0	1.0	0.	429501.	0.	0.0	0.0	0.293
CLIMB	0.	0.378	465879.	2015.	2788.	13.	13.	3.0	4.0	0.	429201.	0.	0.461	18.22	0.461
ACCEL	10000.	0.456	463864.	296.	3084.	3.	16.	0.5	4.5	0.	429201.	0.	0.385	17.63	0.492
CLIMB	10000.	0.547	463568.	6305.	9389.	97.	113.	13.4	17.9	0.	429201.	0.	0.339	16.42	0.549
CRUISE	35000.	0.800	457263.	0.	9389.	0.	113.	0.0	17.9	0.	-429101.	0.	0.432	16.83	0.558
ACCEL	35000.	0.800	457263.	0.	9389.	0.	113.	0.0	17.9	0.	429201.	0.	0.432	16.83	0.558
ACCEL	35000.	0.800	457263.	0.	9389.	0.	113.	0.0	17.9	0.	429201.	0.	0.432	16.83	0.558
CRUISE	35000.	0.800	457263.	2319.	11708.	71.	183.	9.2	27.1	0.	-429101.	0.	0.431	16.82	0.558
CLIMB	35000.	0.800	454944.	1634.	13342.	39.	222.	5.1	32.2	0.	429201.	0.	0.480	16.87	0.558
CRUISE	39000.	0.800	453310.	62966.	76308.	2078.	2300.	271.6	303.8	0.	-429101.	0.	0.482	16.79	0.555
CLIMB	39000.	0.800	390344.	0.	76308.	0.	2300.	0.0	303.8	0.	429201.	0.	0.0	0.0	0.0
CRUISE	39000.	0.800	390344.	0.	76308.	0.	2300.	0.0	303.8	0.	-429101.	0.	0.447	16.71	0.558
DESCENT	39000.	0.800	390344.	1807.	78114.	113.	2413.	15.6	319.4	0.	429301.	0.	0.321	15.57	-0.344
DECEL	10000.	0.547	388538.	78.	78193.	4.	2417.	0.8	320.2	0.	429301.	0.	0.326	16.57	-6.963
DESCENT	10000.	0.456	388459.	766.	78959.	28.	2445.	6.2	326.4	0.	429301.	0.	0.388	17.61	-2.588
CRUISE	39000.	0.800	387693.	1543.	80501.	55.	2500.	7.2	333.6	0.	-429101.	0.	0.443	16.68	0.558
LOITER	1500.	0.330	386150.	740.	81241.	0.	2500.	3.0	336.6	0.	-80101.	0.	0.534	18.00	0.690
CRUISE	1500.	0.378	385411.	532.	81774.	0.	2500.	2.0	338.6	0.	-80101.	0.	0.406	17.80	0.738
RESET	0.	0.0	384878.	0.	81774.	-2500.	0.	0.0	338.6	0.	0.	0.	0.0	0.0	0.0
CRUISE	39000.	0.800	384878.	7229.	89003.	0.	0.	33.9	372.4	0.	-429101.	0.	0.437	16.64	0.559
TAKEOFF POWER 1	0.	0.0	377649.	0.	89003.	0.	0.	0.0	372.4	0.	429601.	0.	0.0	0.0	0.929
POWER 2	0.	0.0	377649.	773.	89776.	0.	0.	1.0	373.4	0.	429501.	0.	0.0	0.0	0.293
CLIMB	0.	0.378	376876.	1534.	91309.	10.	10.	2.3	375.7	0.	429201.	0.	0.371	17.37	0.461
ACCEL	10000.	0.456	375342.	225.	91535.	2.	12.	0.4	376.1	0.	429201.	0.	0.311	16.23	0.492

CLIMB	10000.	0.547	375117.	3421.	94955.	46.	58.	6.8	382.8	0.	429201.	0.	0.266	14.92	0.540
CRUISE	30000.	0.740	371696.	1305.	96260.	42.	100.	5.7	388.5	0.	-429101.	0.	0.327	16.19	0.596
DESCENT	30000.	0.750	370391.	491.	96751.	50.	150.	7.4	396.0	0.	429301.	0.	0.262	14.83	-1.237
DECEL	10000.	0.547	369900.	77.	96827.	4.	154.	0.8	396.8	0.	429301.	0.	0.310	16.20	-6.984
DESCENT	10000.	0.456	369824.	756.	97583.	28.	182.	6.1	402.9	0.	429301.	0.	0.369	17.34	-2.572
CRUISE	30000.	0.735	369068.	569.	98152.	18.	200.	2.5	405.4	0.	-429101.	0.	0.328	16.20	0.597
CRUISE	1500.	0.378	368499.	8317.	106469.	0.	200.	32.0	437.4	0.	-80101.	0.	0.385	17.53	0.751

Configuration 7F

COST SUMMARY

RDT AND E

	TOTAL *
DEVELOPMENT - NONRECURRING	
ENGINEERING	1080.98
TOOLING	564.19
TEST ARTICLES	84.12
DATA	0.0
SYSTEMS ENG/MNGMT	0.0
CRUISE ENGINE	0.0
LIFT ENGINE	0.0
FAN	0.0
AVIONICS	0.0
OTHER SYSTEMS	0.0
FACILITIES	0.0
TOTAL AIR VEHICLE	1729.29
INTEGR LOGISTICS SUPPORT	
PLANNING	12.73
TRAINING	4.33
HANDBOOKS	34.33
SSE	9.05
TOTAL ILS	60.45
TOTAL DVLPMNT-NONREC	1789.73
DEVELOPMENT - RECUR(PROTOTYPES)	
AIR VEHICLE	983.30
SPARES	22.92
TOTAL DVLPMNT-RECUR	1006.22
GOVMNT DVLPMNT COST	0.0
TOTAL DVLPMNT COST	2795.95

PRODUCTION

	MATERIAL	LABOR	TOTAL PER PROD A/C**
STRUCTURE	5768.94	13280.04	19048.97
WING	2106.18	3421.21	5527.39
ROTOR	0.0	0.0	0.0
TAIL	315.28	943.33	1258.61
BODY	1258.59	5936.38	7194.97
ALIGHTING GEAR	988.11	31.22	1019.32
ENG SECT + NACELLE	1100.78	2947.91	4048.69
ENG SECTION	0.0	0.0	0.0
NACELLE	1075.08	2783.21	3858.28
AIR INDUCTION	25.70	164.70	190.40
PROPULSION	208.15	166.00	374.16
ENGINE INSTALL	0.0	49.39	49.39
THRUST REVERSER	0.0	5.88	5.88
EXHAUST SYSTEM	0.0	0.0	0.0
ENGINE CONTROLS	6.30	6.91	13.21
STARTING SYSTEM	89.55	11.69	101.24
PROPELLER INSTALL	0.0	0.0	0.0
LUBRICATING SYSTEM	0.0	0.0	0.0
FUEL SYSTEM	112.30	92.15	204.44
DRIVE SYS(PWR TRN)	0.0	0.0	0.0
SYSTEMS	4472.15	7580.91	12053.06
FLIGHT CONTROLS	1322.36	551.90	1874.26
AUX POWER PLANT	206.46	26.18	232.64
INSTRUMENTS	130.72	77.13	207.85
HYDRAULIC + PNEUM	206.26	387.96	594.21
ELECTRICAL	584.57	1187.64	1772.22
AVIONIC INSTALL	63.25	515.11	578.37
ARMAMENT	0.0	0.0	0.0
FURN AND EQUIP	1425.72	4338.25	5763.98
AIR CONDITIONING	500.63	466.73	967.36
ANTI-ICING	32.18	30.00	62.17
PHOTOGRAPHIC	0.0	0.0	0.0
LOAD AND HANDLING	0.0	0.0	0.0
SYSTEMS INTEGR	974.22	791.24	1765.46
TOTAL COST	11423.47	21818.16	33241.61
TOTAL HRS **		651.52	651.52
ENG CHANGE ORDERS			1082.34
SUSTAINING ENG COST			1613.35
PROD TOOLING COST			2401.78
QUALITY ASSURANCE			2926.94
MISCELLANEOUS ***			1015.77
TOTAL AIRFRAME COST			42281.77
ENGINE COST			16334.52
AVIONICS COST			866.31
TOTAL MANUFACTURING COST			59482.59
WARRANTY			161.93
TOTAL PRODUCTION COST			59644.51

PROCUREMENT

	PER PROD A/C**
TOTAL PRODUCTION	59644.51
INTEGR LOGISTICS SUPPORT	
PLANNING	33.63
TRAINING	11.43
TRAINERS	220.56
HANDBOOKS	42.12
FACILITIES	0.0
SSE - CFE	0.0
SSE - GFE	2803.29
TOTAL ILS	3111.04
INITIAL SPARES COST	9184.78
PRODUCTION DEVELOPMENT	
ENGINEERING	321.83
TOOLING	342.08
ENGINES	0.0
TOTAL PROD DEV	663.92
TOTAL PROCUREMENT	72604.19

* - MILLIONS OF DOLLARS

** -1000 OF DOLLARS OR HOURS PER PROD A/C

*** - INCLUDES PROD DATA, SYSTEMS ENGR AND OTHER SYSTEMS

Configuration 7F

OPERATIONAL COSTS

DIRECT OPERATIONAL COST (DOC)	C/SM***	PERCENT
FLIGHT CREW	0.44770	9.10226
FUEL AND OIL	3.04860	61.98203
INSURANCE	0.03330	0.67711
DEPRECIATION	0.70967	14.42842
MAINTENANCE	0.67926	13.81026
TOTAL DOC	4.91852	100.000

INDIRECT OPERATIONAL COST (IOC)	C/SM***	PERCENT
SYSTEM	0.0	0.0
LOCAL	0.58215	18.65503
AIRCRAFT CONTROL	0.01317	0.42197
CABIN ATTENDANT	0.44060	14.11897
FOOD AND BEVERAGE	0.16703	5.35261
PASSENGER HANDLING	0.63674	20.40433
CARGO HANDLING	0.17677	5.66455
OTHER PASSENGER EXPENSE	0.83200	26.66142
OTHER CARGO EXPENSE	0.00860	0.27546
GENERAL + ADMINISTRATION	0.26356	8.44573
TOTAL IOC	3.12061	100.000

MISC. DATA	
FLIGHT DISTANCE (N. MI.)	2500.00
BLOCK FUEL (LBS)	83374.63
BLOCK TIME (HRS)	5.98
FLIGHT TIME (HRS)	5.64
AVG STAGE LENGTH (N. MI.)	2500.00
AVG CARGO PER FLIGHT	13695.72
UTILIZATION (HRS PER YR)	4140.47
FLIGHTS PER A/C PER YEAR	692.83
FARE ($)	374.96
FUEL COST ($/LB)	0.31600

*** - CENTS PER SEAT N. MILE

RATE OF RETURN ON INVESTMENT

YEAR	AVG NO AIRCRAFT DURING YEAR	AIRCRAFT ADDED DURING YEAR	AVERAGE INVESTMENT DURING YEAR	CUMULATIVE DEPRECIATION	AVERAGE BOOK VALUE OF FLEET	REVENUE	INTEREST EXPENSE	OPERATING EXPENSE	CASH FLOW	ROI
			$M	$M	$M	$M	$M	$M	$M	PERCENT
1	5.0	8.0	397.97	22.39	375.58	304.94	47.76	243.68	-149.15	14.51
2	13.0	8.0	1034.72	80.59	954.13	792.84	116.53	633.56	-149.65	14.45
3	20.4	7.0	1621.73	171.81	1449.92	1242.63	171.68	992.98	-127.68	14.53
4	23.0	0.0	1830.66	274.79	1555.88	1402.72	174.79	1120.91	10.03	14.67
5	23.0	0.0	1830.66	377.76	1452.90	1402.72	152.82	1120.91	21.02	14.96
6	23.0	0.0	1830.66	480.73	1349.93	1402.72	130.85	1120.91	32.00	15.28
7	23.0	0.0	1830.66	583.71	1246.95	1402.72	108.88	1120.91	42.99	15.67
8	23.0	0.0	1830.66	686.68	1143.98	1402.72	86.92	1120.91	53.97	16.12
9	23.0	0.0	1830.66	789.66	1041.01	1402.72	64.95	1120.91	64.95	16.66
10	23.0	0.0	1830.66	892.63	938.03	1402.72	42.98	1120.91	75.94	17.31
11	23.0	0.0	1830.66	995.61	835.06	1402.72	21.01	1120.91	137.86	18.13
12	23.0	0.0	1830.66	1098.58	732.08	1402.72	6.69	1120.91	195.97	19.70
13	23.0	0.0	1830.66	1201.56	629.11	1402.72	-0.00	1120.91	243.88	22.40
14	23.0	0.0	1830.66	1304.53	526.13	1402.72	-0.00	1120.91	243.88	26.78
15	23.0	0.0	1830.66	1407.50	423.16	1402.72	-0.00	1120.91	243.88	33.30
16	23.0	0.0	1830.66	1510.48	320.18	1402.72	-0.00	1120.91	243.88	44.01

AVG ROI OVER THE 16 YEAR PERIOD = 17.56 PERCENT

ATX-350I, DESIGN RANGE = 4600 NMI, M = 0.80, INTERN. RESRVS MISS

T/C=10.30 AR= 7.78 W/S=129.00 T/W=0.265

Configuration 7G

CONFIGURATION GEOMETRY

BASIC WING--	AREA(SQ FT)	SPAN(FT)	TAPER RATIO	C/4 SWEEP	L.E. SWEEP	MAC(FT)		
	4814.0	193.53	0.246	35.000	37.883	27.91		
WING PANELS--	AREA(SQ FT)	EXP. AREA	AVG T/C	L.E. SWEEP	SFLE(SQ FT)	REF L(FT)		
	1143.8	106.8	12.58	37.879	0.0	49.49		
	2328.0	2328.0	11.64	37.879	0.0	39.13		
	424.2	424.2	9.99	37.879	0.0	25.81		
	1465.4	1465.4	9.86	37.879	0.0	19.00		
	156.8	156.8	9.46	37.879	0.0	10.99		
TOTAL WING--	AREA(SQ FT)	EFF AR	AVG T/C	CR(FT)	CT(FT)	MAC(FT)	L(FT)	E SWP
	5518.2	6.79	11.24	57.42	9.83	34.91	85.11	22.988
FUSELAGE--	LENGTH(FT)	S WET(SQ FT)	BWW(FT)	EQUIV D(FT)	SPI(SQ FT)			
	201.00	10809.8	19.32	19.58	301.21			
	BW(FT)	BH(FT)	SBW(SQ FT)					
	19.58	19.58	10538.00					
HORZ. TAIL 1--	SHT1(SQ FT)	SHX1(SQ FT)	REF L1(FT)	L HT1(FT)	HT1 VOL COEF			
	1800.62	1412.87	21.01	71.20	0.9540			
HORZ. TAIL 2--	SHT2(SQ FT)	SHX2(SQ FT)	REF L2(FT)	L HT2(FT)	HT2 VOL COEF			
	0.0	0.0	0.0	201.00	0.0			
VERT. TAIL 1--	SVT1(SQ FT)	SVX1(SQ FT)	REF L1(FT)	L VT1(FT)	VT1 VOL COEF			
	862.91	569.01	22.11	73.68	0.0682			
VERT. TAIL 2--	SVT2(SQ FT)	SVX2(SQ FT)	REF L2(FT)	L VT2(FT)	VT2 VOL COEF			
	0.0	0.0	0.0	201.00	0.0			
PROPULSION--	ENG L(FT)	ENG D(FT)	POD L(FT)	POD D(FT)	POD S WET	NO. PODS	INLET L(FT)	
	14.84	7.54	14.97	9.99	843.23	2.	27.51	
FUEL TANKS--	WING(CU FT)	BOX(CU FT)	FUS(CU FT)					
	5251.39	1369.66	999999.00					
WETTED VOLUMES--	BODY	WING	TAILS	PODS	PYLONS	PONTOONS	TOTAL	
	50721.43	10132.59	3254.26	1983.44	166.14	0.0	66257.81	

Configuration 7G

ATX-350I, DESIGN RANGE = 4600 NMI, M = 0.80, INTERN. RESRVS MISS

T/C=10.30 AR= 7.78 W/S=129.00 T/W=0.265

W E I G H T   S T A T E M E N T

	WEIGHT(POUNDS)		WEIGHT FRACTION	(PERCENT)
GROSS WEIGHT		(621010.)		
FUEL AVAILABLE		236797.	FUEL	38.13
EXTERNAL	0.			
INTERNAL	236795.			
ZERO FUEL WEIGHT		384214.		
PAYLOAD		73500.	PAYLOAD	11.84
PASSENGERS	57750.			
BAGGAGE	15750.			
CARGO	0.			
STORES	0.			
OPERATIONAL EMPTY WEIGHT		310714.		
OPERATIONAL ITEMS	10397.		OPERATIONAL ITEMS	3.23
STANDARD ITEMS	9674.			
EMPTY WEIGHT		290642.		
STRUCTURE	187258.		STRUCTURE	30.15
WING	65453.			
ROTOR	0.			
TAIL	12992.			
BODY	68207.			
ALIGHTING GEAR	25887.			
ENGINE SECTION AND NACELLE	14719.			
PROPULSION	36288.		PROPULSION	5.84
CRUISE ENGINES	28655.			
LIFT ENGINES	0.			
THRUST REVERSER	5077.			
EXHAUST SYSTEM	0.			
ENGINE CONTROL	235.			
STARTING SYSTEM	470.			
PROPELLERS	0.			
LUBRICATING SYSTEM	0.			
FUEL SYSTEM	1852.			
DRIVE SYSTEM (POWER TRANS)	0.			
SYSTEMS	67096.			
FLIGHT CONTROLS	8086.			
AUXILIARY POWER PLANT	1202.			
INSTRUMENTS	1036.			
HYDRAULIC AND PNEUMATIC	2834.			
ELECTRICAL	5673.			
AVIONICS	3075.		SYSTEMS	10.80
ARMAMENT	0.			
FURNISHINGS AND EQUIPMENT	38504.			
AIR CONDITIONING	6302.			
ANTI-ICING	384.			
PHOTOGRAPHIC	0.			
LOAD AND HANDLING	0.			
			TOTAL	(100.)

Configuration 7G

W E I G H T S   M A T R I X

ELEMENT/ / MATERIAL	AL	TIT.	STEEL	COMP.	OTHER	TOTAL
WING	58907.	1309.	4582.	0.	655.	65453.
ROTOR	0.	0.	0.	0.	0.	0.
TAIL	11693.	260.	909.	0.	130.	12992.
BODY	61386.	2728.	682.	1364.	2046.	68207.
L. G.	5695.	259.	17085.	0.	2848.	25887.
ENG SECT	0.	0.	0.	0.	0.	0.
NACELLE	3901.	5016.	2229.	0.	0.	11146.
AIR INDUCT	3216.	357.	0.	0.	0.	3574.
TOTALS	144799.	9929.	25488.	1364.	5678.	187257.

EXCESS FUEL CAPACITY - BODY	50168528.
EXCESS FUEL CAPACITY - WING	26003.
EXCESS BODY LENGTH - FT	0.0
AIRFRAME WEIGHT (A.M.P.R.) - LB	247510.
GUST LOAD FACTOR	0.0

ALTERNATE MISSION NO. 1 SUMMARY

Configuration 7G

ATX-350I, AVRG STAGE L = 2500 NMI, M = 0.80, 60 % LF 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 CL	AVG L/D RATIO	AVG SFC (FF/T)
TAKEOFF POWER 1	0.	0.0	478691.	0.	0.	0.	0.	0.0	0.0	0.	428601.	0.	0.0	0.0	0.933
POWER 2	0.	0.0	478691.	1016.	1016.	0.	0.	1.0	1.0	0.	428501.	0.	0.0	0.0	0.383
CLIMB	0.	0.378	477675.	2551.	3568.	15.	15.	3.2	4.2	0.	428201.	0.	0.465	17.16	0.544
ACCEL	10000.	0.456	475123.	375.	3943.	3.	17.	0.5	4.8	0.	428201.	0.	0.387	16.26	0.574
CLIMB	10000.	0.547	474748.	11186.	15129.	173.	191.	23.5	28.3	0.	428201.	0.	0.390	15.99	0.641
CRUISE	39000.	0.800	463562.	0.	15129.	0.	191.	0.0	28.3	0.	-428101.	0.	0.521	17.07	0.645
ACCEL	39000.	0.800	463562.	0.	15129.	0.	191.	0.0	28.3	0.	428201.	0.	0.521	17.07	0.651
ACCEL	39000.	0.800	463562.	0.	15129.	0.	191.	0.0	28.3	0.	428201.	0.	0.521	17.07	0.651
CRUISE	39000.	0.800	463562.	74801.	89929.	2109.	2300.	275.8	304.1	0.	-428101.	0.	0.478	16.90	0.647
CLIMB	39000.	0.800	388762.	0.	89929.	0.	2300.	0.0	304.1	0.	428201.	0.	0.0	0.0	0.0
CRUISE	39000.	0.800	388762.	0.	89929.	0.	2300.	0.0	304.1	0.	-428101.	0.	0.437	16.57	0.649
CLIMB	39000.	0.800	388762.	0.	89929.	0.	2300.	0.0	304.1	0.	428201.	0.	0.0	0.0	0.0
CRUISE	39000.	0.800	388762.	0.	89929.	0.	2300.	0.0	304.1	0.	-428101.	0.	0.437	16.57	0.649
DESCENT	39000.	0.800	388762.	2283.	92212.	119.	2419.	16.2	320.3	0.	428301.	0.	0.315	14.50	-0.158
DECEL	10000.	0.547	386479.	66.	92278.	4.	2423.	0.7	321.0	0.	428301.	0.	0.318	14.86	-7.028
DESCENT	10000.	0.456	386413.	650.	92928.	26.	2448.	5.6	326.7	0.	428301.	0.	0.379	16.07	-2.668
CRUISE	39000.	0.800	385763.	1713.	94641.	52.	2500.	6.8	333.4	0.	-428101.	0.	0.433	16.51	0.650
LOITER	1500.	0.300	384050.	725.	95366.	0.	2500.	3.0	336.4	0.	-80101.	0.	0.642	16.61	0.628
CRUISE	1500.	0.378	383324.	549.	95916.	0.	2500.	2.0	338.4	0.	-80101.	0.	0.397	16.27	0.700
RESET	0.	0.0	382775.	0.	95916.	-2500.	0.	0.0	338.4	0.	0.	0.	0.0	0.0	0.0
CRUISE	39000.	0.800	382775.	8460.	104376.	0.	0.	33.8	372.3	0.	-428101.	0.	0.426	16.41	0.650
TAKEOFF POWER 1	0.	0.0	374315.	0.	104376.	0.	0.	0.0	372.3	0.	428601.	0.	0.0	0.0	0.933
POWER 2	0.	0.0	374315.	1016.	105392.	0.	0.	1.0	373.3	0.	428501.	0.	0.0	0.0	0.383
CLIMB	0.	0.378	373298.	1859.	107251.	11.	11.	2.4	375.7	0.	428201.	0.	0.361	15.78	0.544
ACCEL	10000.	0.456	371439.	273.	107524.	2.	13.	0.4	376.0	0.	428201.	0.	0.302	14.44	0.574

CLIMB	10000.	0.547	371166.	4346.	111870.	51.	63.	7.4	383.4	0.	428201.	0.	0.258	13.11	0.626
CRUISE	30000.	0.735	366820.	1356.	113227.	37.	100.	5.1	388.5	0.	-428101.	0.	0.319	14.84	0.653
DESCENT	30000.	0.750	365463.	430.	113657.	45.	145.	6.7	395.2	0.	428301.	0.	0.254	12.98	-1.210
DECEL	10000.	0.547	365033.	64.	113721.	4.	149.	0.7	395.9	0.	428301.	0.	0.301	14.39	-7.058
DESCENT	10000.	0.456	364969.	637.	114358.	25.	174.	5.5	401.4	0.	428301.	0.	0.358	15.72	-2.654
CRUISE	30000.	0.735	364332.	966.	115324.	26.	200.	3.6	405.0	0.	-428101.	0.	0.317	14.79	0.653
CRUISE	1500.	0.378	363366.	8550.	123874.	0.	200.	32.0	437.0	0.	-80101.	0.	0.372	15.93	0.711

Configuration 7G

Configuration 7G

COST SUMMARY

RDT AND E

	TOTAL *
DEVELOPMENT - NONRECURRING	
ENGINEERING	1104.11
TOOLING	566.42
TEST ARTICLES	83.51
DATA	0.0
SYSTEMS ENG/MNGMT	0.0
CRUISE ENGINE	0.0
LIFT ENGINE	0.0
FAN	0.0
AVIONICS	0.0
OTHER SYSTEMS	0.0
FACILITIES	0.0
TOTAL AIR VEHICLE	1754.04
INTEGR LOGISTICS SUPPORT	
PLANNING	12.60
TRAINING	4.28
HANDBOOKS	34.17
SSE	8.95
TOTAL ILS	60.00
TOTAL DVLPMNT-NONREC	1814.05
DEVELOPMENT - RECUR(PROTOTYPES)	
AIR VEHICLE	948.33
SPARES	17.20
TOTAL DVLPMNT-RECUR	965.53
GOVMNT DVLPMNT COST	0.0
TOTAL DVLPMNT COST	2779.58

PRODUCTION

	MATERIAL	LABOR	TOTAL PER PROD A/C**
STRUCTURE	5674.61	12900.14	18574.75
WING	2154.83	3508.00	5662.83
ROTOR	0.0	0.0	0.0
TAIL	320.80	961.96	1282.76
BODY	1263.10	5970.88	7233.98
ALIGHTING GEAR	1038.68	32.89	1071.56
ENG SECT + NACELLE	897.21	2426.40	3323.61
ENG SECTION	0.0	0.0	0.0
NACELLE	871.47	2261.12	3132.60
AIR INDUCTION	25.74	165.28	191.02
PROPULSION	194.54	158.78	353.32
ENGINE INSTALL	0.0	39.82	39.82
THRUST REVERSER	0.0	7.05	7.05
EXHAUST SYSTEM	0.0	0.0	0.0
ENGINE CONTROLS	6.29	6.91	13.21
STARTING SYSTEM	72.04	9.42	81.46
PROPELLER INSTALL	0.0	0.0	0.0
LUBRICATING SYSTEM	0.0	0.0	0.0
FUEL SYSTEM	116.21	95.57	211.78
DRIVE SYS(PWR TRN)	0.0	0.0	0.0
SYSTEMS	4510.43	7629.86	12140.29
FLIGHT CONTROLS	1350.76	565.00	1915.76
AUX POWER PLANT	206.52	26.25	232.76
INSTRUMENTS	131.09	77.53	208.62
HYDRAULIC + PNEUM	215.73	406.67	622.40
ELECTRICAL	585.71	1192.60	1778.31
AVIONIC INSTALL	63.27	516.39	579.66
ARMAMENT	0.0	0.0	0.0
FURN AND EQUIP	1426.10	4349.04	5775.14
AIR CONDITIONING	500.76	467.90	968.66
ANTI-ICING	30.49	28.49	58.98
PHOTOGRAPHIC	0.0	0.0	0.0
LOAD AND HANDLING	0.0	0.0	0.0
SYSTEMS INTEGR	956.85	778.86	1735.72
TOTAL COST	11336.45	21467.60	32804.03
TOTAL HRS **		641.05	641.05
ENG CHANGE ORDERS			1067.84
SUSTAINING ENG COST			1624.76
PROD TOOLING COST			2363.19
QUALITY ASSURANCE			2879.92
MISCELLANEOUS ***			999.45
TOTAL AIRFRAME COST			41739.15
ENGINE COST			12098.75
AVIONICS COST			866.31
TOTAL MANUFACTURING COST			54704.21
WARRANTY			159.87
TOTAL PRODUCTION COST			54864.06

PROCUREMENT

	PER PROD A/C**
TOTAL PRODUCTION	54864.06
INTEGR LOGISTICS SUPPORT	
PLANNING	33.06
TRAINING	11.24
TRAINERS	220.56
HANDBOOKS	41.95
FACILITIES	0.0
SSE - CFE	0.0
SSE - GFE	2578.61
TOTAL ILS	2885.42
INITIAL SPARES COST	7981.43
PRODUCTION DEVELOPMENT	
ENGINEERING	316.40
TOOLING	336.59
ENGINES	0.0
TOTAL PROD DEV	652.99
TOTAL PROCUREMENT	66383.88

* - MILLIONS OF DOLLARS

** -1000 OF DOLLARS OR HOURS PER PROD A/C

*** - INCLUDES PROD DATA, SYSTEMS ENGR AND OTHER SYSTEMS

Configuration 7G

OPERATIONAL COSTS

DIRECT OPERATIONAL COST (DOC)	C/SM***	PERCENT
FLIGHT CREW	0.44754	8.28869
FUEL AND OIL	3.56186	65.96765
INSURANCE	0.03090	0.57235
DEPRECIATION	0.65348	12.10275
MAINTENANCE	0.70563	13.06864
TOTAL DOC	5.39941	100.000

INDIRECT OPERATIONAL COST (IOC)	C/SM***	PERCENT
SYSTEM	0.0	0.0
LOCAL	0.61178	19.29211
AIRCRAFT CONTROL	0.01317	0.41524
CABIN ATTENDANT	0.44044	13.88904
FOOD AND BEVERAGE	0.16698	5.26544
PASSENGER HANDLING	0.63674	20.07909
CARGO HANDLING	0.17677	5.57426
OTHER PASSENGER EXPENSE	0.83200	26.23645
OTHER CARGO EXPENSE	0.00860	0.27107
GENERAL + ADMINISTRATION	0.28469	8.97742
TOTAL IOC	3.17116	100.000

MISC. DATA	
FLIGHT DISTANCE (N. MI.)	2500.00
BLOCK FUEL (LBS)	97413.94
BLOCK TIME (HRS)	5.97
FLIGHT TIME (HRS)	5.64
AVG STAGE LENGTH (N. MI.)	2500.00
AVG CARGO PER FLIGHT	13695.72
UTILIZATION (HRS PER YR)	4140.20
FLIGHTS PER A/C PER YEAR	693.03
FARE ($)	374.96
FUEL COST ($/LB)	0.31600

*** - CENTS PER SEAT N. MILE

- -

RATE OF RETURN ON INVESTMENT

YEAR	AVG NO AIRCRAFT DURING YEAR	AIRCRAFT ADDED DURING YEAR	AVERAGE INVESTMENT DURING YEAR	CUMULATIVE DEPRECIATION	AVERAGE BOOK VALUE OF FLEET	REVENUE	INTEREST EXPENSE	OPERATING EXPENSE	CASH FLOW	ROI
			$M	$M	$M	$M	$M	$M	$M	PERCENT
1	5.0	8.0	366.66	20.62	346.04	305.03	44.00	259.86	-143.06	12.88
2	13.0	8.0	953.33	74.25	879.08	793.07	107.36	675.63	-152.53	12.79
3	20.4	7.0	1494.16	158.30	1335.86	1242.98	158.18	1058.92	-140.61	12.81
4	23.0	0.0	1686.65	253.17	1433.48	1403.12	161.04	1195.35	-16.69	12.86
5	23.0	0.0	1686.65	348.04	1338.61	1403.12	140.80	1195.35	-6.57	13.02
6	23.0	0.0	1686.65	442.92	1243.74	1403.12	120.56	1195.35	3.55	13.20
7	23.0	0.0	1686.65	537.79	1148.86	1403.12	100.32	1195.35	13.67	13.41
8	23.0	0.0	1686.65	632.67	1053.99	1403.12	80.08	1195.35	23.79	13.66
9	23.0	0.0	1686.65	727.54	959.11	1403.12	59.84	1195.35	33.91	13.95
10	23.0	0.0	1686.65	822.41	864.24	1403.12	39.60	1195.35	44.03	14.31
11	23.0	0.0	1686.65	917.29	769.37	1403.12	19.36	1195.35	101.08	14.76
12	23.0	0.0	1686.65	1012.16	674.49	1403.12	6.16	1195.35	154.62	15.86
13	23.0	0.0	1686.65	1107.03	579.62	1403.12	-0.00	1195.35	198.76	17.92
14	23.0	0.0	1686.65	1201.91	484.75	1403.12	-0.00	1195.35	198.76	21.43
15	23.0	0.0	1686.65	1296.78	389.87	1403.12	-0.00	1195.35	198.76	26.65
16	23.0	0.0	1686.65	1391.66	295.00	1403.12	-0.00	1195.35	198.76	35.22

AVG ROI OVER THE 16 YEAR PERIOD = 14.81 PERCENT

ATX-350I, DESIGN RANGE = 4600 NMI, M = 0.80, INTERN. RESRVS MISS

T/C=10.30 AR= 7.78 W/S=136.00 T/W=0.291

Configuration 7J

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

BASIC WING--	AREA(SQ FT)	SPAN(FT)	TAPER RATIO	C/4 SWEEP	L.E. SWEEP	MAC(FT)		
	4386.4	184.73	0.246	35.000	37.883	26.64		
WING PANELS--	AREA(SQ FT)	EXP. AREA	AVG T/C	L.E. SWEEP	SFLE(SQ FT)	REF L(FT)		
	1042.2	55.6	12.57	37.879	0.0	47.07		
	2121.2	2121.2	11.64	37.879	0.0	37.35		
	386.5	386.5	9.99	37.879	0.0	24.64		
	1335.2	1335.2	9.86	37.879	0.0	18.13		
	142.9	142.9	9.46	37.879	0.0	10.49		
TOTAL WING--	AREA(SQ FT)	EFF AR	AVG T/C	CR(FT)	CT(FT)	MAC(FT)	L(FT)	E SWP
	5028.0	6.79	11.24	54.81	9.39	33.32	81.24	22.988
FUSELAGE--	LENGTH(FT)	S WET(SQ FT)	BWW(FT)	EQUIV D(FT)	SPI(SQ FT)			
	201.00	11198.2	19.32	19.58	301.21			
	BW(FT)	BH(FT)	SBW(SQ FT)					
	19.58	19.58	10538.00					
HORZ. TAIL 1--	SHT1(SQ FT)	SHX1(SQ FT)	REF L1(FT)	L HT1(FT)	HT1 VOL COEF			
	1547.74	1189.75	19.33	72.04	0.9540			
HORZ. TAIL 2--	SHT2(SQ FT)	SHX2(SQ FT)	REF L2(FT)	L HT2(FT)	HT2 VOL COEF			
	0.0	0.0	0.0	201.00	0.0			
VERT. TAIL 1--	SVT1(SQ FT)	SVX1(SQ FT)	REF L1(FT)	L VT1(FT)	VT1 VOL COEF			
	819.32	533.64	21.45	74.11	0.0749			
VERT. TAIL 2--	SVT2(SQ FT)	SVX2(SQ FT)	REF L2(FT)	L VT2(FT)	VT2 VOL COEF			
	0.0	0.0	0.0	201.00	0.0			
PROPULSION--	ENG L(FT)	ENG D(FT)	POD L(FT)	POD D(FT)	POD S WET	NO. PODS	INLET L(FT)	
	13.31	8.73	13.42	11.55	874.73	2.	35.69	
FUEL TANKS--	WING(CU FT)	BOX(CU FT)	FUS(CU FT)					
	4512.91	1227.23	999999.00					
WETTED VOLUMES--	BODY	WING	TAILS	PODS	PYLONS	PONTOONS	TOTAL	
	51845.41	8648.43	2648.36	2380.69	154.52	0.0	65677.38	

ATX-350I, DESIGN RANGE = 4600 NMI, M = 0.80, INTERN. RESRVS MISS

Configuration 7J

T/C=10.30 AR= 7.78 W/S=136.00 T/W=0.291

W E I G H T   S T A T E M E N T

	WEIGHT(POUNDS)	WEIGHT FRACTION	(PERCENT)
GROSS WEIGHT	(596556.)		
FUEL AVAILABLE	208431.	FUEL	34.94
EXTERNAL	0.		
INTERNAL	208431.		
ZERO FUEL WEIGHT	388125.		
PAYLOAD	73500.	PAYLOAD	12.32
PASSENGERS	57750.		
BAGGAGE	15750.		
CARGO	0.		
STORES	0.		
OPERATIONAL EMPTY WEIGHT	314625.		
OPERATIONAL ITEMS	10412.	OPERATIONAL ITEMS	3.36
STANDARD ITEMS	9639.		
EMPTY WEIGHT	294574.		
STRUCTURE	183470.	STRUCTURE	30.75
WING	60134.		
ROTOR	0.		
TAIL	11418.		
BODY	68035.		
ALIGHTING GEAR	24867.		
ENGINE SECTION AND NACELLE	19016.		
PROPULSION	44866.	PROPULSION	7.52
CRUISE ENGINES	37768.		
LIFT ENGINES	0.		
THRUST REVERSER	4391.		
EXHAUST SYSTEM	0.		
ENGINE CONTROL	248.		
STARTING SYSTEM	619.		
PROPELLERS	0.		
LUBRICATING SYSTEM	0.		
FUEL SYSTEM	1840.		
DRIVE SYSTEM (POWER TRANS)	0.		
SYSTEMS	66238.		
FLIGHT CONTROLS	7368.		
AUXILIARY POWER PLANT	1202.		
INSTRUMENTS	1022.		
HYDRAULIC AND PNEUMATIC	2733.		
ELECTRICAL	5625.		
AVIONICS	3075.	SYSTEMS	11.10
ARMAMENT	0.		
FURNISHINGS AND EQUIPMENT	38504.		
AIR CONDITIONING	6302.		
ANTI-ICING	405.		
PHOTOGRAPHIC	0.		
LOAD AND HANDLING	0.		
		TOTAL	(100.)

WEIGHTS MATRIX

Configuration 7J

ELEMENT/ / MATERIAL	AL	TIT.	STEEL	COMP.	OTHER	TOTAL
WING	54121.	1203.	4209.	0.	601.	60134.
ROTOR	0.	0.	0.	0.	0.	0.
TAIL	10277.	228.	799.	0.	114.	11418.
BODY	61231.	2721.	680.	1361.	2041.	68035.
L. G.	5471.	249.	16413.	0.	2735.	24867.
ENG SECT	0.	0.	0.	0.	0.	0.
NACELLE	3504.	7160.	3199.	1371.	0.	15234.
AIR INDUCT	2610.	378.	0.	794.	0.	3782.
TOTALS	137212.	11939.	25301.	3526.	5492.	183470.

EXCESS FUEL CAPACITY - BODY	50161392.
EXCESS FUEL CAPACITY - WING	17405.
EXCESS BODY LENGTH - FT	0.0
AIRFRAME WEIGHT (A.M.P.R.) - LB	242586.
GUST LOAD FACTOR	0.0

Configuration 7J

ALTERNATE MISSION NO. 1 SUMMARY

ATX-350I, AVRG STAGE L = 2500 NMI, M = 0.80, 60 % LF 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 CL	AVG L/D RATIO	AVG SFC (FF/T)
TAKEOFF POWER 1	0.	0.0	469344.	0.	0.	0.	0.	0.0	0.0	0.	429601.	0.	0.0	0.0	0.927
POWER 2	0.	0.0	469344.	812.	812.	0.	0.	1.0	1.0	0.	429501.	0.	0.0	0.0	0.292
CLIMB	0.	0.378	468532.	2060.	2872.	13.	13.	2.9	3.9	0.	429201.	0.	0.500	16.65	0.460
ACCEL	10000.	0.456	466473.	307.	3178.	3.	15.	0.5	4.4	0.	429201.	0.	0.416	15.91	0.490
CLIMB	10000.	0.547	466166.	8082.	11260.	130.	146.	17.8	22.2	0.	429201.	0.	0.406	15.52	0.550
CRUISE	39000.	0.800	458084.	0.	11260.	0.	146.	0.0	22.2	0.	-429101.	0.	0.565	16.37	0.551
ACCEL	39000.	0.800	458084.	0.	11260.	0.	146.	0.0	22.2	0.	429201.	0.	0.565	16.37	0.559
ACCEL	39000.	0.800	458084.	0.	11260.	0.	146.	0.0	22.2	0.	429201.	0.	0.565	16.37	0.559
CRUISE	39000.	0.800	458084.	67227.	78487.	2154.	2300.	281.7	303.8	0.	-429101.	0.	0.523	16.39	0.554
CLIMB	39000.	0.800	390857.	0.	78487.	0.	2300.	0.0	303.8	0.	429201.	0.	0.0	0.0	0.0
CRUISE	39000.	0.800	390857.	0.	78487.	0.	2300.	0.0	303.8	0.	-429101.	0.	0.482	16.27	0.558
CLIMB	39000.	0.800	390857.	0.	78487.	0.	2300.	0.0	303.8	0.	429201.	0.	0.0	0.0	0.0
CRUISE	39000.	0.800	390857.	0.	78487.	0.	2300.	0.0	303.8	0.	-429101.	0.	0.482	16.27	0.558
DESCENT	39000.	0.800	390857.	2250.	80737.	119.	2419.	16.3	320.1	0.	429301.	0.	0.347	14.51	-0.174
DECEL	10000.	0.547	388607.	74.	80811.	4.	2423.	0.7	320.8	0.	429301.	0.	0.351	14.82	-6.956
DESCENT	10000.	0.456	388533.	723.	81534.	25.	2448.	5.6	326.4	0.	429301.	0.	0.418	15.86	-2.608
CRUISE	39000.	0.800	387810.	1501.	83035.	52.	2500.	6.8	333.2	0.	-429101.	0.	0.478	16.24	0.559
LOITER	1500.	0.305	386309.	779.	83814.	0.	2500.	3.0	336.2	0.	-80101.	0.	0.674	16.07	0.648
CRUISE	1500.	0.378	385530.	573.	84387.	0.	2500.	2.0	338.2	0.	-80101.	0.	0.438	16.12	0.723
RESET	0.	0.0	384957.	0.	84387.	-2500.	0.	0.0	338.2	0.	0.	0.	0.0	0.0	0.0
CRUISE	39000.	0.800	384957.	7437.	91824.	0.	0.	33.8	372.0	0.	-429101.	0.	0.470	16.18	0.560
TAKEOFF POWER 1	0.	0.0	377520.	0.	91824.	0.	0.	0.0	372.0	0.	429601.	0.	0.0	0.0	0.927
POWER 2	0.	0.0	377520.	812.	92636.	0.	0.	1.0	373.0	0.	429501.	0.	0.0	0.0	0.292
CLIMB	0.	0.378	376707.	1558.	94194.	10.	10.	2.2	375.2	0.	429201.	0.	0.399	15.57	0.460
ACCEL	10000.	0.456	375149.	231.	94426.	2.	12.	0.4	375.5	0.	429201.	0.	0.335	14.47	0.491

CLIMB	10000.	0.547	374918.	3599.	98025.	46.	58.	6.8	382.3	0.	429201.	0.	0.286	13.29	0.539
CRUISE	30000.	0.770	371319.	1427.	99452.	42.	100.	5.5	387.8	0.	-429101.	0.	0.323	14.25	0.595
DESCENT	30000.	0.750	369892.	486.	99937.	45.	145.	6.8	394.6	0.	429301.	0.	0.283	13.19	-1.197
DECEL	10000.	0.547	369406.	72.	100009.	4.	149.	0.7	395.3	0.	429301.	0.	0.334	14.45	-6.984
DESCENT	10000.	0.456	369334.	710.	100719.	25.	174.	5.5	400.8	0.	429301.	0.	0.398	15.55	-2.593
CRUISE	30000.	0.770	368624.	886.	101605.	26.	200.	3.4	404.2	0.	-429101.	0.	0.321	14.19	0.596
CRUISE	1500.	0.378	367738.	9014.	110620.	0.	200.	32.0	436.2	0.	-80101.	0.	0.413	15.76	0.733

Configuration 7J

COST SUMMARY

Configuration 7J

RDT AND E

	TOTAL *
DEVELOPMENT - NONRECURRING	
ENGINEERING	1111.52
TOOLING	557.79
TEST ARTICLES	84.60
DATA	0.0
SYSTEMS ENG/MNGMT	0.0
CRUISE ENGINE	0.0
LIFT ENGINE	0.0
FAN	0.0
AVIONICS	0.0
OTHER SYSTEMS	0.0
FACILITIES	0.0
TOTAL AIR VEHICLE	1753.91
INTEGR LOGISTICS SUPPORT	
PLANNING	12.84
TRAINING	4.37
HANDBOOKS	35.56
SSE	9.12
TOTAL ILS	61.90
TOTAL DVLPMNT-NONREC	1815.80
#DEVELOPMENT - RECUR(PROTOTYPES)	
AIR VEHICLE	995.10
SPARES	23.91
TOTAL DVLPMNT-RECUR	1019.00
GOVMNT DVLPMNT COST	0.0
TOTAL DVLPMNT COST	2834.81

PRODUCTION

	MATERIAL	LABOR	TOTAL PER PROD A/C**
STRUCTURE	5736.59	13296.81	19033.39
WING	1979.35	3217.06	5196.41
ROTOR	0.0	0.0	0.0
TAIL	281.88	843.90	1125.78
BODY	1259.66	5944.89	7204.56
ALIGHTING GEAR	997.58	31.53	1029.12
ENG SECT + NACELLE	1218.11	3259.42	4477.53
ENG SECTION	0.0	0.0	0.0
NACELLE	1190.88	3084.81	4275.69
AIR INDUCTION	27.23	174.61	201.85
PROPULSION	217.01	172.93	389.93
ENGINE INSTALL	0.0	52.38	52.38
THRUST REVERSER	0.0	6.09	6.09
EXHAUST SYSTEM	0.0	0.0	0.0
ENGINE CONTROLS	6.64	7.28	13.92
STARTING SYSTEM	94.93	12.40	107.33
PROPELLER INSTALL	0.0	0.0	0.0
LUBRICATING SYSTEM	0.0	0.0	0.0
FUEL SYSTEM	115.44	94.78	210.21
DRIVE SYS(PWR TRN)	0.0	0.0	0.0
SYSTEMS	4377.00	7541.94	11918.94
FLIGHT CONTROLS	1230.56	513.88	1744.44
AUX POWER PLANT	206.48	26.20	232.68
INSTRUMENTS	129.35	76.37	205.71
HYDRAULIC + PNEUM	208.03	391.52	599.56
ELECTRICAL	580.64	1180.35	1760.99
AVIONIC INSTALL	63.26	515.45	578.71
ARMAMENT	0.0	0.0	0.0
FURN AND EQUIP	1425.82	4341.10	5766.92
AIR CONDITIONING	500.66	467.04	967.70
ANTI-ICING	32.20	30.03	62.23
PHOTOGRAPHIC	0.0	0.0	0.0
LOAD AND HANDLING	0.0	0.0	0.0
SYSTEMS INTEGR	969.61	787.96	1757.57
TOTAL COST	11300.20	21799.57	33099.76
TOTAL HRS **		650.97	650.97
ENG CHANGE ORDERS			1078.01
SUSTAINING ENG COST			1663.35
PROD TOOLING COST			2399.73
QUALITY ASSURANCE			2924.45
MISCELLANEOUS ***			1014.90
TOTAL AIRFRAME COST			42180.18
ENGINE COST			17065.79
AVIONICS COST			866.31
TOTAL MANUFACTURING COST			60112.27
WARRANTY			161.54
TOTAL PRODUCTION COST			60273.80

PROCUREMENT

	PER PROD A/C**
TOTAL PRODUCTION	60273.80
INTEGR LOGISTICS SUPPORT	
PLANNING	33.85
TRAINING	11.51
TRAINERS	220.56
HANDBOOKS	43.07
FACILITIES	0.0
SSE - CFE	0.0
SSE - GFE	2832.87
TOTAL ILS	3141.85
INITIAL SPARES COST	9371.04
PRODUCTION DEVELOPMENT	
ENGINEERING	323.95
TOOLING	341.79
ENGINES	0.0
TOTAL PROD DEV	665.74
TOTAL PROCUREMENT	73452.38

* - MILLIONS OF DOLLARS

** -1000 OF DOLLARS OR HOURS PER PROD A/C

*** - INCLUDES PROD DATA, SYSTEMS ENGR AND OTHER SYSTEMS

Configuration 7J

OPERATIONAL COSTS

DIRECT OPERATIONAL COST (DOC)

	C/SM***	PERCENT
FLIGHT CREW	0.44721	8.88635
FUEL AND OIL	3.14709	62.53519
INSURANCE	0.03363	0.66834
DEPRECIATION	0.71752	14.25758
MAINTENANCE	0.68707	13.65266
TOTAL DOC	5.03251	100.000

INDIRECT OPERATIONAL COST (IOC)

	C/SM***	PERCENT
SYSTEM	0.0	0.0
LOCAL	0.58769	18.77834
AIRCRAFT CONTROL	0.01317	0.42075
CABIN ATTENDANT	0.44012	14.06291
FOOD AND BEVERAGE	0.16685	5.33135
PASSENGER HANDLING	0.63674	20.34555
CARGO HANDLING	0.17677	5.64824
OTHER PASSENGER EXPENSE	0.83200	26.58463
OTHER CARGO EXPENSE	0.00860	0.27467
GENERAL + ADMINISTRATION	0.26770	8.55371
TOTAL IOC	3.12962	100.000

MISC. DATA

FLIGHT DISTANCE (N. MI.)	2500.00
BLOCK FUEL (LBS)	86068.69
BLOCK TIME (HRS)	5.97
FLIGHT TIME (HRS)	5.64
AVG STAGE LENGTH (N. MI.)	2500.00
AVG CARGO PER FLIGHT	13695.72
UTILIZATION (HRS PER YR)	4139.61
FLIGHTS PER A/C PER YEAR	693.44
FARE ($)	374.96
FUEL COST ($/LB)	0.31600

*** - CENTS PER SEAT N. MILE

RATE OF RETURN ON INVESTMENT

YEAR	AVG NO AIRCRAFT DURING YEAR	AIRCRAFT ADDED DURING YEAR	AVERAGE INVESTMENT DURING YEAR	CUMULATIVE DEPRECIATION	AVERAGE BOOK VALUE OF FLEET	REVENUE	INTEREST EXPENSE	OPERATING EXPENSE	CASH FLOW	ROI
			$M	$M	$M	$M	$M	$M	$M	PERCENT
1	5.0	8.0	402.70	22.65	380.04	305.21	48.32	247.62	-153.13	13.93
2	13.0	8.0	1047.01	81.55	965.47	793.55	117.91	643.82	-157.15	13.86
3	20.4	7.0	1640.99	173.85	1467.14	1243.73	173.72	1009.07	-138.17	13.92
4	23.0	0.0	1852.41	278.05	1574.36	1403.97	176.86	1139.07	0.02	14.03
5	23.0	0.0	1852.41	382.25	1470.16	1403.97	154.64	1139.07	11.14	14.27
6	23.0	0.0	1852.41	486.44	1365.96	1403.97	132.41	1139.07	22.25	14.54
7	23.0	0.0	1852.41	590.64	1261.76	1403.97	110.18	1139.07	33.36	14.86
8	23.0	0.0	1852.41	694.84	1157.57	1403.97	87.95	1139.07	44.48	15.24
9	23.0	0.0	1852.41	799.04	1053.37	1403.97	65.72	1139.07	55.59	15.69
10	23.0	0.0	1852.41	903.24	949.17	1403.97	43.49	1139.07	66.71	16.25
11	23.0	0.0	1852.41	1007.43	844.97	1403.97	21.26	1139.07	129.37	16.93
12	23.0	0.0	1852.41	1111.63	740.78	1403.97	6.77	1139.07	188.16	18.34
13	23.0	0.0	1852.41	1215.83	636.58	1403.97	-0.00	1139.07	236.65	20.81
14	23.0	0.0	1852.41	1320.03	532.38	1403.97	-0.00	1139.07	236.65	24.88
15	23.0	0.0	1852.41	1424.22	428.18	1403.97	-0.00	1139.07	236.65	30.93
16	23.0	0.0	1852.41	1528.42	323.99	1403.97	-0.00	1139.07	236.65	40.88

AVG ROI OVER THE 16 YEAR PERIOD = 16.58 PERCENT

ATX-350I, DESIGN RANGE = 4600 NMI, M = 0.80, INTERN. RESRVS MISS

T/C=10.30 AR= 7.78 W/S=136.00 T/W=0.290

Configuration 7K

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

BASIC WING--	AREA(SQ FT)	SPAN(FT)	TAPER RATIO	C/4 SWEEP	L.E. SWEEP	MAC(FT)		
	4310.3	183.12	0.246	35.000	37.883	26.41		
WING PANELS--	AREA(SQ FT)	EXP. AREA	AVG T/C	L.E. SWEEP	SFLE(SQ FT)	REF L(FT)		
	1024.1	46.7	12.56	37.879	0.0	46.63		
	2084.4	2084.4	11.64	37.879	0.0	37.03		
	379.8	379.8	9.99	37.879	0.0	24.42		
	1312.0	1312.0	9.86	37.879	0.0	17.97		
	140.4	140.4	9.46	37.879	0.0	10.40		
TOTAL WING--	AREA(SQ FT)	EFF AR	AVG T/C	CR(FT)	CT(FT)	MAC(FT)	L(FT)	E SWP
	4940.8	6.79	11.24	54.33	9.30	33.03	80.53	22.988
FUSELAGE--	LENGTH(FT)	S WET(SQ FT)	BWW(FT)	EQUIV D(FT)	SPI(SQ FT)			
	201.00	11166.4	19.32	19.58	301.21			
	BW(FT)	BH(FT)	SBW(SQ FT)					
	19.58	19.58	10538.00					
HORZ. TAIL 1--	SHT1(SQ FT)	SHX1(SQ FT)	REF L1(FT)	L HT1(FT)	HT1 VOL COEF			
	1504.52	1151.85	19.03	72.19	0.9540			
HORZ. TAIL 2--	SHT2(SQ FT)	SHX2(SQ FT)	REF L2(FT)	L HT2(FT)	HT2 VOL COEF			
	0.0	0.0	0.0	201.00	0.0			
VERT. TAIL 1--	SVT1(SQ FT)	SVX1(SQ FT)	REF L1(FT)	L VT1(FT)	VT1 VOL COEF			
	792.40	511.91	21.03	74.39	0.0747			
VERT. TAIL 2--	SVT2(SQ FT)	SVX2(SQ FT)	REF L2(FT)	L VT2(FT)	VT2 VOL COEF			
	0.0	0.0	0.0	201.00	0.0			
PROPULSION--	ENG L(FT)	ENG D(FT)	POD L(FT)	POD D(FT)	POD S WET	NO. PODS	INLET L(FT)	
	13.18	8.64	13.29	11.43	857.50	2.	35.31	
FUEL TANKS--	WING(CU FT)	BOX(CU FT)	FUS(CU FT)					
	4385.80	1202.01	999999.00					
WETTED VOLUMES--	BODY	WING	TAILS	PODS	PYLONS	PONTOONS	TOTAL	
	51747.36	8393.66	2512.61	2309.49	150.06	0.0	65113.17	

ATX-350I, DESIGN RANGE = 4600 NMI, M = 0.80, INTERN. RESRVS MISS

T/C=10.30 AR= 7.78 W/S=136.00 T/W=0.290

Configuration 7K

WEIGHT STATEMENT

	WEIGHT(POUNDS)	WEIGHT FRACTION	(PERCENT)
GROSS WEIGHT	(586207.)		
FUEL AVAILABLE	202012.	FUEL	34.46
EXTERNAL	0.		
INTERNAL	202012.		
ZERO FUEL WEIGHT	384195.		
PAYLOAD	73500.	PAYLOAD	12.54
PASSENGERS	57750.		
BAGGAGE	15750.		
CARGO	0.		
STORES	0.		
OPERATIONAL EMPTY WEIGHT	310695.		
OPERATIONAL ITEMS	10406.	OPERATIONAL ITEMS	3.42
STANDARD ITEMS	9631.		
EMPTY WEIGHT	290658.		
STRUCTURE	180734.	STRUCTURE	30.83
WING	58959.		
ROTOR	0.		
TAIL	11086.		
BODY	67852.		
ALIGHTING GEAR	24436.		
ENGINE SECTION AND NACELLE	18400.		
PROPULSION	43875.	PROPULSION	7.48
CRUISE ENGINES	36885.		
LIFT ENGINES	0.		
THRUST REVERSER	4329.		
EXHAUST SYSTEM	0.		
ENGINE CONTROL	243.		
STARTING SYSTEM	605.		
PROPELLERS	0.		
LUBRICATING SYSTEM	0.		
FUEL SYSTEM	1813.		
DRIVE SYSTEM (POWER TRANS)	0.		
SYSTEMS	66050.		
FLIGHT CONTROLS	7238.		
AUXILIARY POWER PLANT	1202.		
INSTRUMENTS	1020.		
HYDRAULIC AND PNEUMATIC	2690.		
ELECTRICAL	5616.		
AVIONICS	3075.	SYSTEMS	11.27
ARMAMENT	0.		
FURNISHINGS AND EQUIPMENT	38504.		
AIR CONDITIONING	6302.		
ANTI-ICING	402.		
PHOTOGRAPHIC	0.		
LOAD AND HANDLING	0.		
		TOTAL	(100.)

Configuration 7K

W E I G H T S   M A T R I X

ELEMENT/ / MATERIAL	AL	TIT.	STEEL	COMP.	OTHER	TOTAL
WING	53063.	1179.	4127.	0.	590.	58959.
ROTOR	0.	0.	0.	0.	0.	0.
TAIL	9978.	222.	776.	0.	111.	11086.
BODY	61067.	2714.	679.	1357.	2036.	67852.
L. G.	5376.	244.	16128.	0.	2688.	24436.
ENG SECT	0.	0.	0.	0.	0.	0.
NACELLE	3382.	6912.	3088.	1323.	0.	14705.
AIR INDUCT	2549.	369.	0.	776.	0.	3695.
TOTALS	135415.	11640.	24798.	3456.	5424.	180733.

EXCESS FUEL CAPACITY - BODY	50160144.
EXCESS FUEL CAPACITY - WING	17464.
EXCESS BODY LENGTH - FT	0.0
AIRFRAME WEIGHT (A.M.P.R.) - LB	239712.
GUST LOAD FACTOR	0.0

ALTERNATE MISSION NO. 1 SUMMARY

Configuration 7K

ATX-350I, AVRG STAGE L = 2500 NMI, M = 0.80, 60 % LF   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 CL	AVG L/D RATIO	AVG SFC (FF/T)
TAKEOFF POWER 1	0.	0.0	461963.	0.	0.	0.	0.	0.0	0.0	0.	429601.	0.	0.0	0.0	0.928
POWER 2	0.	0.0	461963.	796.	796.	0.	0.	1.0	1.0	0.	429501.	0.	0.0	0.0	0.292
CLIMB	0.	0.378	461167.	2015.	2811.	13.	13.	2.9	3.9	0.	429201.	0.	0.500	17.00	0.460
ACCEL	10000.	0.456	459152.	299.	3110.	3.	15.	0.5	4.4	0.	429201.	0.	0.417	16.31	0.491
CLIMB	10000.	0.547	458853.	7713.	10823.	126.	142.	17.3	21.6	0.	429201.	0.	0.406	15.90	0.550
CRUISE	39000.	0.800	451140.	0.	10823.	0.	142.	0.0	21.6	0.	-429101.	0.	0.566	16.67	0.552
ACCEL	39000.	0.800	451140.	0.	10823.	0.	142.	0.0	21.6	0.	429201.	0.	0.566	16.67	0.559
ACCEL	39000.	0.800	451140.	0.	10823.	0.	142.	0.0	21.6	0.	429201.	0.	0.566	16.67	0.559
CRUISE	39000.	0.800	451140.	65245.	76068.	2158.	2300.	282.2	303.8	0.	-429101.	0.	0.525	16.72	0.555
CLIMB	39000.	0.800	385895.	0.	76068.	0.	2300.	0.0	303.8	0.	429201.	0.	0.0	0.0	0.0
CRUISE	39000.	0.800	385895.	0.	76068.	0.	2300.	0.0	303.8	0.	-429101.	0.	0.485	16.63	0.560
CLIMB	39000.	0.800	385895.	0.	76068.	0.	2300.	0.0	303.8	0.	429201.	0.	0.0	0.0	0.0
CRUISE	39000.	0.800	385895.	0.	76068.	0.	2300.	0.0	303.8	0.	-429101.	0.	0.485	16.63	0.560
DESCENT	39000.	0.800	385895.	2086.	78154.	118.	2418.	16.1	319.9	0.	429301.	0.	0.349	14.92	-0.212
DECEL	10000.	0.547	383808.	74.	78229.	4.	2421.	0.7	320.7	0.	429301.	0.	0.353	15.25	-6.955
DESCENT	10000.	0.456	383734.	728.	78956.	26.	2447.	5.7	326.4	0.	429301.	0.	0.420	16.27	-2.602
CRUISE	39000.	0.800	383007.	1477.	80433.	53.	2500.	6.9	333.3	0.	-429101.	0.	0.480	16.60	0.561
LOITER	1500.	0.310	381529.	763.	81197.	0.	2500.	3.0	336.3	0.	-80101.	0.	0.656	16.38	0.656
CRUISE	1500.	0.378	380766.	559.	81756.	0.	2500.	2.0	338.3	0.	-80101.	0.	0.440	16.52	0.728
RESET	0.	0.0	380207.	0.	81756.	-2500.	0.	0.0	338.3	0.	0.	0.	0.0	0.0	0.0
CRUISE	39000.	0.800	380207.	7210.	88966.	0.	0.	33.8	372.1	0.	-429101.	0.	0.473	16.55	0.562
TAKEOFF POWER 1	0.	0.0	372997.	0.	88966.	0.	0.	0.0	372.1	0.	429601.	0.	0.0	0.0	0.928
POWER 2	0.	0.0	372997.	796.	89762.	0.	0.	1.0	373.1	0.	429501.	0.	0.0	0.0	0.292
CLIMB	0.	0.378	372201.	1532.	91294.	10.	10.	2.2	375.3	0.	429201.	0.	0.402	15.98	0.460
ACCEL	10000.	0.456	370669.	226.	91520.	2.	12.	0.4	375.7	0.	429201.	0.	0.337	14.91	0.491

CLIMB	10000.	0.547	370442.	3485.	95005.	46.	57.	6.7	382.3	0.	429201.	0.	0.288	13.73	0.539
CRUISE	30000.	0.785	366957.	1404.	96409.	42.	100.	5.5	387.9	0.	-429101.	0.	0.315	14.45	0.602
DESCENT	30000.	0.750	365553.	465.	96874.	46.	146.	6.9	394.7	0.	429301.	0.	0.283	13.60	-1.232
DECEL	10000.	0.547	365088.	72.	96946.	4.	150.	0.7	395.4	0.	429301.	0.	0.336	14.88	-6.982
DESCENT	10000.	0.456	365016.	715.	97661.	26.	175.	5.6	401.1	0.	429301.	0.	0.400	15.96	-2.587
CRUISE	30000.	0.780	364301.	811.	98472.	25.	200.	3.2	404.3	0.	-429101.	0.	0.317	14.49	0.602
CRUISE	1500.	0.378	363490.	8747.	107219.	0.	200.	32.0	436.3	0.	-80101.	0.	0.416	16.17	0.739

Configuration 7K

Configuration 7K

COST SUMMARY

RDT AND E

	TOTAL *
DEVELOPMENT - NONRECURRING	
ENGINEERING	1096.65
TOOLING	552.73
TEST ARTICLES	83.75
DATA	0.0
SYSTEMS ENG/MNGMT	0.0
CRUISE ENGINE	0.0
LIFT ENGINE	0.0
FAN	0.0
AVIONICS	0.0
OTHER SYSTEMS	0.0
FACILITIES	0.0
TOTAL AIR VEHICLE	1733.14
INTEGR LOGISTICS SUPPORT	
PLANNING	12.69
TRAINING	4.31
HANDBOOKS	34.95
SSE	9.02
TOTAL ILS	60.96
TOTAL DVLPMNT-NONREC	1794.10
DEVELOPMENT - RECUR(PROTOTYPES)	
AIR VEHICLE	984.61
SPARES	23.50
TOTAL DVLPMNT-RECUR	1008.11
GOVMNT DVLPMNT COST	0.0
TOTAL DVLPMNT COST	2802.22

PRODUCTION

	MATERIAL	LABOR	TOTAL PER PROD A/C**
STRUCTURE	5628.20	13105.74	18733.93
WING	1941.06	3159.97	5101.04
ROTOR	0.0	0.0	0.0
TAIL	273.74	820.86	1094.60
BODY	1256.52	5939.72	7196.24
ALIGHTING GEAR	980.47	31.04	1011.51
ENG SECT + NACELLE	1176.41	3154.14	4330.56
ENG SECTION	0.0	0.0	0.0
NACELLE	1149.81	2983.27	4133.08
AIR INDUCTION	26.61	170.88	197.48
PROPULSION	213.01	170.11	383.12
ENGINE INSTALL	0.0	51.25	51.25
THRUST REVERSER	0.0	6.02	6.02
EXHAUST SYSTEM	0.0	0.0	0.0
ENGINE CONTROLS	6.50	7.14	13.64
STARTING SYSTEM	92.73	12.13	104.86
PROPELLER INSTALL	0.0	0.0	0.0
LUBRICATING SYSTEM	0.0	0.0	0.0
FUEL SYSTEM	113.78	93.57	207.35
DRIVE SYS(PWR TRN)	0.0	0.0	0.0
SYSTEMS	4351.35	7538.19	11889.55
FLIGHT CONTROLS	1209.02	505.71	1714.74
AUX POWER PLANT	206.52	26.25	232.76
INSTRUMENTS	129.06	76.32	205.38
HYDRAULIC + PNEUM	204.83	386.13	590.96
ELECTRICAL	579.85	1180.65	1760.50
AVIONIC INSTALL	63.27	516.39	579.66
ARMAMENT	0.0	0.0	0.0
FURN AND EQUIP	1426.10	4349.01	5775.11
AIR CONDITIONING	500.76	467.89	968.65
ANTI-ICING	31.94	29.85	61.79
PHOTOGRAPHIC	0.0	0.0	0.0
LOAD AND HANDLING	0.0	0.0	0.0
SYSTEMS INTEGR	956.91	778.90	1735.81
TOTAL COST	11149.48	21592.91	32742.38
TOTAL HRS **		644.80	644.80
ENG CHANGE ORDERS			1066.48
SUSTAINING ENG COST			1647.28
PROD TOOLING COST			2376.98
QUALITY ASSURANCE			2896.73
MISCELLANEOUS ***			1005.28
TOTAL AIRFRAME COST			41735.12
ENGINE COST			16765.08
AVIONICS COST			866.31
TOTAL MANUFACTURING COST			59366.49
WARRANTY			159.85
TOTAL PRODUCTION COST			59526.34

PROCUREMENT

	PER PROD A/C**
TOTAL PRODUCTION	59526.34
INTEGR LOGISTICS SUPPORT	
PLANNING	33.54
TRAINING	11.40
TRAINERS	220.56
HANDBOOKS	42.63
FACILITIES	0.0
SSE - CFE	0.0
SSE - GFE	2797.74
TOTAL ILS	3105.86
INITIAL SPARES COST	9240.89
PRODUCTION DEVELOPMENT	
ENGINEERING	320.93
TOOLING	338.55
ENGINES	0.0
TOTAL PROD DEV	659.48
TOTAL PROCUREMENT	72532.50

* - MILLIONS OF DOLLARS

** -1000 OF DOLLARS OR HOURS PER PROD A/C

*** - INCLUDES PROD DATA, SYSTEMS ENGR AND OTHER SYSTEMS

OPERATIONAL COSTS

DIRECT OPERATIONAL COST (DOC)	C/SM***	PERCENT
FLIGHT CREW	0.44733	9.09668
FUEL AND OIL	3.04968	62.01738
INSURANCE	0.03323	0.67572
DEPRECIATION	0.70872	14.41227
MAINTENANCE	0.67851	13.79794
TOTAL DOC	4.91746	100.000

INDIRECT OPERATIONAL COST (IOC)	C/SM***	PERCENT
SYSTEM	0.0	0.0
LOCAL	0.57750	18.53772
AIRCRAFT CONTROL	0.01317	0.42269
CABIN ATTENDANT	0.44023	14.13151
FOOD AND BEVERAGE	0.16690	5.35736
PASSENGER HANDLING	0.63674	20.43938
CARGO HANDLING	0.17677	5.67428
OTHER PASSENGER EXPENSE	0.83200	26.70724
OTHER CARGO EXPENSE	0.00860	0.27594
GENERAL + ADMINISTRATION	0.26336	8.45393
TOTAL IOC	3.11526	100.000

MISC. DATA	
FLIGHT DISTANCE (N. MI.)	2500.00
BLOCK FUEL (LBS)	83404.06
BLOCK TIME (HRS)	5.97
FLIGHT TIME (HRS)	5.64
AVG STAGE LENGTH (N. MI.)	2500.00
AVG CARGO PER FLIGHT	13695.72
UTILIZATION (HRS PER YR)	4139.82
FLIGHTS PER A/C PER YEAR	693.29
FARE ($)	374.96
FUEL COST ($/LB)	0.31600

*** - CENTS PER SEAT N. MILE

RATE OF RETURN ON INVESTMENT

YEAR	AVG NO AIRCRAFT DURING YEAR	AIRCRAFT ADDED DURING YEAR	AVERAGE INVESTMENT DURING YEAR	CUMULATIVE DEPRECIATION	AVERAGE BOOK VALUE OF FLEET	REVENUE	INTEREST EXPENSE	OPERATING EXPENSE	CASH FLOW	ROI
			$M	$M	$M	$M	$M	$M	$M	PERCENT
1	5.0	8.0	397.69	22.37	375.32	305.14	47.72	243.65	-148.91	14.55
2	13.0	8.0	1033.99	80.53	953.46	793.38	116.44	633.48	-149.18	14.49
3	20.4	7.0	1620.59	171.69	1448.90	1243.46	171.56	992.85	-127.02	14.57
4	23.0	0.0	1829.38	274.59	1554.78	1403.67	174.67	1120.77	10.67	14.71
5	23.0	0.0	1829.38	377.49	1451.88	1403.67	152.71	1120.77	21.64	15.00
6	23.0	0.0	1829.38	480.40	1348.98	1403.67	130.76	1120.77	32.62	15.33
7	23.0	0.0	1829.38	583.30	1246.08	1403.67	108.81	1120.77	43.60	15.72
8	23.0	0.0	1829.38	686.20	1143.18	1403.67	86.86	1120.77	54.57	16.17
9	23.0	0.0	1829.38	789.10	1040.27	1403.67	64.90	1120.77	65.55	16.72
10	23.0	0.0	1829.38	892.00	937.37	1403.67	42.95	1120.77	76.53	17.38
11	23.0	0.0	1829.38	994.91	834.47	1403.67	21.00	1120.77	138.41	18.21
12	23.0	0.0	1829.38	1097.81	731.57	1403.67	6.68	1120.77	196.47	19.79
13	23.0	0.0	1829.38	1200.71	628.67	1403.67	-0.00	1120.77	244.35	22.50
14	23.0	0.0	1829.38	1303.61	525.76	1403.67	-0.00	1120.77	244.35	26.90
15	23.0	0.0	1829.38	1406.51	422.86	1403.67	-0.00	1120.77	244.35	33.45
16	23.0	0.0	1829.38	1509.42	319.96	1403.67	-0.00	1120.77	244.35	44.21

AVG ROI OVER THE 16 YEAR PERIOD = 17.63 PERCENT

Configuration 7L

ATX-350I, DESIGN RANGE = 4600 NMI, M = 0.80, INTERN. RESRVS MISS

T/C=10.30 AR= 7.78 W/S=136.00 T/W=0.289

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

BASIC WING--	AREA(SQ FT)	SPAN(FT)	TAPER RATIO	C/4 SWEEP	L.E. SWEEP	MAC(FT)		
	4215.6	181.10	0.246	35.000	37.883	26.12		
WING PANELS--	AREA(SQ FT)	EXP. AREA	AVG T/C	L.E. SWEEP	SFLE(SQ FT)	REF L(FT)		
	1001.6	35.8	12.56	37.879	0.0	46.07		
	2038.6	2038.6	11.64	37.879	0.0	36.62		
	371.4	371.4	9.99	37.879	0.0	24.15		
	1283.2	1283.2	9.86	37.879	0.0	17.78		
	137.3	137.3	9.46	37.879	0.0	10.28		
TOTAL WING--	AREA(SQ FT)	EFF AR	AVG T/C	CR(FT)	CT(FT)	MAC(FT)	L(FT)	E SWP
	4832.2	6.79	11.24	53.73	9.20	32.67	79.64	22.988
FUSELAGE--	LENGTH(FT)	S WET(SQ FT)	BWW(FT)	EQUIV D(FT)	SPI(SQ FT)			
	201.00	11128.3	19.32	19.58	301.21			
	BW(FT)	BH(FT)	SBW(SQ FT)					
	19.58	19.58	10538.00					
HORZ. TAIL 1--	SHT1(SQ FT)	SHX1(SQ FT)	REF L1(FT)	L HT1(FT)	HT1 VOL COEF			
	1451.41	1105.40	18.66	72.38	0.9540			
HORZ. TAIL 2--	SHT2(SQ FT)	SHX2(SQ FT)	REF L2(FT)	L HT2(FT)	HT2 VOL COEF			
	0.0	0.0	0.0	201.00	0.0			
VERT. TAIL 1--	SVT1(SQ FT)	SVX1(SQ FT)	REF L1(FT)	L VT1(FT)	VT1 VOL COEF			
	760.36	486.15	20.52	74.72	0.0744			
VERT. TAIL 2--	SVT2(SQ FT)	SVX2(SQ FT)	REF L2(FT)	L VT2(FT)	VT2 VOL COEF			
	0.0	0.0	0.0	201.00	0.0			
PROPULSION--	ENG L(FT)	ENG D(FT)	POD L(FT)	POD D(FT)	POD S WET	NO. PODS	INLET L(FT)	
	13.03	8.53	13.14	11.29	836.83	2.	34.84	
FUEL TANKS--	WING(CU FT)	BOX(CU FT)	FUS(CU FT)					
	4229.36	1170.67	999999.00					
WETTED VOLUMES--	BODY	WING	TAILS	PODS	PYLONS	PONTOONS	TOTAL	
	51631.20	8080.42	2351.56	2225.05	144.76	0.0	64432.98	

Configuration 7L

WEIGHTS MATRIX

ELEMENT/ / MATERIAL	AL	TIT.	STEEL	COMP.	OTHER	TOTAL
WING	51754.	1150.	4025.	0.	575.	57504.
ROTOR	0.	0.	0.	0.	0.	0.
TAIL	9614.	214.	748.	0.	107.	10682.
BODY	60865.	2705.	676.	1353.	2029.	67628.
L. G.	5258.	239.	15773.	0.	2629.	23899.
ENG SECT	0.	0.	0.	0.	0.	0.
NACELLE	3291.	6726.	3005.	1288.	0.	14311.
AIR INDUCT	2477.	359.	0.	754.	0.	3590.
TOTALS	133258.	11393.	24228.	3394.	5340.	177612.

EXCESS FUEL CAPACITY - BODY	50158560.
EXCESS FUEL CAPACITY - WING	17968.
EXCESS BODY LENGTH - FT	0.0
AIRFRAME WEIGHT (A.M.P.R.) - LB	236423.
GUST LOAD FACTOR	0.0

Configuration 7L

ATX-350I, DESIGN RANGE = 4600 NMI, M = 0.80, INTERN. RESRVS MISS

T/C=10.30 AR= 7.78 W/S=136.00 T/W=0.289

W E I G H T   S T A T E M E N T

	WEIGHT(POUNDS)	WEIGHT FRACTION	(PERCENT)
GROSS WEIGHT	(573319.)		
FUEL AVAILABLE	193681.	FUEL	33.78
EXTERNAL	0.		
INTERNAL	193681.		
ZERO FUEL WEIGHT	379638.		
PAYLOAD	73500.	PAYLOAD	12.82
PASSENGERS	57750.		
BAGGAGE	15750.		
CARGO	0.		
STORES	0.		
OPERATIONAL EMPTY WEIGHT	306138.		
OPERATIONAL ITEMS	10399.	OPERATIONAL ITEMS	3.49
STANDARD ITEMS	9620.		
EMPTY WEIGHT	286118.		
STRUCTURE	177612.	STRUCTURE	30.98
WING	57504.		
ROTOR	0.		
TAIL	10682.		
BODY	67628.		
ALIGHTING GEAR	23899.		
ENGINE SECTION AND NACELLE	17900.		
PROPULSION	42689.	PROPULSION	7.45
CRUISE ENGINES	35830.		
LIFT ENGINES	0.		
THRUST REVERSER	4255.		
EXHAUST SYSTEM	0.		
ENGINE CONTROL	237.		
STARTING SYSTEM	588.		
PROPELLERS	0.		
LUBRICATING SYSTEM	0.		
FUEL SYSTEM	1780.		
DRIVE SYSTEM (POWER TRANS)	0.		
SYSTEMS	65818.		
FLIGHT CONTROLS	7076.		
AUXILIARY POWER PLANT	1202.		
INSTRUMENTS	1017.		
HYDRAULIC AND PNEUMATIC	2637.		
ELECTRICAL	5605.		
AVIONICS	3075.	SYSTEMS	11.48
ARMAMENT	0.		
FURNISHINGS AND EQUIPMENT	38504.		
AIR CONDITIONING	6302.		
ANTI-ICING	398.		
PHOTOGRAPHIC	0.		
LOAD AND HANDLING	0.		
		TOTAL	(100.)

ALTERNATE MISSION NO. 1 SUMMARY

Configuration 7L

ATX-350I, AVRG STAGE L = 2500 NMI, M = 0.80, 60 % LF 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 CL	AVG L/D RATIO	AVG SFC (FF/T)
TAKEOFF POWER 1	0.	0.0	453111.	0.	0.	0.	0.	0.0	0.0	0.	429601.	0.	0.0	0.0	0.929
POWER 2	0.	0.0	453111.	777.	777.	0.	0.	1.0	1.0	0.	429501.	0.	0.0	0.0	0.293
CLIMB	0.	0.378	452334.	1960.	2736.	13.	13.	2.9	3.9	0.	429201.	0.	0.502	17.52	0.461
ACCEL	10000.	0.456	450374.	289.	3025.	2.	15.	0.5	4.3	0.	429201.	0.	0.419	16.90	0.491
CLIMB	10000.	0.547	450086.	7244.	10269.	121.	136.	16.6	20.9	0.	429201.	0.	0.407	16.48	0.551
CRUISE	39000.	0.800	442841.	0.	10269.	0.	136.	0.0	20.9	0.	-429101.	0.	0.569	17.10	0.553
ACCEL	39000.	0.800	442841.	0.	10269.	0.	136.	0.0	20.9	0.	429201.	0.	0.569	17.10	0.560
ACCEL	39000.	0.800	442841.	0.	10269.	0.	136.	0.0	20.9	0.	429201.	0.	0.569	17.10	0.560
CRUISE	39000.	0.800	442841.	62730.	72999.	2164.	2300.	282.9	303.8	0.	-429101.	0.	0.527	17.20	0.557
CLIMB	39000.	0.800	380111.	0.	72999.	0.	2300.	0.0	303.8	0.	429201.	0.	0.0	0.0	0.0
CRUISE	39000.	0.800	380111.	0.	72999.	0.	2300.	0.0	303.8	0.	-429101.	0.	0.488	17.16	0.563
CLIMB	39000.	0.800	380111.	0.	72999.	0.	2300.	0.0	303.8	0.	429201.	0.	0.0	0.0	0.0
CRUISE	39000.	0.800	380111.	0.	72999.	0.	2300.	0.0	303.8	0.	-429101.	0.	0.488	17.16	0.563
DESCENT	39000.	0.800	380111.	1878.	74878.	115.	2415.	15.9	319.7	0.	429301.	0.	0.351	15.54	-0.272
DECEL	10000.	0.547	378233.	76.	74953.	4.	2420.	0.8	320.4	0.	429301.	0.	0.356	15.89	-6.954
DESCENT	10000.	0.456	378157.	737.	75690.	27.	2447.	6.0	326.4	0.	429301.	0.	0.424	16.88	-2.594
CRUISE	39000.	0.800	377420.	1443.	77134.	53.	2500.	7.0	333.4	0.	-429101.	0.	0.484	17.14	0.564
LOITER	1500.	0.310	375976.	740.	77874.	0.	2500.	3.0	336.4	0.	-80101.	0.	0.661	16.73	0.659
CRUISE	1500.	0.378	375236.	538.	78412.	0.	2500.	2.0	338.4	0.	-80101.	0.	0.444	17.11	0.736
PESET	0.	0.0	374698.	0.	78412.	-2500.	0.	0.0	338.4	0.	0.	0.	0.0	0.0	0.0
CRUISE	39000.	0.800	374698.	6922.	85334.	0.	0.	33.8	372.2	0.	-429101.	0.	0.477	17.09	0.565
TAKEOFF POWER 1	0.	0.0	367776.	0.	85334.	0.	0.	0.0	372.2	0.	429601.	0.	0.0	0.0	0.929
POWER 2	0.	0.0	367776.	777.	86111.	0.	0.	1.0	373.2	0.	429501.	0.	0.0	0.0	0.293
CLIMB	0.	0.378	366999.	1500.	87610.	10.	10.	2.2	375.4	0.	429201.	0.	0.405	16.59	0.460
ACCEL	10000.	0.456	365499.	220.	87831.	2.	12.	0.4	375.8	0.	429201.	0.	0.340	15.57	0.491

CLIMB	10000.	0.547	365279.	3338.	91169.	45.	57.	6.6	382.3	0.	429201.	0.	0.290	14.39	0.540
CRUISE	30000.	0.785	361941.	1366.	92534.	43.	100.	5.6	388.0	0.	-429101.	0.	0.316	15.07	0.609
DESCENT	30000.	0.750	360575.	474.	93008.	48.	148.	7.2	395.1	0.	429301.	0.	0.286	14.27	-1.234
DECEL	10000.	0.547	360101.	74.	93082.	4.	152.	0.7	395.9	0.	429301.	0.	0.339	15.54	-6.980
DESCENT	10000.	0.456	360028.	725.	93807.	27.	179.	5.9	401.7	0.	429301.	0.	0.403	16.57	-2.578
CRUISE	30000.	0.785	359303.	674.	94481.	21.	200.	2.8	404.5	0.	-429101.	0.	0.314	15.02	0.610
CRUISE	1500.	0.378	358629.	8410.	102891.	0.	200.	32.0	436.5	0.	-80101.	0.	0.419	16.79	0.747

Configuration 7L

COST SUMMARY

Configuration 7L

RDT AND E

	TOTAL *
DEVELOPMENT - NONRECURRING	
ENGINEERING	1079.28
TOOLING	546.93
TEST ARTICLES	82.90
DATA	0.0
SYSTEMS ENG/MNGMT	0.0
CRUISE ENGINE	0.0
LIFT ENGINE	0.0
FAN	0.0
AVIONICS	0.0
OTHER SYSTEMS	0.0
FACILITIES	0.0
TOTAL AIR VEHICLE	1709.11
INTEGR LOGISTICS SUPPORT	
PLANNING	12.51
TRAINING	4.25
HANDBOOKS	34.21
SSE	8.89
TOTAL ILS	59.85
TOTAL DVLPMNT-NONREC	1768.96
DEVELOPMENT - RECUR(PROTOTYPES)	
AIR VEHICLE	973.51
SPARES	23.01
TOTAL DVLPMNT-RECUR	996.52
GOVMNT DVLPMNT COST	0.0
TOTAL DVLPMNT COST	2765.48

PRODUCTION

	MATERIAL	LABOR	TOTAL PER PROD A/C**
STRUCTURE	5514.22	12920.18	18434.40
WING	1893.58	3088.58	4982.15
ROTOR	0.0	0.0	0.0
TAIL	263.81	792.60	1056.42
BODY	1252.65	5932.78	7185.43
ALIGHTING GEAR	959.13	30.43	989.55
ENG SECT + NACELLE	1145.05	3075.79	4220.84
ENG SECTION	0.0	0.0	0.0
NACELLE	1119.19	2909.40	4028.60
AIR INDUCTION	25.86	166.39	192.24
PROPULSION	208.14	166.64	374.79
ENGINE INSTALL	0.0	49.89	49.89
THRUST REVERSER	0.0	5.92	5.92
EXHAUST SYSTEM	0.0	0.0	0.0
ENGINE CONTROLS	6.34	6.98	13.31
STARTING SYSTEM	90.10	11.81	101.90
PROPELLER INSTALL	0.0	0.0	0.0
LUBRICATING SYSTEM	0.0	0.0	0.0
FUEL SYSTEM	111.71	92.04	203.75
DRIVE SYS(PWR TRN)	0.0	0.0	0.0
SYSTEMS	4319.49	7532.57	11852.06
FLIGHT CONTROLS	1182.34	495.50	1677.84
AUX POWER PLANT	206.57	26.30	232.87
INSTRUMENTS	128.69	76.25	204.94
HYDRAULIC + PNEUM	200.84	379.34	580.18
ELECTRICAL	578.83	1180.85	1759.68
AVIONIC INSTALL	63.29	517.50	580.78
ARMAMENT	0.0	0.0	0.0
FURN AND EQUIP	1426.43	4358.33	5784.76
AIR CONDITIONING	500.87	468.89	969.77
ANTI-ICING	31.63	29.61	61.24
PHOTOGRAPHIC	0.0	0.0	0.0
LOAD AND HANDLING	0.0	0.0	0.0
SYSTEMS INTEGR	942.18	768.38	1710.55
TOTAL COST	10984.04	21387.76	32371.79
TOTAL HRS **		638.67	638.67
ENG CHANGE ORDERS			1054.57
SUSTAINING ENG COST			1628.49
PROD TOOLING COST			2354.40
QUALITY ASSURANCE			2869.21
MISCELLANEOUS ***			995.73
TOTAL AIRFRAME COST			41274.16
ENGINE COST			16403.43
AVIONICS COST			866.31
TOTAL MANUFACTURING COST			58543.89
WARRANTY			158.10
TOTAL PRODUCTION COST			58701.98

PROCUREMENT

	PER PROD A/C**
TOTAL PRODUCTION	58701.98
INTEGR LOGISTICS SUPPORT	
PLANNING	33.16
TRAINING	11.28
TRAINERS	220.56
HANDBOOKS	42.09
FACILITIES	0.0
SSE - CFE	0.0
SSE - GFE	2758.99
TOTAL ILS	3066.08
INITIAL SPARES COST	9092.54
PRODUCTION DEVELOPMENT	
ENGINEERING	317.35
TOOLING	335.34
ENGINES	0.0
TOTAL PROD DEV	652.68
TOTAL PROCUREMENT	71513.25

* - MILLIONS OF DOLLARS

** -1000 OF DOLLARS OR HOURS PER PROD A/C

*** - INCLUDES PROD DATA, SYSTEMS ENGR AND OTHER SYSTEMS

OPERATIONAL COSTS

DIRECT OPERATIONAL COST (DOC)

	C/SM***	PERCENT
FLIGHT CREW	0.44748	9.37389
FUEL AND OIL	2.92597	61.29367
INSURANCE	0.03278	0.68670
DEPRECIATION	0.69898	14.64232
MAINTENANCE	0.66848	14.00349
TOTAL DOC	4.77369	100.000

INDIRECT OPERATIONAL COST (IOC)

	C/SM***	PERCENT
SYSTEM	0.0	0.0
LOCAL	0.56480	18.23523
AIRCRAFT CONTROL	0.01317	0.42514
CABIN ATTENDANT	0.44039	14.21834
FOOD AND BEVERAGE	0.16695	5.39028
PASSENGER HANDLING	0.63674	20.55786
CARGO HANDLING	0.17677	5.70717
OTHER PASSENGER EXPENSE	0.83200	26.86206
OTHER CARGO EXPENSE	0.00860	0.27754
GENERAL + ADMINISTRATION	0.25790	8.32648
TOTAL IOC	3.09730	100.000

MISC. DATA

FLIGHT DISTANCE (N. MI.)	2500.00
BLOCK FUEL (LBS)	80020.19
BLOCK TIME (HRS)	5.97
FLIGHT TIME (HRS)	5.64
AVG STAGE LENGTH (N. MI.)	2500.00
AVG CARGO PER FLIGHT	13695.72
UTILIZATION (HRS PER YR)	4140.09
FLIGHTS PER A/C PER YEAR	693.10
FARE ($)	374.96
FUEL COST ($/LB)	0.31600

*** - CENTS PER SEAT N. MILE

- -

RATE OF RETURN ON INVESTMENT

YEAR	AVG NO AIRCRAFT DURING YEAR	AIRCRAFT ADDED DURING YEAR	AVERAGE INVESTMENT DURING YEAR $M	CUMULATIVE DEPRECIATION $M	AVERAGE BOOK VALUE OF FLEET $M	REVENUE $M	INTEREST EXPENSE $M	OPERATING EXPENSE $M	CASH FLOW $M	ROI PERCENT
1	5.0	8.0	392.13	22.06	370.08	305.06	47.06	238.67	-143.95	15.33
2	13.0	8.0	1019.55	79.41	940.14	793.16	114.82	620.55	-139.63	15.29
3	20.4	7.0	1597.95	169.29	1428.66	1243.12	169.17	972.59	-113.54	15.39
4	23.0	0.0	1803.82	270.76	1533.06	1403.27	172.23	1097.90	23.74	15.58
5	23.0	0.0	1803.82	372.22	1431.60	1403.27	150.58	1097.90	34.56	15.92
6	23.0	0.0	1803.82	473.69	1330.13	1403.27	128.93	1097.90	45.38	16.33
7	23.0	0.0	1803.82	575.15	1228.67	1403.27	107.29	1097.90	56.20	16.79
8	23.0	0.0	1803.82	676.61	1127.21	1403.27	85.64	1097.90	67.03	17.34
9	23.0	0.0	1803.82	778.08	1025.74	1403.27	64.00	1097.90	77.85	18.01
10	23.0	0.0	1803.82	879.54	924.28	1403.27	42.35	1097.90	88.67	18.81
11	23.0	0.0	1803.82	981.01	822.81	1403.27	20.70	1097.90	149.69	19.82
12	23.0	0.0	1803.82	1082.47	721.35	1403.27	6.59	1097.90	206.94	21.62
13	23.0	0.0	1803.82	1183.94	619.88	1403.27	-0.00	1097.90	254.15	24.63
14	23.0	0.0	1803.82	1285.40	518.42	1403.27	-0.00	1097.90	254.15	29.45
15	23.0	0.0	1803.82	1386.87	416.95	1403.27	-0.00	1097.90	254.15	36.62
16	23.0	0.0	1803.82	1488.33	315.49	1403.27	-0.00	1097.90	254.15	48.40

AVG ROI OVER THE 16 YEAR PERIOD = 18.94 PERCENT

ATX-350I, DESIGN RANGE = 4600 NMI, M = 0.80, INTERN. RESRVS MISS

T/C=10.30 AR= 7.78 W/S=129.00 T/W=0.264

Configuration 9

CONFIGURATION GEOMETRY

BASIC WING--	AREA(SQ FT)	SPAN(FT)	TAPER RATIO	C/4 SWEEP	L.E. SWEEP	MAC(FT)		
	4379.2	184.58	0.246	35.000	37.883	26.62		
WING PANELS--	AREA(SQ FT)	EXP. AREA	AVG T/C	L.E. SWEEP	SFLE(SQ FT)	REF L(FT)		
	1040.5	54.7	11.15	37.879	0.0	47.03		
	2117.7	2117.7	10.61	37.879	0.0	37.32		
	385.9	385.9	9.29	37.879	0.0	24.62		
	1333.0	1333.0	9.03	37.879	0.0	18.12		
	142.7	142.7	9.03	37.879	0.0	10.48		
TOTAL WING--	AREA(SQ FT)	EFF AR	AVG T/C	CR(FT)	CT(FT)	MAC(FT)	L(FT)	E SWP
	5019.8	6.79	9.99	54.77	9.38	33.29	81.17	22.988
FUSELAGE--	LENGTH(FT)	S WET(SQ FT)	BWW(FT)	EQUIV D(FT)	SPI(SQ FT)			
	201.00	10702.3	19.32	19.58	301.21			
	BW(FT)	BH(FT)	SBW(SQ FT)					
	19.58	19.58	10538.00					
HORZ. TAIL 1--	SHT1(SQ FT)	SHX1(SQ FT)	REF L1(FT)	L HT1(FT)	HT1 VOL COEF			
	1543.61	1186.13	19.30	72.05	0.9540			
HORZ. TAIL 2--	SHT2(SQ FT)	SHX2(SQ FT)	REF L2(FT)	L HT2(FT)	HT2 VOL COEF			
	0.0	0.0	0.0	201.00	0.0			
VERT. TAIL 1--	SVT1(SQ FT)	SVX1(SQ FT)	REF L1(FT)	L VT1(FT)	VT1 VOL COEF			
	732.51	463.87	20.07	75.02	0.0680			
VERT. TAIL 2--	SVT2(SQ FT)	SVX2(SQ FT)	REF L2(FT)	L VT2(FT)	VT2 VOL COEF			
	0.0	0.0	0.0	201.00	0.0			
PROPULSION--	ENG L(FT)	ENG D(FT)	POD L(FT)	POD D(FT)	POD S WET	NO. PODS	INLET L(FT)	
	14.20	7.18	14.32	9.51	767.95	2.	26.11	
FUEL TANKS--	WING(CU FT)	BOX(CU FT)	FUS(CU FT)					
	4111.21	1080.31	999999.00					
WETTED VOLUMES--	BODY	WING	TAILS	PODS	PYLONS	PONTOONS	TOTAL	
	50440.39	7868.52	2477.02	1719.59	144.75	0.0	62650.26	

ATX-350I, DESIGN RANGE = 4600 NMI, M = 0.80, INTERN. RESRVS MISS

T/C=10.30 AR= 7.78 W/S=129.00 T/W=0.264

Configuration 9

W E I G H T   S T A T E M E N T

	WEIGHT(POUNDS)	WEIGHT FRACTION	(PERCENT)
GROSS WEIGHT	(564918.)		
FUEL AVAILABLE	216345.	FUEL	38.30
EXTERNAL	0.		
INTERNAL	216345.		
ZERO FUEL WEIGHT	348573.		
PAYLOAD	73500.	PAYLOAD	13.01
PASSENGERS	57750.		
BAGGAGE	15750.		
CARGO	0.		
STORES	0.		
OPERATIONAL EMPTY WEIGHT	275073.		
OPERATIONAL ITEMS	10372.	OPERATIONAL ITEMS	3.54
STANDARD ITEMS	9649.		
EMPTY WEIGHT	255052.		
STRUCTURE	156010.	STRUCTURE	27.62
WING	43483.		
ROTOR	0.		
TAIL	8891.		
BODY	67151.		
ALIGHTING GEAR	23549.		
ENGINE SECTION AND NACELLE	12936.		
PROPULSION	33010.	PROPULSION	5.84
CRUISE ENGINES	25714.		
LIFT ENGINES	0.		
THRUST REVERSER	4750.		
EXHAUST SYSTEM	0.		
ENGINE CONTROL	213.		
STARTING SYSTEM	422.		
PROPELLERS	0.		
LUBRICATING SYSTEM	0.		
FUEL SYSTEM	1911.		
DRIVE SYSTEM (POWER TRANS)	0.		
SYSTEMS	66032.		
FLIGHT CONTROLS	7330.		
AUXILIARY POWER PLANT	1202.		
INSTRUMENTS	1022.		
HYDRAULIC AND PNEUMATIC	2603.		
ELECTRICAL	5624.		
AVIONICS	3075.	SYSTEMS	11.69
ARMAMENT	0.		
FURNISHINGS AND EQUIPMENT	38504.		
AIR CONDITIONING	6302.		
ANTI-ICING	369.		
PHOTOGRAPHIC	0.		
LOAD AND HANDLING	0.		
		TOTAL	(100.)

Configuration 9

W E I G H T S   M A T R I X

ELEMENT/ / MATERIAL	AL	TIT.	STEEL	COMP.	OTHER	TOTAL
WING	10001.	1305.	3913.	27829.	435.	43483.
ROTOR	0.	0.	0.	0.	0.	0.
TAIL	2845.	267.	711.	4979.	89.	8891.
BODY	60436.	2686.	672.	1343.	2015.	67151.
L. G.	5181.	235.	15542.	0.	2590.	23549.
ENG SECT	0.	0.	0.	0.	0.	0.
NACELLE	3407.	4381.	1947.	0.	0.	9735.
AIR INDUCT	2880.	320.	0.	0.	0.	3200.
TOTALS	84750.	9194.	22785.	34152.	5129.	156009.

EXCESS FUEL CAPACITY - BODY	50143408.
EXCESS FUEL CAPACITY - WING	0.
EXCESS BODY LENGTH - FT	0.0
AIRFRAME WEIGHT (A.M.P.R.) - LB	215694.
GUST LOAD FACTOR	0.0

A L T E R N A T E   M I S S I O N   N O. 1   S U M M A R Y

Configuration 9

ATX-350I, AVRG STAGE L = 2500 NMI, M = 0.80, 60 % LF   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 CL	AVG L/D RATIO	AVG SFC (FF/T)
TAKEOFF POWER 1	0.	0.0	430281.	0.	0.	0.	0.	0.0	0.0	0.	428601.	0.	0.0	0.0	0.937
POWER 2	0.	0.0	430281.	925.	925.	0.	0.	1.0	1.0	0.	428501.	0.	0.0	0.0	0.385
CLIMB	0.	0.378	429356.	2237.	3161.	14.	14.	3.1	4.1	0.	428201.	0.	0.459	18.13	0.546
ACCEL	10000.	0.456	427119.	323.	3484.	3.	17.	0.5	4.6	0.	428201.	0.	0.383	17.51	0.576
CLIMB	10000.	0.547	426797.	7022.	10506.	103.	120.	14.3	18.9	0.	428201.	0.	0.338	16.28	0.639
CRUISE	35000.	0.800	419774.	0.	10506.	0.	120.	0.0	18.9	0.	-428101.	0.	0.428	16.73	0.650
ACCEL	35000.	0.800	419774.	0.	10506.	0.	120.	0.0	18.9	0.	428201.	0.	0.428	16.73	0.650
ACCEL	35000.	0.800	419774.	0.	10506.	0.	120.	0.0	18.9	0.	428201.	0.	0.428	16.73	0.650
CRUISE	35000.	0.800	419774.	2781.	13287.	79.	199.	10.3	29.2	0.	-428101.	0.	0.427	16.72	0.650
CLIMB	35000.	0.800	416994.	2507.	15794.	61.	260.	7.9	37.1	0.	428201.	0.	0.478	16.80	0.650
CRUISE	39000.	0.800	414487.	65801.	81595.	2040.	2300.	266.8	303.9	0.	-428101.	0.	0.471	16.70	0.649
CLIMB	39000.	0.800	348686.	0.	81595.	0.	2300.	0.0	303.9	0.	428201.	0.	0.0	0.0	0.0
CRUISE	39000.	0.800	348686.	0.	81595.	0.	2300.	0.0	303.9	0.	-428101.	0.	0.431	16.53	0.652
DESCENT	39000.	0.800	348685.	1783.	83378.	114.	2414.	15.7	319.6	0.	428301.	0.	0.309	15.21	-0.289
DECEL	10000.	0.547	346902.	65.	83443.	4.	2418.	0.8	320.4	0.	428301.	0.	0.314	16.20	-7.028
DESCENT	10000.	0.456	346837.	640.	84083.	28.	2446.	6.1	326.5	0.	428301.	0.	0.374	17.32	-2.643
CRUISE	39000.	0.800	346197.	1612.	85695.	54.	2500.	7.1	333.6	0.	-428101.	0.	0.427	16.50	0.653
LOITER	1500.	0.325	344586.	649.	86344.	0.	2500.	3.0	336.6	0.	-80101.	0.	0.531	17.93	0.676
CRUISE	1500.	0.378	343936.	474.	86818.	0.	2500.	2.0	338.6	0.	-80101.	0.	0.392	17.54	0.725
RESET	0.	0.0	343463.	0.	86818.	-2500.	0.	0.0	338.6	0.	0.	0.	0.0	0.0	0.0
CRUISE	39000.	0.800	343463.	7620.	94438.	0.	0.	33.9	372.4	0.	-428101.	0.	0.420	16.43	0.653
TAKEOFF POWER 1	0.	0.0	335843.	0.	94438.	0.	0.	0.0	372.4	0.	428601.	0.	0.0	0.0	0.937
POWER 2	0.	0.0	335843.	925.	95362.	0.	0.	1.0	373.4	0.	428501.	0.	0.0	0.0	0.385
CLIMB	0.	0.378	334918.	1624.	96986.	10.	10.	2.3	375.7	0.	428201.	0.	0.356	17.02	0.546
ACCEL	10000.	0.456	333294.	235.	97221.	2.	12.	0.[illegible]	376.0	0.	428201.	0.	0.298	15.81	0.576

CLIMB	10000.	0.547	333059.	3556.	100777.	46.	58.	6.6	382.7	0.	428201.	0.	0.255	14.42	0.629
CRUISE	30000.	0.710	329503.	1333.	102110.	42.	100.	6.1	388.8	0.	-428101.	0.	0.338	16.40	0.655
DESCENT	30000.	0.750	328170.	407.	102517.	49.	149.	7.3	396.0	0.	428301.	0.	0.250	14.32	-1.247
DECEL	10000.	0.547	327763.	64.	102581.	4.	153.	0.8	396.8	0.	428301.	0.	0.297	15.75	-7.052
DESCENT	10000.	0.456	327699.	628.	103208.	27.	180.	6.0	402.8	0.	428301.	0.	0.353	16.98	-2.627
CRUISE	30000.	0.710	327071.	623.	103831.	20.	200.	2.9	405.6	0.	-428101.	0.	0.336	16.35	0.655
CRUISE	1500.	0.378	326448.	7383.	111215.	0.	200.	32.0	437.6	0.	-80101.	0.	0.368	17.19	0.737

Configuration 9

COST SUMMARY

Configuration 9

RDT AND E

	TOTAL *
DEVELOPMENT - NONRECURRING	
ENGINEERING	1156.06
TOOLING	542.64
TEST ARTICLES	77.98
DATA	0.0
SYSTEMS ENG/MNGMT	0.0
CRUISE ENGINE	0.0
LIFT ENGINE	0.0
FAN	0.0
AVIONICS	0.0
OTHER SYSTEMS	0.0
FACILITIES	0.0
TOTAL AIR VEHICLE	1776.68
INTEGR LOGISTICS SUPPORT	
PLANNING	13.06
TRAINING	4.44
HANDBOOKS	32.25
SSE	9.28
TOTAL ILS	59.02
TOTAL DVLPMNT-NONREC	1835.69
DEVELOPMENT - RECUR(PROTOTYPES)	
AIR VEHICLE	901.62
SPARES	15.89
TOTAL DVLPMNT-RECUR	917.51
GOVMNT DVLPMNT COST	0.0
TOTAL DVLPMNT COST	2753.20

PRODUCTION

	MATERIAL	LABOR	TOTAL PER PROD A/C**
STRUCTURE	5289.52	11493.12	16782.62
WING	1955.10	2589.70	4544.80
ROTOR	0.0	0.0	0.0
TAIL	356.15	728.07	1084.22
BODY	1245.90	5983.81	7229.70
ALIGHTING GEAR	946.65	30.45	977.10
ENG SECT + NACELLE	785.73	2161.08	2946.81
ENG SECTION	0.0	0.0	0.0
NACELLE	762.64	2010.40	2773.04
AIR INDUCTION	23.09	150.68	173.77
PROPULSION	190.67	158.49	349.16
ENGINE INSTALL	0.0	36.37	36.37
THRUST REVERSER	0.0	6.72	6.72
EXHAUST SYSTEM	0.0	0.0	0.0
ENGINE CONTROLS	5.72	6.38	12.09
STARTING SYSTEM	64.77	8.61	73.37
PROPELLER INSTALL	0.0	0.0	0.0
LUBRICATING SYSTEM	0.0	0.0	0.0
FUEL SYSTEM	120.18	100.42	220.60
DRIVE SYS(PWR TRN)	0.0	0.0	0.0
SYSTEMS	4366.91	7666.60	12033.51
FLIGHT CONTROLS	1226.83	521.37	1748.20
AUX POWER PLANT	206.91	26.72	233.63
INSTRUMENTS	129.59	77.86	207.45
HYDRAULIC + PNEUM	198.54	380.27	578.81
ELECTRICAL	581.77	1203.54	1785.31
AVIONIC INSTALL	63.39	525.65	589.04
ARMAMENT	0.0	0.0	0.0
FURN AND EQUIP	1428.81	4427.03	5855.84
AIR CONDITIONING	501.71	476.29	978.00
ANTI-ICING	29.37	27.88	57.25
PHOTOGRAPHIC	0.0	0.0	0.0
LOAD AND HANDLING	0.0	0.0	0.0
SYSTEMS INTEGR	841.28	695.75	1537.02
TOTAL COST	10688.38	20013.93	30702.30
TOTAL HRS **		597.65	597.65
ENG CHANGE ORDERS			1005.13
SUSTAINING ENG COST			1705.43
PROD TOOLING COST			2203.17
QUALITY ASSURANCE			2891.44
MISCELLANEOUS ***			940.02
TOTAL AIRFRAME COST			39447.44
ENGINE COST			11128.63
AVIONICS COST			866.31
TOTAL MANUFACTURING COST			51442.37
WARRANTY			238.67
TOTAL PRODUCTION COST			51681.04

PROCUREMENT

	PER PROD A/C**
TOTAL PRODUCTION	51681.04
INTEGR LOGISTICS SUPPORT	
PLANNING	33.56
TRAINING	11.41
TRAINERS	220.56
HANDBOOKS	41.40
FACILITIES	0.0
SSE - CFE	0.0
SSE - GFE	2429.01
TOTAL ILS	2735.93
INITIAL SPARES COST	7467.41
PRODUCTION DEVELOPMENT	
ENGINEERING	321.14
TOOLING	313.80
ENGINES	0.0
TOTAL PROD DEV	634.93
TOTAL PROCUREMENT	62519.29

* - MILLIONS OF DOLLARS

** -1000 OF DOLLARS OR HOURS PER PROD A/C

*** - INCLUDES PROD DATA, SYSTEMS ENGR AND OTHER SYSTEMS

Configuration 9

OPERATIONAL COSTS

DIRECT OPERATIONAL COST (DOC)

	C/SM***	PERCENT
FLIGHT CREW	0.44768	8.97227
FUEL AND OIL	3.22431	64.62080
INSURANCE	0.03418	0.68497
DEPRECIATION	0.61856	12.39699
MAINTENANCE	0.66486	13.32506
TOTAL DOC	4.98958	100.000

INDIRECT OPERATIONAL COST (IOC)

	C/SM***	PERCENT
SYSTEM	0.0	0.0
LOCAL	0.57456	18.42265
AIRCRAFT CONTROL	0.01317	0.42222
CABIN ATTENDANT	0.44058	14.12677
FOOD AND BEVERAGE	0.16703	5.35557
PASSENGER HANDLING	0.63674	20.41644
CARGO HANDLING	0.17677	5.66792
OTHER PASSENGER EXPENSE	0.83200	26.67726
OTHER CARGO EXPENSE	0.00860	0.27563
GENERAL + ADMINISTRATION	0.26932	8.63558
TOTAL IOC	3.11876	100.000

MISC. DATA

FLIGHT DISTANCE (N. MI.)	2500.00
BLOCK FUEL (LBS)	88180.63
BLOCK TIME (HRS)	5.98
FLIGHT TIME (HRS)	5.64
AVG STAGE LENGTH (N. MI.)	2500.00
AVG CARGO PER FLIGHT	13695.72
UTILIZATION (HRS PER YR)	4140.44
FLIGHTS PER A/C PER YEAR	692.85
FARE ($)	374.96
FUEL COST ($/LB)	0.31600

*** - CENTS PER SEAT N. MILE

- -

RATE OF RETURN ON INVESTMENT

YEAR	AVG NO AIRCRAFT DURING YEAR	AIRCRAFT ADDED DURING YEAR	AVERAGE INVESTMENT DURING YEAR	CUMULATIVE DEPRECIATION	AVERAGE BOOK VALUE OF FLEET	REVENUE	INTEREST EXPENSE	OPERATING EXPENSE	CASH FLOW	ROI
			$M	$M	$M	$M	$M	$M	$M	PERCENT
1	5.0	8.0	347.01	19.52	327.49	304.95	41.64	245.78	-127.18	15.39
2	13.0	8.0	902.23	70.27	831.96	792.87	101.60	639.03	-123.01	15.35
3	20.4	7.0	1414.07	149.81	1264.26	1242.67	149.70	1001.56	-99.62	15.46
4	23.0	0.0	1596.25	239.60	1356.65	1402.77	152.41	1130.60	21.97	15.65
5	23.0	0.0	1596.25	329.39	1266.86	1402.77	133.25	1130.60	31.55	16.00
6	23.0	0.0	1596.25	419.18	1177.07	1402.77	114.10	1130.60	41.13	16.41
7	23.0	0.0	1596.25	508.97	1087.28	1402.77	94.94	1130.60	50.70	16.88
8	23.0	0.0	1596.25	598.76	997.50	1402.77	75.79	1130.60	60.28	17.44
9	23.0	0.0	1596.25	688.55	907.71	1402.77	56.63	1130.60	69.86	18.11
10	23.0	0.0	1596.25	778.33	817.92	1402.77	37.48	1130.60	79.44	18.93
11	23.0	0.0	1596.25	868.12	728.13	1402.77	18.32	1130.60	133.43	19.95
12	23.0	0.0	1596.25	957.91	638.34	1402.77	5.83	1130.60	184.10	21.78
13	23.0	0.0	1596.25	1047.70	548.55	1402.77	-0.00	1130.60	225.88	24.81
14	23.0	0.0	1596.25	1137.49	458.76	1402.77	-0.00	1130.60	225.88	29.66
15	23.0	0.0	1596.25	1227.28	368.97	1402.77	-0.00	1130.60	225.88	36.88
16	23.0	0.0	1596.25	1317.07	279.18	1402.77	-0.00	1130.60	225.88	48.74

AVG ROI OVER THE 16 YEAR PERIOD = 19.05 PERCENT

ATX-350I, DESIGN RANGE = 4600 NMI, M = 0.80, INTERN. RESRVS MISS

T/C=10.30 AR= 7.78 W/S=129.00 T/W=0.264

Configuration 10

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

BASIC WING--	AREA(SQ FT)	SPAN(FT)	TAPER RATIO	C/4 SWEEP	L.E. SWEEP	MAC(FT)		
	4583.5	188.84	0.246	35.000	37.883	27.24		
WING PANELS--	AREA(SQ FT)	EXP. AREA	AVG T/C	L.E. SWEEP	SFLE(SQ FT)	REF L(FT)		
	1089.0	78.9	11.13	37.879	0.0	48.20		
	2216.5	2216.5	10.61	37.879	0.0	38.18		
	403.9	403.9	9.29	37.879	0.0	25.18		
	1395.2	1395.2	9.03	37.879	0.0	18.53		
	149.3	149.3	9.03	37.879	0.0	10.72		
TOTAL WING--	AREA(SQ FT)	EFF AR	AVG T/C	CR(FT)	CT(FT)	MAC(FT)	L(FT)	E SWP
	5253.9	6.79	9.99	56.03	9.59	34.06	83.04	22.988
FUSELAGE--	LENGTH(FT)	S WET(SQ FT)	BWW(FT)	EQUIV D(FT)	SPI(SQ FT)			
	201.00	10750.8	19.32	19.58	301.21			
	BW(FT)	BH(FT)	SBW(SQ FT)					
	19.58	19.58	10538.00					
HORZ. TAIL 1--	SHT1(SQ FT)	SHX1(SQ FT)	REF L1(FT)	L HT1(FT)	HT1 VOL COEF			
	1662.26	1290.51	20.11	71.65	0.9540			
HORZ. TAIL 2--	SHT2(SQ FT)	SHX2(SQ FT)	REF L2(FT)	L HT2(FT)	HT2 VOL COEF			
	0.0	0.0	0.0	201.00	0.0			
VERT. TAIL 1--	SVT1(SQ FT)	SVX1(SQ FT)	REF L1(FT)	L VT1(FT)	VT1 VOL COEF			
	790.82	510.63	21.00	74.41	0.0680			
VERT. TAIL 2--	SVT2(SQ FT)	SVX2(SQ FT)	REF L2(FT)	L VT2(FT)	VT2 VOL COEF			
	0.0	0.0	0.0	201.00	0.0			
PROPULSION--	ENG L(FT)	ENG D(FT)	POD L(FT)	POD D(FT)	POD S WET	NO. PODS	INLET L(FT)	
	14.50	7.35	14.61	9.73	801.93	2.	26.75	
FUEL TANKS--	WING(CU FT)	BOX(CU FT)	FUS(CU FT)					
	4427.53	1134.76	999999.00					
WETTED VOLUMES--	BODY	WING	TAILS	PODS	PYLONS	PONTOONS	TOTAL	
	50565.38	8501.80	2822.18	1837.09	154.29	0.0	63880.73	

Configuration 10

ATX-350I, DESIGN RANGE = 4600 NMI, M = 0.80, INTERN. RESRVS MISS

T/C=10.30 AR= 7.78 W/S=129.00 T/W=0.264

W E I G H T   S T A T E M E N T

	WEIGHT(POUNDS)	WEIGHT FRACTION	(PERCENT)
GROSS WEIGHT	(591266.)		
FUEL AVAILABLE	225696.	FUEL	38.17
EXTERNAL	0.		
INTERNAL	225695.		
ZERO FUEL WEIGHT	365570.		
PAYLOAD	73500.	PAYLOAD	12.43
PASSENGERS	57750.		
BAGGAGE	15750.		
CARGO	0.		
STORES	0.		
OPERATIONAL EMPTY WEIGHT	292070.		
OPERATIONAL ITEMS	10383.	OPERATIONAL ITEMS	3.39
STANDARD ITEMS	9660.		
EMPTY WEIGHT	272027.		
STRUCTURE	171037.	STRUCTURE	28.93
WING	54615.		
ROTOR	0.		
TAIL	10538.		
BODY	67634.		
ALIGHTING GEAR	24647.		
ENGINE SECTION AND NACELLE	13604.		
PROPULSION	34460.	PROPULSION	5.83
CRUISE ENGINES	27036.		
LIFT ENGINES	0.		
THRUST REVERSER	4899.		
EXHAUST SYSTEM	0.		
ENGINE CONTROL	223.		
STARTING SYSTEM	443.		
PROPELLERS	0.		
LUBRICATING SYSTEM	0.		
FUEL SYSTEM	1859.		
DRIVE SYSTEM (POWER TRANS)	0.		
SYSTEMS	66530.		
FLIGHT CONTROLS	7682.		
AUXILIARY POWER PLANT	1202.		
INSTRUMENTS	1029.		
HYDRAULIC AND PNEUMATIC	2711.		
ELECTRICAL	5648.		
AVIONICS	3075.	SYSTEMS	11.25
ARMAMENT	0.		
FURNISHINGS AND EQUIPMENT	38504.		
AIR CONDITIONING	6302.		
ANTI-ICING	376.		
PHOTOGRAPHIC	0.		
LOAD AND HANDLING	0.		
		TOTAL	(100.)

Configuration 10

WEIGHTS MATRIX

ELEMENT/ / MATERIAL	AL	TIT.	STEEL	COMP.	OTHER	TOTAL
WING	48607.	1092.	4369.	0.	546.	54615.
ROTOR	0.	0.	0.	0.	0.	0.
TAIL	9379.	211.	843.	0.	105.	10538.
BODY	60870.	2705.	676.	1353.	2029.	67634.
L. G.	5422.	246.	16267.	0.	2711.	24647.
ENG SECT	0.	0.	0.	0.	0.	0.
NACELLE	3583.	4606.	2047.	0.	0.	10236.
AIR INDUCT	3031.	337.	0.	0.	0.	3368.
TOTALS	130892.	9198.	24203.	1353.	5392.	171037.

EXCESS FUEL CAPACITY - BODY	50152608.
EXCESS FUEL CAPACITY - WING	0.
EXCESS BODY LENGTH - FT	0.0
AIRFRAME WEIGHT (A.M.P.R.) - LB	230956.
GUST LOAD FACTOR	0.0

Configuration 10

A L T E R N A T E   M I S S I O N   N O. 1   S U M M A R Y

ATX-350I, AVRG STAGE L = 2500 NMI, M = 0.80, 60 % LF   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 CL	AVG L/D RATIO	AVG SFC (FF/T)
TAKEOFF POWER 1	0.	0.0	452702.	0.	0.	0.	0.	0.0	0.0	0.	428601.	0.	0.0	0.0	0.935
POWER 2	0.	0.0	452702.	966.	966.	0.	0.	1.0	1.0	0.	428501.	0.	0.0	0.0	0.384
CLIMB	0.	0.378	451736.	2352.	3318.	14.	14.	3.2	4.2	0.	428201.	0.	0.462	18.18	0.545
ACCEL	10000.	0.456	449384.	339.	3658.	3.	17.	0.5	4.6	0.	428201.	0.	0.385	17.57	0.575
CLIMB	10000.	0.547	449044.	7386.	11043.	104.	121.	14.4	19.0	0.	428201.	0.	0.340	16.35	0.638
CRUISE	35000.	0.800	441659.	0.	11043.	0.	121.	0.0	19.0	0.	-428101.	0.	0.431	16.78	0.649
ACCEL	35000.	0.800	441659.	0.	11043.	0.	121.	0.0	19.0	0.	428201.	0.	0.431	16.78	0.649
ACCEL	35000.	0.800	441659.	0.	11043.	0.	121.	0.0	19.0	0.	428201.	0.	0.431	16.78	0.649
CRUISE	35000.	0.800	441659.	5757.	16800.	156.	277.	20.3	39.4	0.	-428101.	0.	0.428	16.75	0.649
CLIMB	35000.	0.800	435902.	2573.	19373.	60.	337.	7.8	47.2	0.	428201.	0.	0.477	16.83	0.649
CRUISE	39000.	0.800	433329.	66167.	85540.	1963.	2300.	256.7	303.8	0.	-428101.	0.	0.472	16.74	0.648
CLIMB	39000.	0.800	367162.	0.	85540.	0.	2300.	0.0	303.8	0.	428201.	0.	0.0	0.0	0.0
CRUISE	39000.	0.800	367162.	0.	85541.	0.	2300.	0.0	303.8	0.	-428101.	0.	0.434	16.58	0.651
DESCENT	39000.	0.800	367161.	1844.	87385.	114.	2414.	15.7	319.5	0.	428301.	0.	0.311	15.29	-0.298
DECEL	10000.	0.547	365317.	69.	87453.	4.	2418.	0.8	320.3	0.	428301.	0.	0.316	16.28	-7.012
DESCENT	10000.	0.456	365249.	671.	88124.	28.	2446.	6.1	326.4	0.	428301.	0.	0.376	17.40	-2.639
CRUISE	39000.	0.800	364578.	1693.	89817.	54.	2500.	7.1	333.5	0.	-428101.	0.	0.430	16.55	0.651
LOITER	1500.	0.330	362885.	684.	90501.	0.	2500.	3.0	336.5	0.	-80101.	0.	0.518	18.01	0.680
CRUISE	1500.	0.378	362201.	496.	90996.	0.	2500.	2.0	338.5	0.	-80101.	0.	0.394	17.61	0.723
RESET	0.	0.0	361705.	0.	90996.	-2500.	0.	0.0	338.5	0.	0.	0.	0.0	0.0	0.0
CRUISE	39000.	0.800	361705.	7981.	98978.	0.	0.	33.9	372.4	0.	-428101.	0.	0.422	16.49	0.652
TAKEOFF POWER 1	0.	0.0	353724.	0.	98978.	0.	0.	0.0	372.4	0.	428601.	0.	0.0	0.0	0.935
POWER 2	0.	0.0	353724.	966.	99944.	0.	0.	1.0	373.4	0.	428501.	0.	0.0	0.0	0.384
CLIMB	0.	0.378	352758.	1708.	101652.	10.	10.	2.3	375.7	0.	428201.	0.	0.358	17.10	0.545
ACCEL	10000.	0.456	351049.	247.	101899.	2.	12.	0.4	376.0	0.	428201.	0.	0.300	15.90	0.575

CLIMB	10000.	0.547	350803.	3737.	105636.	46.	58.	6.7	382.7	0.	428201.	0.	0.256	14.52	0.627
CRUISE	30000.	0.710	347065.	1382.	107018.	42.	100.	6.0	388.8	0.	-428101.	0.	0.340	16.48	0.653
DESCENT	30000.	0.750	345683.	428.	107447.	49.	149.	7.3	396.1	0.	428301.	0.	0.252	14.42	-1.245
DECEL	10000.	0.547	345255.	67.	107513.	4.	153.	0.8	396.8	0.	428301.	0.	0.299	15.84	-7.036
DESCENT	10000.	0.456	345188.	659.	108172.	27.	180.	6.0	402.8	0.	428301.	0.	0.356	17.06	-2.622
CRUISE	30000.	0.710	344529.	636.	108808.	19.	200.	2.8	405.6	0.	-428101.	0.	0.338	16.44	0.654
CRUISE	1500.	0.378	343893.	7723.	116532.	0.	200.	32.0	437.6	0.	-80101.	0.	0.370	17.27	0.735

Configuration 10

COST SUMMARY

RDT AND E

	TOTAL *
DEVELOPMENT - NONRECURRING	
ENGINEERING	1079.14
TOOLING	552.77
TEST ARTICLES	81.14
DATA	0.0
SYSTEMS ENG/MNGMT	0.0
CRUISE ENGINE	0.0
LIFT ENGINE	0.0
FAN	0.0
AVIONICS	0.0
OTHER SYSTEMS	0.0
FACILITIES	0.0
TOTAL AIR VEHICLE	1713.05
INTEGR LOGISTICS SUPPORT	
PLANNING	12.45
TRAINING	4.23
HANDBOOKS	33.19
SSE	8.84
TOTAL ILS	58.71
TOTAL DVLPMNT-NONREC	1771.76
DEVELOPMENT - RECUR(PROTOTYPES)	
AIR VEHICLE	923.70
SPARES	16.48
TOTAL DVLPMNT-RECUR	940.19
GOVMNT DVLPMNT COST	0.0
TOTAL DVLPMNT COST	2711.95

PRODUCTION

	MATERIAL	LABOR	TOTAL PER PROD A/C**
STRUCTURE	5949.44	12372.29	18321.73
WING	2509.25	3248.10	5757.35
ROTOR	0.0	0.0	0.0
TAIL	371.25	865.84	1237.09
BODY	1253.69	5974.23	7227.92
ALIGHTING GEAR	989.88	31.60	1021.47
ENG SECT + NACELLE	825.38	2252.52	3077.90
ENG SECTION	0.0	0.0	0.0
NACELLE	801.10	2095.33	2896.43
AIR INDUCTION	24.28	157.19	181.47
PROPULSION	190.79	157.18	347.97
ENGINE INSTALL	0.0	37.91	37.91
THRUST REVERSER	0.0	6.87	6.87
EXHAUST SYSTEM	0.0	0.0	0.0
ENGINE CONTROLS	5.98	6.62	12.59
STARTING SYSTEM	68.03	8.97	77.00
PROPELLER INSTALL	0.0	0.0	0.0
LUBRICATING SYSTEM	0.0	0.0	0.0
FUEL SYSTEM	116.78	96.81	213.60
DRIVE SYS(PWR TRN)	0.0	0.0	0.0
SYSTEMS	4433.77	7646.15	12079.92
FLIGHT CONTROLS	1284.57	541.66	1826.23
AUX POWER PLANT	206.72	26.48	233.20
INSTRUMENTS	130.30	77.68	207.98
HYDRAULIC + PNEUM	206.61	392.64	599.25
ELECTRICAL	583.63	1197.96	1781.59
AVIONIC INSTALL	63.33	521.06	584.40
ARMAMENT	0.0	0.0	0.0
FURN AND EQUIP	1427.47	4388.39	5815.86
AIR CONDITIONING	501.24	472.13	973.37
ANTI-ICING	29.89	28.15	58.04
PHOTOGRAPHIC	0.0	0.0	0.0
LOAD AND HANDLING	0.0	0.0	0.0
SYSTEMS INTEGR	896.43	735.57	1632.00
TOTAL COST	11470.43	20911.18	32381.60
TOTAL HRS **		624.44	624.44
ENG CHANGE ORDERS			1053.00
SUSTAINING ENG COST			1580.97
PROD TOOLING COST			2301.94
QUALITY ASSURANCE			2805.27
MISCELLANEOUS ***			973.54
TOTAL AIRFRAME COST			41096.29
ENGINE COST			11567.77
AVIONICS COST			866.31
TOTAL MANUFACTURING COST			53530.35
WARRANTY			248.57
TOTAL PRODUCTION COST			53778.91

PROCUREMENT

	PER PROD A/C**
TOTAL PRODUCTION	53778.91
INTEGR LOGISTICS SUPPORT	
PLANNING	32.12
TRAINING	10.92
TRAINERS	220.56
HANDBOOKS	41.21
FACILITIES	0.0
SSE - CFE	0.0
SSE - GFE	2527.61
TOTAL ILS	2832.41
INITIAL SPARES COST	7767.35
PRODUCTION DEVELOPMENT	
ENGINEERING	307.36
TOOLING	327.86
ENGINES	0.0
TOTAL PROD DEV	635.22
TOTAL PROCUREMENT	65013.87

* - MILLIONS OF DOLLARS

** -1000 OF DOLLARS OR HOURS PER PROD A/C

*** - INCLUDES PROD DATA, SYSTEMS ENGR AND OTHER SYSTEMS

OPERATIONAL COSTS

DIRECT OPERATIONAL COST (DOC)

	C/SM***	PERCENT
FLIGHT CREW	0.44766	8.61455
FUEL AND OIL	3.37930	65.03012
INSURANCE	0.03331	0.64098
DEPRECIATION	0.63983	12.31260
MAINTENANCE	0.69642	13.40172
TOTAL DOC	5.19651	100.000

INDIRECT OPERATIONAL COST (IOC)

	C/SM***	PERCENT
SYSTEM	0.0	0.0
LOCAL	0.59122	18.81102
AIRCRAFT CONTROL	0.01317	0.41897
CABIN ATTENDANT	0.44056	14.01743
FOOD AND BEVERAGE	0.16702	5.31411
PASSENGER HANDLING	0.63674	20.25940
CARGO HANDLING	0.17677	5.62432
OTHER PASSENGER EXPENSE	0.83200	26.47208
OTHER CARGO EXPENSE	0.00860	0.27351
GENERAL + ADMINISTRATION	0.27687	8.80924
TOTAL IOC	3.14293	100.000

MISC. DATA

FLIGHT DISTANCE (N. MI.)	2500.00
BLOCK FUEL (LBS)	92420.19
BLOCK TIME (HRS)	5.98
FLIGHT TIME (HRS)	5.64
AVG STAGE LENGTH (N. MI.)	2500.00
AVG CARGO PER FLIGHT	13695.72
UTILIZATION (HRS PER YR)	4140.40
FLIGHTS PER A/C PER YEAR	692.88
FARE ($)	374.96
FUEL COST ($/LB)	0.31600

*** - CENTS PER SEAT N. MILE

RATE OF RETURN ON INVESTMENT

YEAR	AVG NO AIRCRAFT DURING YEAR	AIRCRAFT ADDED DURING YEAR	AVERAGE INVESTMENT DURING YEAR	CUMULATIVE DEPRECIATION	AVERAGE BOOK VALUE OF FLEET	REVENUE	INTEREST EXPENSE	OPERATING EXPENSE	CASH FLOW	ROI
			$M	$M	$M	$M	$M	$M	$M	PERCENT
1	5.0	8.0	358.97	20.19	338.78	304.96	43.08	252.80	-136.08	14.06
2	13.0	8.0	933.32	72.69	860.63	792.90	105.11	657.27	-139.01	13.99
3	20.4	7.0	1462.80	154.97	1307.82	1242.72	154.86	1030.15	-121.47	14.05
4	23.0	0.0	1651.26	247.86	1403.40	1402.83	157.66	1162.87	1.93	14.17
5	23.0	0.0	1651.26	340.74	1310.52	1402.83	137.84	1162.87	11.84	14.41
6	23.0	0.0	1651.26	433.62	1217.63	1402.83	118.03	1162.87	21.75	14.70
7	23.0	0.0	1651.26	526.50	1124.75	1402.83	98.21	1162.87	31.66	15.03
8	23.0	0.0	1651.26	619.39	1031.87	1402.83	78.40	1162.87	41.56	15.43
9	23.0	0.0	1651.26	712.27	938.99	1402.83	58.58	1162.87	51.47	15.90
10	23.0	0.0	1651.26	805.15	846.10	1402.83	38.77	1162.87	61.38	16.47
11	23.0	0.0	1651.26	898.04	753.22	1402.83	18.95	1162.87	117.23	17.19
12	23.0	0.0	1651.26	990.92	660.34	1402.83	6.03	1162.87	169.64	18.63
13	23.0	0.0	1651.26	1083.80	567.45	1402.83	-0.00	1162.87	212.86	21.14
14	23.0	0.0	1651.26	1176.68	474.57	1402.83	-0.00	1162.87	212.86	25.28
15	23.0	0.0	1651.26	1269.57	381.69	1402.83	-0.00	1162.87	212.86	31.43
16	23.0	0.0	1651.26	1362.45	288.81	1402.83	-0.00	1162.87	212.86	41.54

AVG ROI OVER THE 16 YEAR PERIOD = 16.79 PERCENT

Configuration 12

ATX-350I, DESIGN RANGE = 4600 NMI, M = 0.80, INTERN. RESRVS MISS

T/C=10.30 AR= 7.78 W/S=129.00 T/W=0.264

CONFIGURATION GEOMETRY

BASIC WING--	AREA(SQ FT)	SPAN(FT)	TAPER RATIO	C/4 SWEEP	L.E. SWEEP	MAC(FT)		
	4495.4	187.01	0.246	35.000	37.883	26.97		
WING PANELS--	AREA(SQ FT)	EXP. AREA	AVG T/C	L.E. SWEEP	SFLE(SQ FT)	REF L(FT)		
	1068.1	68.4	11.14	37.879	0.0	47.70		
	2173.9	2173.9	10.61	37.879	0.0	37.81		
	396.1	396.1	9.29	37.879	0.0	24.94		
	1368.4	1368.4	9.03	37.879	0.0	18.36		
	146.5	146.5	9.03	37.879	0.0	10.62		
TOTAL WING--	AREA(SQ FT)	EFF AR	AVG T/C	CR(FT)	CT(FT)	MAC(FT)	L(FT)	E SWP
	5152.9	6.79	9.99	55.49	9.50	33.73	82.24	22.988
FUSELAGE--	LENGTH(FT)	S WET(SQ FT)	BWW(FT)	EQUIV D(FT)	SPI(SQ FT)			
	201.00	10729.9	19.32	19.58	301.21			
	BW(FT)	BH(FT)	SBW(SQ FT)					
	19.58	19.58	10538.00					
HORZ. TAIL 1--	SHT1(SQ FT)	SHX1(SQ FT)	REF L1(FT)	L HT1(FT)	HT1 VOL COEF			
	1610.68	1245.07	19.76	71.82	0.9540			
HORZ. TAIL 2--	SHT2(SQ FT)	SHX2(SQ FT)	REF L2(FT)	L HT2(FT)	HT2 VOL COEF			
	0.0	0.0	0.0	201.00	0.0			
VERT. TAIL 1--	SVT1(SQ FT)	SVX1(SQ FT)	REF L1(FT)	L VT1(FT)	VT1 VOL COEF			
	765.42	490.20	20.60	74.67	0.0680			
VERT. TAIL 2--	SVT2(SQ FT)	SVX2(SQ FT)	REF L2(FT)	L VT2(FT)	VT2 VOL COEF			
	0.0	0.0	0.0	201.00	0.0			
PROPULSION--	ENG L(FT)	ENG D(FT)	POD L(FT)	POD D(FT)	POD S WET	NO. PODS	INLET L(FT)	
	14.37	7.28	14.49	9.63	787.29	2.	26.48	
FUEL TANKS--	WING(CU FT)	BOX(CU FT)	FUS(CU FT)					
	4290.11	1111.27	999999.00					
WETTED VOLUMES--	BODY	WING	TAILS	PODS	PYLONS	PONTOONS	TOTAL	
	50511.14	8226.53	2669.92	1786.13	150.16	0.0	63343.86	

ATX-350I, DESIGN RANGE = 4600 NMI, M = 0.80, INTERN. RESRVS MISS

Configuration 12

T/C=10.30 AR= 7.78 W/S=129.00 T/W=0.264

W E I G H T   S T A T E M E N T

	WEIGHT(POUNDS)		WEIGHT FRACTION	(PERCENT)
GROSS WEIGHT		(579905.)		
FUEL AVAILABLE		221686.	FUEL	38.23
EXTERNAL	0.			
INTERNAL	221685.			
ZERO FUEL WEIGHT		358219.		
PAYLOAD		73500.	PAYLOAD	12.67
PASSENGERS	57750.			
BAGGAGE	15750.			
CARGO	0.			
STORES	0.			
OPERATIONAL EMPTY WEIGHT		284719.		
OPERATIONAL ITEMS	10379.		OPERATIONAL ITEMS	3.45
STANDARD ITEMS	9655.			
EMPTY WEIGHT		264685.		
STRUCTURE		164535.	STRUCTURE	28.37
WING	50002.			
ROTOR	0.			
TAIL	9629.			
BODY	67416.			
ALIGHTING GEAR	24173.			
ENGINE SECTION AND NACELLE	13315.			
PROPULSION		33836.	PROPULSION	5.83
CRUISE ENGINES	26465.			
LIFT ENGINES	0.			
THRUST REVERSER	4835.			
EXHAUST SYSTEM	0.			
ENGINE CONTROL	219.			
STARTING SYSTEM	434.			
PROPELLERS	0.			
LUBRICATING SYSTEM	0.			
FUEL SYSTEM	1883.			
DRIVE SYSTEM (POWER TRANS)	0.			
SYSTEMS		66315.		
FLIGHT CONTROLS	7530.			
AUXILIARY POWER PLANT	1202.			
INSTRUMENTS	1026.			
HYDRAULIC AND PNEUMATIC	2665.			
ELECTRICAL	5638.			
AVIONICS	3075.		SYSTEMS	11.44
ARMAMENT	0.			
FURNISHINGS AND EQUIPMENT	38504.			
AIR CONDITIONING	6302.			
ANTI-ICING	373.			
PHOTOGRAPHIC	0.			
LOAD AND HANDLING	0.			
			TOTAL	(100.)

Configuration 12

W E I G H T S   M A T R I X

ELEMENT/ / MATERIAL	AL	TIT.	STEEL	COMP.	OTHER	TOTAL
WING	44002.	1000.	4500.	0.	500.	50002.
ROTOR	0.	0.	0.	0.	0.	0.
TAIL	8473.	241.	818.	0.	96.	9629.
BODY	60674.	2697.	674.	1348.	2022.	67416.
L. G.	5318.	242.	15954.	0.	2659.	24173.
ENG SECT	0.	0.	0.	0.	0.	0.
NACELLE	3507.	4509.	2004.	0.	0.	10020.
AIR INDUCT	2966.	330.	0.	0.	0.	3296.
TOTALS	124940.	9018.	23951.	1348.	5278.	164535.

EXCESS FUEL CAPACITY - BODY	50148560.
EXCESS FUEL CAPACITY - WING	0.
EXCESS BODY LENGTH - FT	0.0
AIRFRAME WEIGHT (A.M.P.R.) - LB	224354.
GUST LOAD FACTOR	0.0

Configuration 12

ALTERNATE MISSION NO. 1 SUMMARY

ATX-350I, AVRG STAGE L = 2500 NMI, M = 0.80, 60 % LF 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 CL	AVG L/D RATIO	AVG SFC (FF/T)
TAKEOFF POWER 1	0.	0.0	443126.	0.	0.	0.	0.	0.0	0.0	0.	428601.	0.	0.0	0.0	0.936
POWER 2	0.	0.0	443126.	948.	948.	0.	0.	1.0	1.0	0.	428501.	0.	0.0	0.0	0.384
CLIMB	0.	0.378	442178.	2304.	3252.	14.	14.	3.1	4.1	0.	428201.	0.	0.461	18.15	0.545
ACCEL	10000.	0.456	439874.	332.	3584.	3.	17.	0.5	4.6	0.	428201.	0.	0.384	17.53	0.575
CLIMB	10000.	0.547	439542.	7240.	10824.	104.	121.	14.4	19.0	0.	428201.	0.	0.339	16.31	0.639
CRUISE	35000.	0.800	432302.	0.	10824.	0.	121.	0.0	19.0	0.	-428101.	0.	0.430	16.75	0.649
ACCEL	35000.	0.800	432302.	0.	10824.	0.	121.	0.0	19.0	0.	428201.	0.	0.430	16.75	0.649
ACCEL	35000.	0.800	432302.	0.	10824.	0.	121.	0.0	19.0	0.	428201.	0.	0.430	16.75	0.649
CRUISE	35000.	0.800	432302.	4475.	15299.	124.	244.	16.1	35.1	0.	-428101.	0.	0.428	16.73	0.649
CLIMB	35000.	0.800	427828.	2557.	17856.	60.	305.	7.9	43.0	0.	428201.	0.	0.477	16.81	0.650
CRUISE	39000.	0.800	425271.	66036.	83891.	1995.	2300.	260.9	303.9	0.	-428101.	0.	0.471	16.71	0.649
CLIMB	39000.	0.800	359235.	0.	83891.	0.	2300.	0.0	303.9	0.	428201.	0.	0.0	0.0	0.0
CRUISE	39000.	0.800	359235.	0.	83891.	0.	2300.	0.0	303.9	0.	-428101.	0.	0.433	16.55	0.651
DESCENT	39000.	0.800	359235.	1822.	85713.	114.	2414.	15.7	319.6	0.	428301.	0.	0.310	15.25	-0.293
DECEL	10000.	0.547	357413.	67.	85780.	4.	2418.	0.8	320.3	0.	428301.	0.	0.315	16.23	-7.019
DESCENT	10000.	0.456	357346.	657.	86437.	28.	2446.	6.1	326.5	0.	428301.	0.	0.375	17.35	-2.640
CRUISE	39000.	0.800	356689.	1658.	88095.	54.	2500.	7.1	333.5	0.	-428101.	0.	0.428	16.52	0.652
LOITER	1500.	0.330	355031.	669.	88764.	0.	2500.	3.0	336.5	0.	-80101.	0.	0.525	17.96	0.678
CRUISE	1500.	0.378	354362.	486.	89250.	0.	2500.	2.0	338.5	0.	-80101.	0.	0.393	17.57	0.724
RESET	0.	0.0	353876.	0.	89250.	-2500.	0.	0.0	338.5	0.	0.	0.	0.0	0.0	0.0
CRUISE	39000.	0.800	353876.	7830.	97080.	0.	0.	33.9	372.4	0.	-428101.	0.	0.421	16.45	0.652
TAKEOFF POWER 1	0.	0.0	346045.	0.	97080.	0.	0.	0.0	372.4	0.	428601.	0.	0.0	0.0	0.936
POWER 2	0.	0.0	346045.	948.	98028.	0.	0.	1.0	373.4	0.	428501.	0.	0.0	0.0	0.384
CLIMB	0.	0.378	345097.	1673.	99701.	10.	10.	2.3	375.7	0.	428201.	0.	0.357	17.06	0.545
ACCEL	10000.	0.456	343425.	242.	99943.	2.	12.	0.4	376.0	0.	428201.	0.	0.300	15.84	0.575

Configuration 12

CLIMB	10000.	0.547	343183.	3662.	103605.	46.	58.	6.7	382.7	0.	428201.	0.	0.256	14.47	0.628
CRUISE	30000.	0.710	339521.	1360.	104965.	42.	100.	6.1	388.8	0.	-428101.	0.	0.339	16.43	0.654
DESCENT	30000.	0.750	338160.	419.	105384.	49.	149.	7.3	396.0	0.	428301.	0.	0.251	14.36	-1.245
DECEL	10000.	0.547	337741.	65.	105449.	4.	153.	0.8	396.8	0.	428301.	0.	0.298	15.79	-7.042
DESCENT	10000.	0.456	337676.	645.	106094.	27.	180.	6.0	402.8	0.	428301.	0.	0.355	17.01	-2.624
CRUISE	30000.	0.710	337031.	633.	106727.	20.	200.	2.8	405.6	0.	-428101.	0.	0.337	16.39	0.654
CRUISE	1500.	0.378	336398.	7580.	114307.	0.	200.	32.0	437.6	0.	-80101.	0.	0.369	17.22	0.736

COST SUMMARY

Configuration 12

RDT AND E

	TOTAL *
DEVELOPMENT - NONRECURRING	
ENGINEERING	1076.73
TOOLING	548.60
TEST ARTICLES	80.08
DATA	0.0
SYSTEMS ENG/MNGMT	0.0
CRUISE ENGINE	0.0
LIFT ENGINE	0.0
FAN	0.0
AVIONICS	0.0
OTHER SYSTEMS	0.0
FACILITIES	0.0
TOTAL AIR VEHICLE	1705.40
INTEGR LOGISTICS SUPPORT	
PLANNING	12.42
TRAINING	4.22
HANDBOOKS	32.78
SSE	8.83
TOTAL ILS	58.25
TOTAL DVLPMNT-NONREC	1763.65
DEVELOPMENT - RECUR(PROTOTYPES)	
AIR VEHICLE	912.44
SPARES	16.23
TOTAL DVLPMNT-RECUR	928.67
GOVMNT DVLPMNT COST	0.0
TOTAL DVLPMNT COST	2692.32

PRODUCTION

	MATERIAL	LABOR	TOTAL PER PROD A/C**
STRUCTURE	6102.24	12033.10	18135.34
WING	2659.60	3009.40	5669.00
ROTOR	0.0	0.0	0.0
TAIL	413.00	802.28	1215.28
BODY	1250.14	5977.20	7227.34
ALIGHTING GEAR	971.24	31.10	1002.35
ENG SECT + NACELLE	808.26	2213.12	3021.38
ENG SECTION	0.0	0.0	0.0
NACELLE	784.50	2058.73	2843.23
AIR INDUCTION	23.77	154.38	178.15
PROPULSION	190.81	157.80	348.61
ENGINE INSTALL	0.0	37.24	37.24
THRUST REVERSER	0.0	6.80	6.80
EXHAUST SYSTEM	0.0	0.0	0.0
ENGINE CONTROLS	5.86	6.51	12.38
STARTING SYSTEM	66.62	8.81	75.44
PROPELLER INSTALL	0.0	0.0	0.0
LUBRICATING SYSTEM	0.0	0.0	0.0
FUEL SYSTEM	118.33	98.42	216.75
DRIVE SYS(PWR TRN)	0.0	0.0	0.0
SYSTEMS	4404.84	7654.54	12059.38
FLIGHT CONTROLS	1259.58	532.89	1792.47
AUX POWER PLANT	206.80	26.58	233.38
INSTRUMENTS	129.99	77.76	207.75
HYDRAULIC + PNEUM	203.13	387.31	590.45
ELECTRICAL	582.83	1200.31	1783.14
AVIONIC INSTALL	63.36	523.01	586.36
ARMAMENT	0.0	0.0	0.0
FURN AND EQUIP	1428.04	4404.75	5832.79
AIR CONDITIONING	501.44	473.89	975.33
ANTI-ICING	29.66	28.03	57.70
PHOTOGRAPHIC	0.0	0.0	0.0
LOAD AND HANDLING	0.0	0.0	0.0
SYSTEMS INTEGR	872.58	718.39	1590.97
TOTAL COST	11570.48	20563.80	32134.29
TOTAL HRS **		614.07	614.07
ENG CHANGE ORDERS			1044.23
SUSTAINING ENG COST			1577.06
PROD TOOLING COST			2263.70
QUALITY ASSURANCE			2758.67
MISCELLANEOUS ***			957.37
TOTAL AIRFRAME COST			40735.29
ENGINE COST			11378.78
AVIONICS COST			866.31
TOTAL MANUFACTURING COST			52980.38
WARRANTY			246.40
TOTAL PRODUCTION COST			53226.77

PROCUREMENT

	PER PROD A/C**
TOTAL PRODUCTION	53226.77
INTEGR LOGISTICS SUPPORT	
PLANNING	32.07
TRAINING	10.90
TRAINERS	220.56
HANDBOOKS	40.89
FACILITIES	0.0
SSE - CFE	0.0
SSE - GFE	2501.66
TOTAL ILS	2806.08
INITIAL SPARES COST	7676.61
PRODUCTION DEVELOPMENT	
ENGINEERING	306.87
TOOLING	322.42
ENGINES	0.0
TOTAL PROD DEV	629.29
TOTAL PROCUREMENT	64338.72

* - MILLIONS OF DOLLARS

** -1000 OF DOLLARS OR HOURS PER PROD A/C

*** - INCLUDES PROD DATA, SYSTEMS ENGR AND OTHER SYSTEMS

Configuration 12

OPERATIONAL COSTS

DIRECT OPERATIONAL COST (DOC)	C/SM***	PERCENT
FLIGHT CREW	0.44766	8.74720
FUEL AND OIL	3.31450	64.76413
INSURANCE	0.03398	0.66392
DEPRECIATION	0.63336	12.37564
MAINTENANCE	0.68830	13.44915
TOTAL DOC	5.11779	100.000

INDIRECT OPERATIONAL COST (IOC)	C/SM***	PERCENT
SYSTEM	0.0	0.0
LOCAL	0.58386	18.63800
AIRCRAFT CONTROL	0.01317	0.42035
CABIN ATTENDANT	0.44057	14.06384
FOOD AND BEVERAGE	0.16702	5.33171
PASSENGER HANDLING	0.63674	20.32614
CARGO HANDLING	0.17677	5.64285
OTHER PASSENGER EXPENSE	0.83200	26.55928
OTHER CARGO EXPENSE	0.00860	0.27441
GENERAL + ADMINISTRATION	0.27390	8.74347
TOTAL IOC	3.13261	100.000

MISC. DATA	
FLIGHT DISTANCE (N. MI.)	2500.00
BLOCK FUEL (LBS)	90647.63
BLOCK TIME (HRS)	5.98
FLIGHT TIME (HRS)	5.64
AVG STAGE LENGTH (N. MI.)	2500.00
AVG CARGO PER FLIGHT	13695.72
UTILIZATION (HRS PER YR)	4140.41
FLIGHTS PER A/C PER YEAR	692.87
FARE ($)	374.96
FUEL COST ($/LB)	0.31600

*** - CENTS PER SEAT N. MILE

- -

RATE OF RETURN ON INVESTMENT

YEAR	AVG NO AIRCRAFT DURING YEAR	AIRCRAFT ADDED DURING YEAR	AVERAGE INVESTMENT DURING YEAR	CUMULATIVE DEPRECIATION	AVERAGE BOOK VALUE OF FLEET	REVENUE	INTEREST EXPENSE	OPERATING EXPENSE	CASH FLOW	ROI
			$M	$M	$M	$M	$M	$M	$M	PERCENT
1	5.0	8.0	355.35	19.99	335.36	304.96	42.64	250.10	-133.10	14.54
2	13.0	8.0	923.90	71.96	851.95	792.89	104.05	650.25	-133.41	14.48
3	20.4	7.0	1448.04	153.41	1294.63	1242.70	153.30	1019.14	-113.68	14.55
4	23.0	0.0	1634.60	245.36	1389.24	1402.81	156.07	1150.44	9.33	14.70
5	23.0	0.0	1634.60	337.30	1297.30	1402.81	136.45	1150.44	19.14	14.99
6	23.0	0.0	1634.60	429.25	1205.35	1402.81	116.84	1150.44	28.94	15.32
7	23.0	0.0	1634.60	521.19	1113.40	1402.81	97.22	1150.44	38.75	15.70
8	23.0	0.0	1634.60	613.14	1021.46	1402.81	77.61	1150.44	48.56	16.15
9	23.0	0.0	1634.60	705.08	929.51	1402.81	57.99	1150.44	58.37	16.69
10	23.0	0.0	1634.60	797.03	837.57	1402.81	38.38	1150.44	68.18	17.36
11	23.0	0.0	1634.60	888.98	745.62	1402.81	18.76	1150.44	123.47	18.18
12	23.0	0.0	1634.60	980.92	653.68	1402.81	5.97	1150.44	175.35	19.76
13	23.0	0.0	1634.60	1072.87	561.73	1402.81	-0.00	1150.44	218.13	22.46
14	23.0	0.0	1634.60	1164.81	469.78	1402.81	-0.00	1150.44	218.13	26.86
15	23.0	0.0	1634.60	1256.76	377.84	1402.81	-0.00	1150.44	218.13	33.40
16	23.0	0.0	1634.60	1348.71	285.89	1402.81	-0.00	1150.44	218.13	44.14

AVG ROI OVER THE 16 YEAR PERIOD = 17.60 PERCENT

ATX-350I, DESIGN RANGE = 4600 NMI, M = 0.80, INTERN. RESRVS MISS

T/C=10.00 AR=12.00 W/S=136.00 T/W=0.231

Configuration 13A

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

BASIC WING--	AREA(SQ FT)	SPAN(FT)	TAPER RATIO	C/4 SWEEP	L.E. SWEEP	MAC(FT)		
	4424.6	230.42	0.246	25.000	27.327	21.55		
WING PANELS--	AREA(SQ FT)	EXP. AREA	AVG T/C	L.E. SWEEP	SFLE(SQ FT)	REF L(FT)		
	1051.3	241.8	12.26	28.516	0.0	38.67		
	2139.7	2139.7	11.30	28.516	0.0	30.21		
	389.9	389.9	9.70	28.516	0.0	19.92		
	1346.8	1346.8	9.58	28.516	0.0	14.66		
	144.2	144.2	9.19	28.516	0.0	8.48		
TOTAL WING--	AREA(SQ FT)	EFF AR	AVG T/C	CR(FT)	CT(FT)	MAC(FT)	L(FT)	E SWP
	5071.8	10.47	10.91	44.33	7.59	26.95	70.19	17.525
FUSELAGE--	LENGTH(FT)	S WET(SQ FT)	BWW(FT)	EQUIV D(FT)	SPI(SQ FT)			
	201.00	10631.7	19.32	19.58	301.21			
	BW(FT)	BH(FT)	SBW(SQ FT)					
	19.58	19.58	10538.00					
HORZ. TAIL 1--	SHT1(SQ FT)	SHX1(SQ FT)	REF L1(FT)	L HT1(FT)	HT1 VOL COEF			
	1243.46	924.72	17.12	73.15	0.9541			
HORZ. TAIL 2--	SHT2(SQ FT)	SHX2(SQ FT)	REF L2(FT)	L HT2(FT)	HT2 VOL COEF			
	0.0	0.0	0.0	201.00	0.0			
VERT. TAIL 1--	SVT1(SQ FT)	SVX1(SQ FT)	REF L1(FT)	L VT1(FT)	VT1 VOL COEF			
	818.17	532.71	21.43	74.13	0.0595			
VERT. TAIL 2--	SVT2(SQ FT)	SVX2(SQ FT)	REF L2(FT)	L VT2(FT)	VT2 VOL COEF			
	0.0	0.0	0.0	201.00	0.0			
PROPULSION--	ENG L(FT)	ENG D(FT)	POD L(FT)	POD D(FT)	POD S WET	NO. PODS	INLET L(FT)	
	13.76	6.93	13.87	9.18	718.28	2.	25.16	
FUEL TANKS--	WING(CU FT)	BOX(CU FT)	FUS(CU FT)					
	3767.83	837.54	999999.00					
WETTED VOLUMES--	BODY	WING	TAILS	PODS	PYLONS	PONTOONS	TOTAL	
	50263.46	7434.24	2089.95	1552.76	131.17	0.0	61471.57	

ATX-350I, DESIGN RANGE = 4600 NMI, M = 0.80, INTERN. RESRVS MISS

T/C=10.00 AR=12.00 W/S=136.00 T/W=0.231

Configuration 13A

W E I G H T   S T A T E M E N T

	WEIGHT(POUNDS)	WEIGHT FRACTION	(PERCENT)
GROSS WEIGHT	(601745.)		
FUEL AVAILABLE	205279.	FUEL	34.11
EXTERNAL	0.		
INTERNAL	205288.		
ZERO FUEL WEIGHT	396466.		
PAYLOAD	73500.	PAYLOAD	12.21
PASSENGERS	57750.		
BAGGAGE	15750.		
CARGO	0.		
STORES	0.		
OPERATIONAL EMPTY WEIGHT	322966.		
OPERATIONAL ITEMS	10355.	OPERATIONAL ITEMS	3.32
STANDARD ITEMS	9635.		
EMPTY WEIGHT	302976.		
STRUCTURE	205927.	STRUCTURE	34.22
WING	91572.		
ROTOR	0.		
TAIL	9691.		
BODY	67613.		
ALIGHTING GEAR	25084.		
ENGINE SECTION AND NACELLE	11968.		
PROPULSION	30857.	PROPULSION	5.13
CRUISE ENGINES	23798.		
LIFT ENGINES	0.		
THRUST REVERSER	4530.		
EXHAUST SYSTEM	0.		
ENGINE CONTROL	199.		
STARTING SYSTEM	390.		
PROPELLERS	0.		
LUBRICATING SYSTEM	0.		
FUEL SYSTEM	1940.		
DRIVE SYSTEM (POWER TRANS)	0.		
SYSTEMS	66193.		
FLIGHT CONTROLS	6993.		
AUXILIARY POWER PLANT	1202.		
INSTRUMENTS	1093.		
HYDRAULIC AND PNEUMATIC	2754.		
ELECTRICAL	5873.		
AVIONICS	3075.	SYSTEMS	11.00
ARMAMENT	0.		
FURNISHINGS AND EQUIPMENT	38504.		
AIR CONDITIONING	6302.		
ANTI-ICING	395.		
PHOTOGRAPHIC	0.		
LOAD AND HANDLING	0.		
		TOTAL	(100.)

Configuration 13A

W E I G H T S   M A T R I X

ELEMENT/ / MATERIAL	AL	TIT.	STEEL	COMP.	OTHER	TOTAL
WING	82414.	1831.	6410.	0.	916.	91572.
ROTOR	0.	0.	0.	0.	0.	0.
TAIL	8722.	194.	678.	0.	97.	9691.
BODY	60852.	2705.	676.	1352.	2028.	67613.
L. G.	5518.	251.	16555.	0.	2759.	25084.
ENG SECT	0.	0.	0.	0.	0.	0.
NACELLE	3153.	4054.	1802.	0.	0.	9010.
AIR INDUCT	2662.	296.	0.	0.	0.	2958.
TOTALS	163322.	9331.	26122.	1352.	5800.	205927.

EXCESS FUEL CAPACITY - BODY	50125104.
EXCESS FUEL CAPACITY - WING	0.
EXCESS BODY LENGTH - FT	0.0
AIRFRAME WEIGHT (A.M.P.R.) - LB	264952.
GUST LOAD FACTOR	0.0

Configuration 13A

ALTERNATE MISSION NO. 1 SUMMARY

ATX-350I, AVRG STAGE L = 2500 NMI, M = 0.80, 60 % LF 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 CL	AVG L/D RATIO	AVG SFC (FF/T)
TAKEOFF POWER 1	0.	0.0	476736.	0.	0.	0.	0.	0.0	0.0	0.	428601.	0.	0.0	0.0	0.941
POWER 2	0.	0.0	476736.	865.	865.	0.	0.	1.0	1.0	0.	428501.	0.	0.0	0.0	0.386
CLIMB	0.	0.378	475871.	2578.	3444.	17.	17.	3.9	4.9	0.	428201.	0.	0.506	20.04	0.548
ACCEL	10000.	0.456	473292.	383.	3827.	3.	21.	0.6	5.5	0.	428201.	0.	0.419	18.69	0.578
CLIMB	10000.	0.547	472909.	12154.	15981.	223.	243.	30.1	35.6	0.	428201.	0.	0.423	18.24	0.646
CRUISE	39000.	0.800	460756.	0.	15981.	0.	243.	0.0	35.6	0.	-428101.	0.	0.564	19.97	0.650
ACCEL	39000.	0.800	460756.	0.	15981.	0.	243.	0.0	35.6	0.	428201.	0.	0.564	19.97	0.656
ACCEL	39000.	0.800	460756.	0.	15981.	0.	243.	0.0	35.6	0.	428201.	0.	0.564	19.97	0.656
CRUISE	39000.	0.800	460755.	63658.	79638.	2057.	2300.	268.9	304.5	0.	-428101.	0.	0.524	19.63	0.651
CLIMB	39000.	0.800	397098.	0.	79638.	0.	2300.	0.0	304.5	0.	428201.	0.	0.0	0.0	0.0
CRUISE	39000.	0.800	397098.	0.	79638.	0.	2300.	0.0	304.5	0.	-428101.	0.	0.486	19.16	0.653
CLIMB	39000.	0.800	397097.	0.	79638.	0.	2300.	0.0	304.5	0.	428201.	0.	0.0	0.0	0.0
CRUISE	39000.	0.800	397097.	0.	79638.	0.	2300.	0.0	304.5	0.	-428101.	0.	0.486	19.16	0.653
DESCENT	39000.	0.800	397097.	1475.	81114.	110.	2410.	15.2	319.8	0.	428301.	0.	0.347	16.45	-0.415
DECEL	10000.	0.547	395622.	65.	81179.	4.	2414.	0.8	320.6	0.	428301.	0.	0.355	17.12	-7.091
DESCENT	10000.	0.456	395557.	640.	81819.	30.	2444.	6.5	327.1	0.	428301.	0.	0.422	18.62	-2.707
CRUISE	39000.	0.800	394917.	1643.	83462.	56.	2500.	7.3	334.5	0.	-428101.	0.	0.482	19.10	0.653
LOITER	1500.	0.295	393274.	614.	84075.	0.	2500.	3.0	337.5	0.	-80101.	0.	0.728	20.22	0.631
CRUISE	1500.	0.378	392660.	477.	84553.	0.	2500.	2.0	339.4	0.	-80101.	0.	0.442	19.02	0.697
RESET	0.	0.0	392183.	0.	84553.	-2500.	0.	0.0	339.4	0.	0.	0.	0.0	0.0	0.0
CRUISE	39000.	0.800	392183.	7562.	92114.	0.	0.	33.9	373.4	0.	-428101.	0.	0.475	18.98	0.653
TAKEOFF POWER 1	0.	0.0	384621.	0.	92114.	0.	0.	0.0	373.4	0.	428601.	0.	0.0	0.0	0.941
POWER 2	0.	0.0	384621.	865.	92980.	0.	0.	1.0	374.4	0.	428501.	0.	0.0	0.0	0.386
CLIMB	0.	0.378	383756.	1965.	94945.	13.	13.	2.9	377.3	0.	428201.	0.	0.406	18.29	0.548
ACCEL	10000.	0.456	381791.	292.	95236.	3.	16.	0.5	377.8	0.	428201.	0.	0.338	16.64	0.578

Configuration 13A

CLIMB	10000.	0.547	381499.	4786.	100022.	66.	82.	9.6	387.4	0.	428201.	0.	0.289	15.09	0.632
CRUISE	30000.	0.695	376713.	600.	100622.	18.	100.	2.7	390.1	0.	-428101.	0.	0.400	18.01	0.641
DESCENT	30000.	0.750	376113.	403.	101025.	52.	152.	7.7	397.8	0.	428301.	0.	0.284	14.93	-1.248
DECEL	10000.	0.547	375710.	63.	101088.	4.	156.	0.8	398.6	0.	428301.	0.	0.337	16.60	-7.116
DESCENT	10000.	0.456	375647.	626.	101714.	29.	185.	6.4	404.9	0.	428301.	0.	0.401	18.20	-2.695
CRUISE	30000.	0.695	375021.	493.	102206.	15.	200.	2.2	407.2	0.	-428101.	0.	0.398	17.97	0.641
CRUISE	1500.	0.375	374529.	7458.	109664.	0.	200.	32.0	439.2	0.	-80101.	0.	0.425	18.63	0.702

Configuration 13A

COST SUMMARY

RDT AND E

	TOTAL *
DEVELOPMENT - NONRECURRING	
ENGINEERING	1128.88
TOOLING	596.67
TEST ARTICLES	84.97
DATA	0.0
SYSTEMS ENG/MNGMT	0.0
CRUISE ENGINE	0.0
LIFT ENGINE	0.0
FAN	0.0
AVIONICS	0.0
OTHER SYSTEMS	0.0
FACILITIES	0.0
TOTAL AIR VEHICLE	1810.51
INTEGR LOGISTICS SUPPORT	
PLANNING	12.44
TRAINING	4.23
HANDBOOKS	31.34
SSE	8.84
TOTAL ILS	56.84
TOTAL DVLPMNT-NONREC	1867.35
DEVELOPMENT - RECUR(PROTOTYPES)	
AIR VEHICLE	954.28
SPARES	15.02
TOTAL DVLPMNT-RECUR	969.30
GOVMNT DVLPMNT COST	0.0
TOTAL DVLPMNT COST	2836.65

PRODUCTION

	MATERIAL	LABOR	TOTAL PER PROD A/C**
STRUCTURE	6234.59	13464.46	19699.04
WING	3012.90	4880.20	7893.11
ROTOR	0.0	0.0	0.0
TAIL	239.13	713.47	952.60
BODY	1251.35	5885.52	7136.87
ALIGHTING GEAR	1005.85	31.69	1037.54
ENG SECT + NACELLE	725.35	1953.58	2678.94
ENG SECTION	0.0	0.0	0.0
NACELLE	704.06	1817.55	2521.61
AIR INDUCTION	21.29	136.03	157.32
PROPULSION	186.76	152.27	339.03
ENGINE INSTALL	0.0	32.88	32.88
THRUST REVERSER	0.0	6.26	6.26
EXHAUST SYSTEM	0.0	0.0	0.0
ENGINE CONTROLS	5.31	5.81	11.12
STARTING SYSTEM	59.79	7.78	67.57
PROPELLER INSTALL	0.0	0.0	0.0
LUBRICATING SYSTEM	0.0	0.0	0.0
FUEL SYSTEM	121.65	99.54	221.19
DRIVE SYS(PWR TRN)	0.0	0.0	0.0
SYSTEMS	4348.00	7546.41	11894.41
FLIGHT CONTROLS	1167.54	485.90	1653.44
AUX POWER PLANT	206.39	26.10	232.49
INSTRUMENTS	138.23	81.33	219.56
HYDRAULIC + PNEUM	209.57	393.07	602.65
ELECTRICAL	605.93	1227.56	1833.49
AVIONIC INSTALL	63.23	513.48	576.71
ARMAMENT	0.0	0.0	0.0
FURN AND EQUIP	1425.24	4324.52	5749.76
AIR CONDITIONING	500.46	465.26	965.72
ANTI-ICING	31.40	29.20	60.60
PHOTOGRAPHIC	0.0	0.0	0.0
LOAD AND HANDLING	0.0	0.0	0.0
SYSTEMS INTEGR	996.86	807.34	1804.20
TOTAL COST	11766.20	21970.45	33736.64
TOTAL HRS **		656.07	656.07
ENG CHANGE ORDERS			1097.78
SUSTAINING ENG COST			1638.66
PROD TOOLING COST			2418.54
QUALITY ASSURANCE			2947.38
MISCELLANEOUS ***			1022.86
TOTAL AIRFRAME COST			42861.84
ENGINE COST			10483.14
AVIONICS COST			866.31
TOTAL MANUFACTURING COST			54211.28
WARRANTY			164.13
TOTAL PRODUCTION COST			54375.41

PROCUREMENT

	PER PROD A/C**
TOTAL PRODUCTION	54375.41
INTEGR LOGISTICS SUPPORT	
PLANNING	32.73
TRAINING	11.13
TRAINERS	220.56
HANDBOOKS	39.99
FACILITIES	0.0
SSE - CFE	0.0
SSE - GFE	2555.64
TOTAL ILS	2860.04
INITIAL SPARES COST	7668.71
PRODUCTION DEVELOPMENT	
ENGINEERING	313.20
TOOLING	344.47
ENGINES	0.0
TOTAL PROD DEV	657.67
TOTAL PROCUREMENT	65561.75

* - MILLIONS OF DOLLARS

** -1000 OF DOLLARS OR HOURS PER PROD A/C

*** - INCLUDES PROD DATA, SYSTEMS ENGR AND OTHER SYSTEMS

Configuration 13A

OPERATIONAL COSTS

DIRECT OPERATIONAL COST (DOC)

	C/SM***	PERCENT
FLIGHT CREW	0.44879	9.03826
FUEL AND OIL	3.13830	63.20219
INSURANCE	0.03080	0.62037
DEPRECIATION	0.64888	13.06774
MAINTENANCE	0.69872	14.07148
TOTAL DOC	4.96549	100.000

INDIRECT OPERATIONAL COST (IOC)

	C/SM***	PERCENT
SYSTEM	0.0	0.0
LOCAL	0.59280	18.89581
AIRCRAFT CONTROL	0.01317	0.41973
CABIN ATTENDANT	0.44168	14.07861
FOOD AND BEVERAGE	0.16744	5.33731
PASSENGER HANDLING	0.63674	20.29626
CARGO HANDLING	0.17677	5.63455
OTHER PASSENGER EXPENSE	0.83200	26.52023
OTHER CARGO EXPENSE	0.00860	0.27400
GENERAL + ADMINISTRATION	0.26803	8.54355
TOTAL IOC	3.13722	100.000

MISC. DATA

FLIGHT DISTANCE (N. MI.)	2500.00
BLOCK FUEL (LBS)	85828.00
BLOCK TIME (HRS)	5.99
FLIGHT TIME (HRS)	5.66
AVG STAGE LENGTH (N. MI.)	2500.00
AVG CARGO PER FLIGHT	13695.72
UTILIZATION (HRS PER YR)	4142.41
FLIGHTS PER A/C PER YEAR	691.46
FARE ($)	374.96
FUEL COST ($/LB)	0.31600

*** - CENTS PER SEAT N. MILE

RATE OF RETURN ON INVESTMENT

YEAR	AVG NO AIRCRAFT DURING YEAR	AIRCRAFT ADDED DURING YEAR	AVERAGE INVESTMENT DURING YEAR	CUMULATIVE DEPRECIATION	AVERAGE BOOK VALUE OF FLEET	REVENUE	INTEREST EXPENSE	OPERATING EXPENSE	CASH FLOW	ROI
			$M	$M	$M	$M	$M	$M	$M	PERCENT
1	5.0	8.0	363.27	20.43	342.83	304.34	43.59	245.12	-134.50	14.99
2	13.0	8.0	944.49	73.56	870.93	791.28	106.36	637.31	-132.31	14.95
3	20.4	7.0	1480.31	156.83	1323.48	1240.17	156.71	998.85	-109.83	15.04
4	23.0	0.0	1671.03	250.82	1420.20	1399.95	159.55	1127.54	16.74	15.21
5	23.0	0.0	1671.03	344.82	1326.21	1399.95	139.49	1127.54	26.77	15.53
6	23.0	0.0	1671.03	438.81	1232.21	1399.95	119.44	1127.54	36.80	15.90
7	23.0	0.0	1671.03	532.81	1138.22	1399.95	99.39	1127.54	46.82	16.33
8	23.0	0.0	1671.03	626.80	1044.22	1399.95	79.34	1127.54	56.85	16.84
9	23.0	0.0	1671.03	720.80	950.23	1399.95	59.28	1127.54	66.88	17.45
10	23.0	0.0	1671.03	814.79	856.23	1399.95	39.23	1127.54	76.90	18.20
11	23.0	0.0	1671.03	908.79	762.24	1399.95	19.18	1127.54	133.43	19.13
12	23.0	0.0	1671.03	1002.78	668.24	1399.95	6.10	1127.54	186.46	20.84
13	23.0	0.0	1671.03	1096.78	574.25	1399.95	-0.00	1127.54	230.20	23.72
14	23.0	0.0	1671.03	1190.77	480.25	1399.95	-0.00	1127.54	230.20	28.36
15	23.0	0.0	1671.03	1284.77	386.26	1399.95	-0.00	1127.54	230.20	35.26
16	23.0	0.0	1671.03	1378.76	292.26	1399.95	-0.00	1127.54	230.20	46.60

AVG ROI OVER THE 16 YEAR PERIOD = 18.38 PERCENT

ATX-350I, DESIGN RANGE = 4600 NMI, M = 0.80, INTERN. RESRVS MISS

Configuration 14A

T/C=10.00 AR=12.00 W/S=136.00 T/W=0.222

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

BASIC WING--	AREA(SQ FT)	SPAN(FT)	TAPER RATIO	C/4 SWEEP	L.E. SWEEP	MAC(FT)		
	4010.2	219.37	0.246	25.000	27.327	20.51		
WING PANELS--	AREA(SQ FT)	EXP. AREA	AVG T/C	L.E. SWEEP	SFLE(SQ FT)	REF L(FT)		
	952.8	184.4	12.25	28.516	0.0	36.70		
	1939.3	1939.3	11.30	28.516	0.0	28.76		
	353.3	353.3	9.70	28.516	0.0	18.97		
	1220.7	1220.7	9.58	28.516	0.0	13.96		
	130.7	130.7	9.19	28.516	0.0	8.08		
TOTAL WING--	AREA(SQ FT)	EFF AR	AVG T/C	CR(FT)	CT(FT)	MAC(FT)	L(FT)	E SWP
	4596.7	10.47	10.91	42.20	7.23	25.65	66.82	17.525
FUSELAGE--	LENGTH(FT)	S WET(SQ FT)	BWW(FT)	EQUIV D(FT)	SPI(SQ FT)			
	201.00	10506.8	19.32	19.58	301.21			
	BW(FT)	BH(FT)	SBW(SQ FT)					
	19.58	19.58	10538.00					
HORZ. TAIL 1--	SHT1(SQ FT)	SHX1(SQ FT)	REF L1(FT)	L HT1(FT)	HT1 VOL COEF			
	858.09	596.80	13.89	74.77	0.7800			
HORZ. TAIL 2--	SHT2(SQ FT)	SHX2(SQ FT)	REF L2(FT)	L HT2(FT)	HT2 VOL COEF			
	0.0	0.0	0.0	201.00	0.0			
VERT. TAIL 1--	SVT1(SQ FT)	SVX1(SQ FT)	REF L1(FT)	L VT1(FT)	VT1 VOL COEF			
	663.67	409.27	18.92	75.78	0.0572			
VERT. TAIL 2--	SVT2(SQ FT)	SVX2(SQ FT)	REF L2(FT)	L VT2(FT)	VT2 VOL COEF			
	0.0	0.0	0.0	201.00	0.0			
PROPULSION--	ENG L(FT)	ENG D(FT)	POD L(FT)	POD D(FT)	POD S WET	NO. PODS	INLET L(FT)	
	12.93	6.47	13.04	8.56	629.97	2.	23.40	
FUEL TANKS--	WING(CU FT)	BOX(CU FT)	FUS(CU FT)					
	3216.05	748.17	999999.00					
WETTED VOLUMES--	BODY	WING	TAILS	PODS	PYLONS	PONTOONS	TOTAL	
	49966.15	6308.76	1224.74	1271.01	108.11	0.0	58878.77	

ATX-350I, DESIGN RANGE = 4600 NMI, M = 0.80, INTERN. RESRVS MISS

T/C=10.00 AR=12.00 W/S=136.00 T/W=0.222

Configuration 14A

W E I G H T   S T A T E M E N T

	WEIGHT(POUNDS)	WEIGHT FRACTION	(PERCENT)
GROSS WEIGHT	(545382.)		
FUEL AVAILABLE	177931.	FUEL	32.63
EXTERNAL	0.		
INTERNAL	177931.		
ZERO FUEL WEIGHT	367451.		
PAYLOAD	73500.	PAYLOAD	13.48
PASSENGERS	57750.		
BAGGAGE	15750.		
CARGO	0.		
STORES	0.		
OPERATIONAL EMPTY WEIGHT	293951.		
OPERATIONAL ITEMS	10326.	OPERATIONAL ITEMS	3.65
STANDARD ITEMS	9601.		
EMPTY WEIGHT	274024.		
STRUCTURE	187861.	STRUCTURE	34.45
WING	81557.		
ROTOR	0.		
TAIL	7008.		
BODY	66265.		
ALIGHTING GEAR	22757.		
ENGINE SECTION AND NACELLE	10274.		
PROPULSION	27646.	PROPULSION	5.07
CRUISE ENGINES	20444.		
LIFT ENGINES	0.		
THRUST REVERSER	4222.		
EXHAUST SYSTEM	0.		
ENGINE CONTROL	173.		
STARTING SYSTEM	0.		
PROPELLERS	0.		
LUBRICATING SYSTEM	0.		
FUEL SYSTEM	2807.		
DRIVE SYSTEM (POWER TRANS)	0.		
SYSTEMS	58517.		
FLIGHT CONTROLS	4937.		
AUXILIARY POWER PLANT	1000.		
INSTRUMENTS	1096.		
HYDRAULIC AND PNEUMATIC	0.		
ELECTRICAL	5888.		
AVIONICS	2921.	SYSTEMS	10.73
ARMAMENT	0.		
FURNISHINGS AND EQUIPMENT	38504.		
AIR CONDITIONING	4053.		
ANTI-ICING	118.		
PHOTOGRAPHIC	0.		
LOAD AND HANDLING	0.		
		TOTAL	(100.)

Configuration 14A

WEIGHTS MATRIX

ELEMENT/ / MATERIAL	AL	TIT.	STEEL	COMP.	OTHER	TOTAL
WING	73402.	1631.	5709.	0.	816.	81557.
ROTOR	0.	0.	0.	0.	0.	0.
TAIL	6307.	140.	491.	0.	70.	7008.
BODY	59639.	2651.	663.	1325.	1988.	66265.
L. G.	5006.	228.	15019.	0.	2503.	22757.
ENG SECT	0.	0.	0.	0.	0.	0.
NACELLE	2709.	3483.	1548.	0.	0.	7740.
AIR INDUCT	2281.	253.	0.	0.	0.	2534.
TOTALS	149343.	8386.	23430.	1325.	5377.	187861.

EXCESS FUEL CAPACITY - BODY	50120368.
EXCESS FUEL CAPACITY - WING	0.
EXCESS BODY LENGTH - FT	0.0
AIRFRAME WEIGHT (A.M.P.R.) - LB	240860.
GUST LOAD FACTOR	0.0

A L T E R N A T E   M I S S I O N   N O.   1   S U M M A R Y

Configuration 14A

ATX-350I, AVRG STAGE L = 2500 NMI, M = 0.80, 60 % LF   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 CL	AVG L/D RATIO	AVG SFC (FF/T)
TAKEOFF POWER 1	0.	0.0	433666.	0.	0.	0.	0.	0.0	0.0	0.	428601.	0.	0.0	0.0	0.943
POWER 2	0.	0.0	433666.	763.	763.	0.	0.	1.0	1.0	0.	428501.	0.	0.0	0.0	0.385
CLIMB	0.	0.378	432903.	2282.	3045.	17.	17.	3.8	4.8	0.	428201.	0.	0.508	20.70	0.540
ACCEL	10000.	0.456	430620.	338.	3383.	3.	20.	0.6	5.4	0.	428201.	0.	0.421	19.32	0.570
CLIMB	10000.	0.547	430283.	10163.	13546.	206.	227.	27.9	33.4	0.	428201.	0.	0.420	18.76	0.636
CRUISE	39000.	0.800	420120.	0.	13546.	0.	227.	0.0	33.4	0.	-428101.	0.	0.567	20.69	0.639
ACCEL	39000.	0.800	420120.	0.	13546.	0.	227.	0.0	33.4	0.	428201.	0.	0.567	20.69	0.646
ACCEL	39000.	0.800	420120.	0.	13546.	0.	227.	0.0	33.4	0.	428201.	0.	0.567	20.69	0.646
CRUISE	39000.	0.800	420119.	55855.	69401.	2073.	2300.	271.1	304.5	0.	-428101.	0.	0.529	20.28	0.640
CLIMB	39000.	0.800	364264.	0.	69401.	0.	2300.	0.0	304.5	0.	428201.	0.	0.0	0.0	0.0
CRUISE	39000.	0.800	364264.	0.	69401.	0.	2300.	0.0	304.5	0.	-428101.	0.	0.492	19.76	0.641
CLIMB	39000.	0.800	364264.	0.	69401.	0.	2300.	0.0	304.5	0.	428201.	0.	0.0	0.0	0.0
CRUISE	39000.	0.800	364264.	0.	69401.	0.	2300.	0.0	304.5	0.	-428101.	0.	0.492	19.76	0.641
DESCENT	39000.	0.800	364264.	1150.	70551.	107.	2407.	14.9	319.5	0.	428301.	0.	0.349	16.98	-0.509
DECEL	10000.	0.547	363114.	59.	70610.	5.	2412.	0.9	320.3	0.	428301.	0.	0.359	17.77	-7.114
DESCENT	10000.	0.456	363055.	581.	71191.	31.	2443.	6.8	327.1	0.	428301.	0.	0.428	19.38	-2.717
CRUISE	39000.	0.800	362474.	1467.	72659.	57.	2500.	7.5	334.6	0.	-428101.	0.	0.488	19.70	0.641
LOITER	1500.	0.295	361007.	535.	73193.	0.	2500.	3.0	337.6	0.	-80101.	0.	0.737	20.78	0.616
CRUISE	1500.	0.378	360472.	415.	73609.	0.	2500.	2.0	339.6	0.	-80101.	0.	0.448	19.70	0.681
RESET	0.	0.0	360056.	0.	73609.	-2500.	0.	0.0	339.6	0.	0.	0.	0.0	0.0	0.0
CRUISE	39000.	0.800	360056.	6616.	80225.	0.	0.	34.0	373.5	0.	-428101.	0.	0.481	19.58	0.642
TAKEOFF POWER 1	0.	0.0	353440.	0.	80225.	0.	0.	0.0	373.5	0.	428601.	0.	0.0	0.0	0.943
POWER 2	0.	0.0	353440.	763.	80987.	0.	0.	1.0	374.5	0.	428501.	0.	0.0	0.0	0.385
CLIMB	0.	0.378	352678.	1763.	82750.	13.	13.	3.0	377.5	0.	428201.	0.	0.411	19.05	0.540
ACCEL	10000.	0.456	350915.	261.	83011.	3.	16.	0.5	378.0	0.	428201.	0.	0.343	17.28	0.570

Configuration 14A

CLIMB	10000.	0.547	350654.	4240.	87250.	65.	81.	9.5	387.5	0.	428201.	0.	0.293	15.64	0.622
CRUISE	30000.	0.710	346414.	533.	87783.	19.	100.	2.7	390.2	0.	-428101.	0.	0.388	18.40	0.635
DESCENT	30000.	0.750	345881.	365.	88148.	54.	154.	8.0	398.1	0.	428301.	0.	0.288	15.48	-1.251
DECEL	10000.	0.547	345516.	57.	88205.	4.	158.	0.8	399.0	0.	428301.	0.	0.342	17.24	-7.136
DESCENT	10000.	0.456	345459.	569.	88774.	30.	188.	6.7	405.6	0.	428301.	0.	0.407	18.95	-2.707
CRUISE	30000.	0.710	344890.	335.	89110.	12.	200.	1.7	407.3	0.	-428101.	0.	0.387	18.36	0.635
CRUISE	1500.	0.378	344555.	6503.	95613.	0.	200.	32.0	439.3	0.	-80101.	0.	0.425	19.28	0.689

COST SUMMARY

Configuration 14A

RDT AND E

	TOTAL *
DEVELOPMENT - NONRECURRING	
ENGINEERING	1061.64
TOOLING	554.75
TEST ARTICLES	77.39
DATA	0.0
SYSTEMS ENG/MNGMT	0.0
CRUISE ENGINE	0.0
LIFT ENGINE	0.0
FAN	0.0
AVIONICS	0.0
OTHER SYSTEMS	0.0
FACILITIES	0.0
TOTAL AIR VEHICLE	1693.78
INTEGR LOGISTICS SUPPORT	
PLANNING	12.38
TRAINING	4.21
HANDBOOKS	25.16
SSE	8.79
TOTAL ILS	50.54
TOTAL DVLPMNT-NONREC	1744.32
DEVELOPMENT - RECUR(PROTOTYPES)	
AIR VEHICLE	885.62
SPARES	13.70
TOTAL DVLPMNT-RECUR	899.32
GOVMNT DVLPMNT COST	0.0
TOTAL DVLPMNT COST	2643.64

PRODUCTION

	MATERIAL	LABOR	TOTAL PER PROD A/C**
STRUCTURE	5626.54	12507.07	18133.60
WING	2687.33	4406.32	7093.65
ROTOR	0.0	0.0	0.0
TAIL	173.18	523.03	696.20
BODY	1228.19	5847.53	7075.72
ALIGHTING GEAR	913.86	29.14	943.00
ENG SECT + NACELLE	623.99	1701.05	2325.04
ENG SECTION	0.0	0.0	0.0
NACELLE	605.73	1582.90	2188.63
AIR INDUCTION	18.26	118.14	136.41
PROPULSION	151.18	210.43	361.61
ENGINE INSTALL	0.0	28.64	28.64
THRUST REVERSER	0.0	5.91	5.91
EXHAUST SYSTEM	0.0	0.0	0.0
ENGINE CONTROLS	4.64	5.13	9.76
STARTING SYSTEM	0.0	0.0	0.0
PROPELLER INSTALL	0.0	0.0	0.0
LUBRICATING SYSTEM	0.0	0.0	0.0
FUEL SYSTEM	146.54	170.76	317.30
DRIVE SYS(PWR TRN)	0.0	0.0	0.0
SYSTEMS	3925.79	6585.87	10511.66
FLIGHT CONTROLS	866.74	229.19	1095.93
AUX POWER PLANT	171.96	22.01	193.97
INSTRUMENTS	138.80	82.67	221.47
HYDRAULIC + PNEUM	0.0	0.0	0.0
ELECTRICAL	900.33	1068.62	1968.94
AVIONIC INSTALL	57.12	523.12	580.24
ARMAMENT	0.0	0.0	0.0
FURN AND EQUIP	1427.32	4384.02	5811.34
AIR CONDITIONING	353.24	268.42	621.66
ANTI-ICING	10.29	7.82	18.12
PHOTOGRAPHIC	0.0	0.0	0.0
LOAD AND HANDLING	0.0	0.0	0.0
SYSTEMS INTEGR	902.91	740.24	1643.15
TOTAL COST	10606.43	20043.60	30650.02
TOTAL HRS **		598.53	598.53
ENG CHANGE ORDERS			997.67
SUSTAINING ENG COST			1581.64
PROD TOOLING COST			2206.43
QUALITY ASSURANCE			2688.89
MISCELLANEOUS ***			933.15
TOTAL AIRFRAME COST			39057.76
ENGINE COST			9323.45
AVIONICS COST			1111.01
TOTAL MANUFACTURING COST			49492.21
WARRANTY			277.41
TOTAL PRODUCTION COST			49769.61

PROCUREMENT

	PER PROD A/C**
TOTAL PRODUCTION	49769.61
INTEGR LOGISTICS SUPPORT	
PLANNING	32.12
TRAINING	10.92
TRAINERS	220.56
HANDBOOKS	35.55
FACILITIES	0.0
SSE - CFE	0.0
SSE - GFE	2339.17
TOTAL ILS	2638.31
INITIAL SPARES COST	6969.14
PRODUCTION DEVELOPMENT	
ENGINEERING	307.33
TOOLING	314.26
ENGINES	0.0
TOTAL PROD DEV	621.59
TOTAL PROCUREMENT	59998.64

* - MILLIONS OF DOLLARS

** -1000 OF DOLLARS OR HOURS PER PROD A/C

*** - INCLUDES PROD DATA, SYSTEMS ENGR AND OTHER SYSTEMS

Configuration 14A

OPERATIONAL COSTS

DIRECT OPERATIONAL COST (DOC)

	C/SM***	PERCENT
FLIGHT CREW	0.44897	10.19296
FUEL AND OIL	2.73229	62.03165
INSURANCE	0.03298	0.74884
DEPRECIATION	0.59492	13.50647
MAINTENANCE	0.59552	13.52015
TOTAL DOC	4.40467	100.000

INDIRECT OPERATIONAL COST (IOC)

	C/SM***	PERCENT
SYSTEM	0.0	0.0
LOCAL	0.53728	17.55260
AIRCRAFT CONTROL	0.01317	0.43019
CABIN ATTENDANT	0.44185	14.43491
FOOD AND BEVERAGE	0.16751	5.47238
PASSENGER HANDLING	0.63674	20.80194
CARGO HANDLING	0.17677	5.77493
OTHER PASSENGER EXPENSE	0.83200	27.18097
OTHER CARGO EXPENSE	0.00860	0.28083
GENERAL + ADMINISTRATION	0.24706	8.07139
TOTAL IOC	3.06096	100.000

MISC. DATA

FLIGHT DISTANCE (N. MI.)	2500.00
BLOCK FUEL (LBS)	74722.13
BLOCK TIME (HRS)	5.99
FLIGHT TIME (HRS)	5.66
AVG STAGE LENGTH (N. MI.)	2500.00
AVG CARGO PER FLIGHT	13695.72
UTILIZATION (HRS PER YR)	4142.71
FLIGHTS PER A/C PER YEAR	691.25
FARE ($)	374.96
FUEL COST ($/LB)	0.31600

*** - CENTS PER SEAT N. MILE

RATE OF RETURN ON INVESTMENT

YEAR	AVG NO AIRCRAFT DURING YEAR	AIRCRAFT ADDED DURING YEAR	AVERAGE INVESTMENT DURING YEAR	CUMULATIVE DEPRECIATION	AVERAGE BOOK VALUE OF FLEET	REVENUE	INTEREST EXPENSE	OPERATING EXPENSE	CASH FLOW	ROI
			$M	$M	$M	$M	$M	$M	$M	PERCENT
1	5.0	8.0	333.04	18.73	314.30	304.24	39.96	225.78	-111.22	18.84
2	13.0	8.0	865.90	67.44	798.46	791.03	97.51	587.02	-89.87	18.88
3	20.4	7.0	1357.13	143.78	1213.35	1239.79	143.67	920.03	-51.43	19.10
4	23.0	0.0	1531.98	229.95	1302.02	1399.52	146.27	1038.57	70.96	19.48
5	23.0	0.0	1531.98	316.13	1215.85	1399.52	127.89	1038.57	80.15	20.10
6	23.0	0.0	1531.98	402.30	1129.68	1399.52	109.50	1038.57	89.34	20.82
7	23.0	0.0	1531.98	488.47	1043.50	1399.52	91.12	1038.57	98.53	21.66
8	23.0	0.0	1531.98	574.65	957.33	1399.52	72.74	1038.57	107.72	22.65
9	23.0	0.0	1531.98	660.82	871.16	1399.52	54.35	1038.57	116.92	23.84
10	23.0	0.0	1531.98	746.99	784.98	1399.52	35.97	1038.57	126.11	25.28
11	23.0	0.0	1531.98	833.17	698.81	1399.52	17.58	1038.57	177.93	27.08
12	23.0	0.0	1531.98	919.34	612.64	1399.52	5.59	1038.57	226.55	29.92
13	23.0	0.0	1531.98	1005.51	526.46	1399.52	-0.00	1038.57	266.65	34.28
14	23.0	0.0	1531.98	1091.69	440.29	1399.52	-0.00	1038.57	266.65	40.99
15	23.0	0.0	1531.98	1177.86	354.12	1399.52	-0.00	1038.57	266.65	50.97
16	23.0	0.0	1531.98	1264.03	267.94	1399.52	-0.00	1038.57	266.65	67.36

AVG ROI OVER THE 16 YEAR PERIOD = 24.89 PERCENT

ATX-350I, DESIGN RANGE = 4600 NMI, M = 0.80, INTERN. RESRVS MISS

Configuration 15

T/C=10.00 AR=12.00 W/S=136.00 T/W=0.237

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

BASIC WING--	AREA(SQ FT)	SPAN(FT)	TAPER RATIO	C/4 SWEEP	L.E. SWEEP	MAC(FT)		
	3776.0	212.87	0.246	25.000	27.327	19.90		
WING PANELS--	AREA(SQ FT)	EXP. AREA	AVG T/C	L.E. SWEEP	SFLE(SQ FT)	REF L(FT)		
	897.2	152.9	12.24	28.516	0.0	35.54		
	1826.0	1826.0	11.30	28.516	0.0	27.90		
	332.7	332.7	9.70	28.516	0.0	18.40		
	1149.4	1149.4	9.58	28.516	0.0	13.55		
	123.0	123.0	9.19	28.516	0.0	7.84		
TOTAL WING--	AREA(SQ FT)	EFF AR	AVG T/C	CR(FT)	CT(FT)	MAC(FT)	L(FT)	E SWP
	4328.3	10.47	10.91	40.95	7.01	24.89	64.84	17.525
FUSELAGE--	LENGTH(FT)	S WET(SQ FT)	BWW(FT)	EQUIV D(FT)	SPI(SQ FT)			
	201.00	10571.1	19.32	19.58	301.21			
	BW(FT)	BH(FT)	SBW(SQ FT)					
	19.58	19.58	10538.00					
HORZ. TAIL 1--	SHT1(SQ FT)	SHX1(SQ FT)	REF L1(FT)	L HT1(FT)	HT1 VOL COEF			
	780.17	531.99	13.15	75.14	0.7800			
HORZ. TAIL 2--	SHT2(SQ FT)	SHX2(SQ FT)	REF L2(FT)	L HT2(FT)	HT2 VOL COEF			
	0.0	0.0	0.0	201.00	0.0			
VERT. TAIL 1--	SVT1(SQ FT)	SVX1(SQ FT)	REF L1(FT)	L VT1(FT)	VT1 VOL COEF			
	645.55	395.03	18.61	75.99	0.0610			
VERT. TAIL 2--	SVT2(SQ FT)	SVX2(SQ FT)	REF L2(FT)	L VT2(FT)	VT2 VOL COEF			
	0.0	0.0	0.0	201.00	0.0			
PROPULSION--	ENG L(FT)	ENG D(FT)	POD L(FT)	POD D(FT)	POD S WET	NO. PODS	INLET L(FT)	
	11.34	7.31	20.94	8.60	991.49	2.	26.37	
FUEL TANKS--	WING(CU FT)	BOX(CU FT)	FUS(CU FT)					
	2918.34	697.96	999999.00					
WETTED VOLUMES--	BODY	WING	TAILS	PODS	PYLONS	PONTOONS	TOTAL	
	50115.52	5703.43	1094.78	2059.73	119.85	0.0	59093.29	

ATX-350I, DESIGN RANGE = 4600 NMI, M = 0.80, INTERN. RESRVS MISS

T/C=10.00 AR=12.00 W/S=136.00 T/W=0.237

Configuration 15

W E I G H T   S T A T E M E N T

	WEIGHT(POUNDS)		WEIGHT FRACTION	(PERCENT)
GROSS WEIGHT		(513531.)		
FUEL AVAILABLE		150765.	FUEL	29.36
EXTERNAL	0.			
INTERNAL	150764.			
ZERO FUEL WEIGHT		362766.		
PAYLOAD		73500.	PAYLOAD	14.31
PASSENGERS	57750.			
BAGGAGE	15750.			
CARGO	0.			
STORES	0.			
OPERATIONAL EMPTY WEIGHT		289266.		
OPERATIONAL ITEMS	10327.		OPERATIONAL ITEMS	3.87
STANDARD ITEMS	9567.			
EMPTY WEIGHT		269373.		
STRUCTURE	179561.		STRUCTURE	34.97
WING	75330.			
ROTOR	0.			
TAIL	6507.			
BODY	65677.			
ALIGHTING GEAR	21427.			
ENGINE SECTION AND NACELLE	10420.			
PROPULSION	31564.		PROPULSION	6.15
CRUISE ENGINES	25284.			
LIFT ENGINES	0.			
THRUST REVERSER	3534.			
EXHAUST SYSTEM	0.			
ENGINE CONTROL	174.			
STARTING SYSTEM	0.			
PROPELLERS	0.			
LUBRICATING SYSTEM	0.			
FUEL SYSTEM	2571.			
DRIVE SYSTEM (POWER TRANS)	0.			
SYSTEMS	58248.			
FLIGHT CONTROLS	4712.			
AUXILIARY POWER PLANT	1000.			
INSTRUMENTS	1086.			
HYDRAULIC AND PNEUMATIC	0.			
ELECTRICAL	5853.			
AVIONICS	2921.		SYSTEMS	11.34
ARMAMENT	0.			
FURNISHINGS AND EQUIPMENT	38504.			
AIR CONDITIONING	4053.			
ANTI-ICING	119.			
PHOTOGRAPHIC	0.			
LOAD AND HANDLING	0.			
			TOTAL	(100.)

Configuration 15

W E I G H T S   M A T R I X

ELEMENT/ / MATERIAL	AL	TIT.	STEEL	COMP.	OTHER	TOTAL
WING	67797.	1507.	5273.	0.	753.	75330.
ROTOR	0.	0.	0.	0.	0.	0.
TAIL	5857.	130.	456.	0.	65.	6507.
BODY	59289.	2635.	659.	1318.	1976.	65877.
L. G.	4714.	214.	14142.	0.	2357.	21427.
ENG SECT	0.	0.	0.	0.	0.	0.
NACELLE	1812.	3703.	1654.	709.	0.	7879.
AIR INDUCT	1753.	254.	0.	534.	0.	2541.
TOTALS	141222.	8443.	22184.	2560.	5152.	179561.

EXCESS FUEL CAPACITY - BODY	50130144.
EXCESS FUEL CAPACITY - WING	0.
EXCESS BODY LENGTH - FT	0.0
AIRFRAME WEIGHT (A.M.P.R.) - LB	231821.
GUST LOAD FACTOR	0.0

Configuration 15

ALTERNATE MISSION NO. 1 SUMMARY

ATX-350I, AVRG STAGE L = 2500 NMI, M = 0.80, 60 % LF 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 CL	AVG L/D RATIO	AVG SFC (FF/T)
TAKEOFF POWER 1	0.	0.0	415678.	0.	0.	0.	0.	0.0	0.0	0.	429601.	0.	0.0	0.0	0.941
POWER 2	0.	0.0	415678.	586.	586.	0.	0.	1.0	1.0	0.	429501.	0.	0.0	0.0	0.295
CLIMB	0.	0.378	415091.	1829.	2416.	16.	16.	3.5	4.5	0.	429201.	0.	0.517	20.25	0.460
ACCEL	10000.	0.456	413262.	276.	2692.	3.	19.	0.6	5.1	0.	429201.	0.	0.428	18.89	0.491
CLIMB	10000.	0.547	412986.	7595.	10287.	168.	187.	22.9	28.0	0.	429201.	0.	0.416	18.19	0.550
CRUISE	39000.	0.800	405391.	0.	10287.	0.	187.	0.0	28.0	0.	-429101.	0.	0.581	20.26	0.545
ACCEL	39000.	0.800	405391.	0.	10287.	0.	187.	0.0	28.0	0.	429201.	0.	0.581	20.26	0.559
ACCEL	39000.	0.800	405391.	0.	10287.	0.	187.	0.0	28.0	0.	429201.	0.	0.581	20.26	0.559
CRUISE	39000.	0.800	405391.	48038.	58325.	2113.	2300.	276.3	304.3	0.	-429101.	0.	0.546	19.94	0.546
CLIMB	39000.	0.800	357353.	0.	58325.	0.	2300.	0.0	304.3	0.	429201.	0.	0.0	0.0	0.0
CRUISE	39000.	0.800	357353.	0.	58325.	0.	2300.	0.0	304.3	0.	-429101.	0.	0.512	19.54	0.548
CLIMB	39000.	0.800	357353.	0.	58325.	0.	2300.	0.0	304.3	0.	429201.	0.	0.0	0.0	0.0
CRUISE	39000.	0.800	357353.	0.	58325.	0.	2300.	0.0	304.3	0.	-429101.	0.	0.512	19.54	0.548
DESCENT	39000.	0.800	357353.	1154.	59479.	108.	2408.	15.0	319.4	0.	429301.	0.	0.365	16.88	-0.498
DECEL	10000.	0.547	356198.	63.	59542.	5.	2413.	0.9	320.2	0.	429301.	0.	0.374	17.61	-7.095
DESCENT	10000.	0.456	356136.	618.	60160.	30.	2443.	6.7	326.9	0.	429301.	0.	0.445	19.11	-2.680
CRUISE	39000.	0.800	355518.	1235.	61395.	57.	2500.	7.4	334.4	0.	-429101.	0.	0.509	19.49	0.548
LOITER	1500.	0.295	354283.	544.	61939.	0.	2500.	3.0	337.4	0.	-80101.	0.	0.768	20.31	0.624
CRUISE	1500.	0.378	353739.	418.	62357.	0.	2500.	2.0	339.4	0.	-80101.	0.	0.467	19.45	0.694
RESET	0.	0.0	353320.	0.	62357.	-2500.	0.	0.0	339.4	0.	0.	0.	0.0	0.0	0.0
CRUISE	39000.	0.800	353320.	5605.	67962.	0.	0.	33.9	373.3	0.	-429101.	0.	0.502	19.39	0.548
TAKEOFF POWER 1	0.	0.0	347715.	0.	67962.	0.	0.	0.0	373.3	0.	429601.	0.	0.0	0.0	0.941
POWER 2	0.	0.0	347715.	586.	68548.	0.	0.	1.0	374.3	0.	429501.	0.	0.0	0.0	0.295
CLIMB	0.	0.378	347129.	1463.	70011.	13.	13.	2.8	377.1	0.	429201.	0.	0.430	18.84	0.460
ACCEL	10000.	0.456	345666.	220.	70232.	2.	15.	0.5	377.6	0.	429201.	0.	0.358	17.17	0.491

Configuration 15

CLIMB	10000.	0.547	345445.	3574.	73806.	63.	79.	9.2	386.8	0.	429201.	0.	0.306	15.61	0.539
CRUISE	30000.	0.710	341871.	533.	74339.	21.	100.	3.1	389.9	0.	-429101.	0.	0.407	18.26	0.559
DESCENT	30000.	0.750	341338.	389.	74728.	53.	153.	7.9	397.8	0.	429301.	0.	0.302	15.47	-1.249
DECEL	10000.	0.547	340949.	61.	74789.	4.	158.	0.8	398.6	0.	429301.	0.	0.358	17.16	-7.116
DESCENT	10000.	0.456	340888.	607.	75396.	30.	187.	6.6	405.2	0.	429301.	0.	0.426	18.77	-2.669
CRUISE	30000.	0.710	340281.	311.	75708.	12.	200.	1.8	407.0	0.	-429101.	0.	0.405	18.22	0.559
CRUISE	1500.	0.378	339969.	6604.	82311.	0.	200.	32.0	439.0	0.	-80101.	0.	0.445	19.06	0.701

COST SUMMARY

Configuration 15

RDT AND E

DEVELOPMENT - NONRECURRING	TOTAL *
ENGINEERING	1040.47
TOOLING	538.78
TEST ARTICLES	75.83
DATA	0.0
SYSTEMS ENG/MNGMT	0.0
CRUISE ENGINE	0.0
LIFT ENGINE	0.0
FAN	0.0
AVIONICS	0.0
OTHER SYSTEMS	0.0
FACILITIES	0.0
TOTAL AIR VEHICLE	1655.08
INTEGR LOGISTICS SUPPORT	
PLANNING	12.27
TRAINING	4.17
HANDBOOKS	24.98
SSE	8.72
TOTAL ILS	50.14
TOTAL DVLPMNT-NONREC	1705.22
DEVELOPMENT - RECUR(PROTOTYPES)	
AIR VEHICLE	891.30
SPARES	18.15
TOTAL DVLPMNT-RECUR	909.45
GOVMNT DVLPMNT COST	0.0
TOTAL DVLPMNT COST	2614.67

PRODUCTION

	MATERIAL	LABOR	TOTAL PER PROD A/C**
STRUCTURE	5360.62	12154.21	17514.83
WING	2482.75	4079.37	6562.12
ROTOR	0.0	0.0	0.0
TAIL	160.86	486.84	647.69
BODY	1221.29	5826.81	7048.11
ALIGHTING GEAR	860.70	27.50	888.20
ENG SECT + NACELLE	635.02	1733.69	2368.71
ENG SECTION	0.0	0.0	0.0
NACELLE	616.70	1614.94	2231.64
AIR INDUCTION	18.32	118.75	137.07
PROPULSION	136.29	204.48	340.77
ENGINE INSTALL	0.0	35.50	35.50
THRUST REVERSER	0.0	4.96	4.96
EXHAUST SYSTEM	0.0	0.0	0.0
ENGINE CONTROLS	4.66	5.17	9.83
STARTING SYSTEM	0.0	0.0	0.0
PROPELLER INSTALL	0.0	0.0	0.0
LUBRICATING SYSTEM	0.0	0.0	0.0
FUEL SYSTEM	131.63	158.85	290.48
DRIVE SYS(PWR TRN)	0.0	0.0	0.0
SYSTEMS	3895.85	6585.32	10481.18
FLIGHT CONTROLS	839.62	222.10	1061.72
AUX POWER PLANT	172.00	22.06	194.06
INSTRUMENTS	137.56	82.10	219.66
HYDRAULIC + PNEUM	0.0	0.0	0.0
ELECTRICAL	898.20	1063.55	1961.75
AVIONIC INSTALL	57.13	524.34	581.47
ARMAMENT	0.0	0.0	0.0
FURN AND EQUIP	1427.67	4394.24	5821.92
AIR CONDITIONING	353.33	269.05	622.38
ANTI-ICING	10.34	7.88	18.22
PHOTOGRAPHIC	0.0	0.0	0.0
LOAD AND HANDLING	0.0	0.0	0.0
SYSTEMS INTEGR	887.81	729.37	1617.18
TOTAL COST	10280.58	19673.38	29953.95
TOTAL HRS **		587.48	587.48
ENG CHANGE ORDERS			975.34
SUSTAINING ENG COST			1570.56
PROD TOOLING COST			2165.68
QUALITY ASSURANCE			2639.22
MISCELLANEOUS ***			915.91
TOTAL AIRFRAME COST			38220.64
ENGINE COST			12623.69
AVIONICS COST			1111.01
TOTAL MANUFACTURING COST			51955.32
WARRANTY			271.55
TOTAL PRODUCTION COST			52226.86

PROCUREMENT

	PER PROD A/C**
TOTAL PRODUCTION	52226.86
INTEGR LOGISTICS SUPPORT	
PLANNING	32.04
TRAINING	10.89
TRAINERS	220.56
HANDBOOKS	35.41
FACILITIES	0.0
SSE - CFE	0.0
SSE - GFE	2454.66
TOTAL ILS	2753.56
INITIAL SPARES COST	7768.12
PRODUCTION DEVELOPMENT	
ENGINEERING	306.62
TOOLING	308.46
ENGINES	0.0
TOTAL PROD DEV	615.08
TOTAL PROCUREMENT	63363.60

* - MILLIONS OF DOLLARS

** -1000 OF DOLLARS OR HOURS PER PROD A/C

*** - INCLUDES PROD DATA, SYSTEMS ENGR AND OTHER SYSTEMS

OPERATIONAL COSTS

Configuration 15

DIRECT OPERATIONAL COST (DOC)	C/SM***	PERCENT
FLIGHT CREW	0.44869	11.20689
FUEL AND OIL	2.32399	58.04684
INSURANCE	0.03729	0.93132
DEPRECIATION	0.62415	15.58947
MAINTENANCE	0.56954	14.22554
TOTAL DOC	4.00365	100.000

INDIRECT OPERATIONAL COST (IOC)	C/SM***	PERCENT
SYSTEM	0.0	0.0
LOCAL	0.50590	16.79631
AIRCRAFT CONTROL	0.01317	0.43719
CABIN ATTENDANT	0.44157	14.66051
FOOD AND BEVERAGE	0.16740	5.55791
PASSENGER HANDLING	0.63674	21.14026
CARGO HANDLING	0.17677	5.86886
OTHER PASSENGER EXPENSE	0.83200	27.62305
OTHER CARGO EXPENSE	0.00860	0.28540
GENERAL + ADMINISTRATION	0.22983	7.63052
TOTAL IOC	3.01197	100.000

MISC. DATA	
FLIGHT DISTANCE (N. MI.)	2500.00
BLOCK FUEL (LBS)	63553.90
BLOCK TIME (HRS)	5.99
FLIGHT TIME (HRS)	5.66
AVG STAGE LENGTH (N. MI.)	2500.00
AVG CARGO PER FLIGHT	13695.72
UTILIZATION (HRS PER YR)	4142.22
FLIGHTS PER A/C PER YEAR	691.59
FARE ($)	374.96
FUEL COST ($/LB)	0.31600

*** - CENTS PER SEAT N. MILE

- -

RATE OF RETURN ON INVESTMENT

YEAR	AVG NO AIRCRAFT DURING YEAR	AIRCRAFT ADDED DURING YEAR	AVERAGE INVESTMENT DURING YEAR	CUMULATIVE DEPRECIATION	AVERAGE BOOK VALUE OF FLEET	REVENUE	INTEREST EXPENSE	OPERATING EXPENSE	CASH FLOW	ROI
			$M	$M	$M	$M	$M	$M	$M	PERCENT
1	5.0	8.0	349.50	19.66	329.84	304.40	41.94	212.27	-111.83	20.32
2	13.0	8.0	908.70	70.77	837.93	791.43	102.33	551.91	-81.60	20.40
3	20.4	7.0	1424.22	150.89	1273.33	1240.42	150.77	865.01	-34.05	20.66
4	23.0	0.0	1607.71	241.32	1366.39	1400.23	153.50	976.46	96.95	21.12
5	23.0	0.0	1607.71	331.75	1275.95	1400.23	134.21	976.46	106.60	21.87
6	23.0	0.0	1607.71	422.19	1185.52	1400.23	114.92	976.46	116.24	22.72
7	23.0	0.0	1607.71	512.62	1095.09	1400.23	95.62	976.46	125.89	23.71
8	23.0	0.0	1607.71	603.05	1004.65	1400.23	76.33	976.46	135.54	24.89
9	23.0	0.0	1607.71	693.48	914.22	1400.23	57.04	976.46	145.18	26.30
10	23.0	0.0	1607.71	783.92	823.79	1400.23	37.75	976.46	154.83	28.01
11	23.0	0.0	1607.71	874.35	733.35	1400.23	18.45	976.46	209.21	30.15
12	23.0	0.0	1607.71	964.78	642.92	1400.23	5.87	976.46	260.24	33.41
13	23.0	0.0	1607.71	1055.22	552.49	1400.23	-0.00	976.46	302.32	38.35
14	23.0	0.0	1607.71	1145.65	462.06	1400.23	-0.00	976.46	302.32	45.86
15	23.0	0.0	1607.71	1236.08	371.62	1400.23	-0.00	976.46	302.32	57.02
16	23.0	0.0	1607.71	1326.52	281.19	1400.23	-0.00	976.46	302.32	75.35

AVG ROI OVER THE 16 YEAR PERIOD = 27.39 PERCENT

Configuration 16

ATX-350I, DESIGN RANGE = 4600 NMI, M = 0.80, INTERN. RESRVS MISS

T/C=10.00 AR=12.00 W/S=136.00 T/W=0.237

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

BASIC WING--	AREA(SQ FT)	SPAN(FT)	TAPER RATIO	C/4 SWEEP	L.E. SWEEP	MAC(FT)		
	3408.4	202.24	0.246	25.000	27.327	18.91		
WING PANELS--	AREA(SQ FT)	EXP. AREA	AVG T/C	L.E. SWEEP	SFLE(SQ FT)	REF L(FT)		
	809.8	105.1	12.23	28.516	0.0	33.64		
	1648.3	1648.3	11.30	28.516	0.0	26.51		
	300.3	300.3	9.70	28.516	0.0	17.49		
	1037.5	1037.5	9.58	28.516	0.0	12.87		
	111.0	111.0	9.19	28.516	0.0	7.45		
TOTAL WING--	AREA(SQ FT)	EFF AR	AVG T/C	CR(FT)	CT(FT)	MAC(FT)	L(FT)	E SWP
	3907.0	10.47	10.91	38.90	6.66	23.65	61.60	17.525
FUSELAGE--	LENGTH(FT)	S WET(SQ FT)	BWW(FT)	EQUIV D(FT)	SPI(SQ FT)			
	201.00	10482.7	19.32	19.58	301.21			
	BW(FT)	BH(FT)	SBW(SQ FT)					
	19.58	19.58	10538.00					
HORZ. TAIL 1--	SHT1(SQ FT)	SHX1(SQ FT)	REF L1(FT)	L HT1(FT)	HT1 VOL COEF			
	663.84	436.51	11.97	75.73	0.7800			
HORZ. TAIL 2--	SHT2(SQ FT)	SHX2(SQ FT)	REF L2(FT)	L HT2(FT)	HT2 VOL COEF			
	0.0	0.0	0.0	201.00	0.0			
VERT. TAIL 1--	SVT1(SQ FT)	SVX1(SQ FT)	REF L1(FT)	L VT1(FT)	VT1 VOL COEF			
	545.09	317.10	16.79	77.18	0.0610			
VERT. TAIL 2--	SVT2(SQ FT)	SVX2(SQ FT)	REF L2(FT)	L VT2(FT)	VT2 VOL COEF			
	0.0	0.0	0.0	201.00	0.0			
PROPULSION--	ENG L(FT)	ENG D(FT)	POD L(FT)	POD D(FT)	POD S WET	NO. PODS	INLET L(FT)	
	10.83	6.94	20.00	8.17	899.57	2.	25.00	
FUEL TANKS--	WING(CU FT)	BOX(CU FT)	FUS(CU FT)					
	2472.54	619.67	999999.00					
WETTED VOLUMES--	BODY	WING	TAILS	PODS	PYLONS	PONTOONS	TOTAL	
	49910.29	4799.98	803.62	1775.50	103.84	0.0	57393.22	

ATX-350I, DESIGN RANGE = 4600 NMI, M = 0.80, INTERN. RESRVS MISS

T/C=10.00 AR=12.00 W/S=136.00 T/W=0.237 Configuration 16

WEIGHT STATEMENT

	WEIGHT(POUNDS)	WEIGHT FRACTION	(PERCENT)
GROSS WEIGHT	(463543.)		
FUEL AVAILABLE	138361.	FUEL	29.85
EXTERNAL	0.		
INTERNAL	138361.		
ZERO FUEL WEIGHT	325182.		
PAYLOAD	73500.	PAYLOAD	15.86
PASSENGERS	57750.		
BAGGAGE	15750.		
CARGO	0.		
STORES	0.		
OPERATIONAL EMPTY WEIGHT	251682.		
OPERATIONAL ITEMS	10308.	OPERATIONAL ITEMS	4.28
STANDARD ITEMS	9551.		
EMPTY WEIGHT	231823.		
STRUCTURE	145384.	STRUCTURE	31.36
WING	49627.		
ROTOR	0.		
TAIL	4419.		
BODY	64920.		
ALIGHTING GEAR	17408.		
ENGINE SECTION AND NACELLE	9011.		
PROPULSION	28618.	PROPULSION	6.17
CRUISE ENGINES	22521.		
LIFT ENGINES	0.		
THRUST REVERSER	3298.		
EXHAUST SYSTEM	0.		
ENGINE CONTROL	157.		
STARTING SYSTEM	0.		
PROPELLERS	0.		
LUBRICATING SYSTEM	0.		
FUEL SYSTEM	2642.		
DRIVE SYSTEM (POWER TRANS)	0.		
SYSTEMS	57821.		
FLIGHT CONTROLS	4363.		
AUXILIARY POWER PLANT	1000.		
INSTRUMENTS	1069.		
HYDRAULIC AND PNEUMATIC	0.		
ELECTRICAL	5795.		
AVIONICS	2921.	SYSTEMS	12.47
ARMAMENT	0.		
FURNISHINGS AND EQUIPMENT	38504.		
AIR CONDITIONING	4053.		
ANTI-ICING	116.		
PHOTOGRAPHIC	0.		
LOAD AND HANDLING	0.		
		TOTAL	(100.)

Configuration 16

WEIGHTS MATRIX

ELEMENT/ / MATERIAL	AL	TIT.	STEEL	COMP.	OTHER	TOTAL
WING	11414.	1489.	4466.	31761.	496.	49627.
ROTOR	0.	0.	0.	0.	0.	0.
TAIL	1414.	133.	354.	2475.	44.	4419.
BODY	58428.	2597.	649.	1298.	1948.	64920.
L. G.	6963.	174.	8182.	0.	2089.	17408.
ENG SECT	0.	0.	0.	0.	0.	0.
NACELLE	1614.	3298.	1474.	632.	0.	7018.
AIR INDUCT	638.	239.	0.	1117.	0.	1994.
TOTALS	80471.	7930.	15124.	37282.	4577.	145384.

EXCESS FUEL CAPACITY - BODY	50116304.
EXCESS FUEL CAPACITY - WING	0.
EXCESS BODY LENGTH - FT	0.0
AIRFRAME WEIGHT (A.M.P.R.) - LB	198396.
GUST LOAD FACTOR	0.0

ALTERNATE MISSION NO. 1 SUMMARY

Configuration 16

ATX-350I, AVRG STAGE L = 2500 NMI, M = 0.80, 60 % LF   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 CL	AVG L/D RATIO	AVG SFC (FF/T)
TAKEOFF POWER 1	0.	0.0	370745.	0.	0.	0.	0.	0.0	0.0	0.	429601.	0.	0.0	0.0	0.944
POWER 2	0.	0.0	370745.	531.	531.	0.	0.	1.0	1.0	0.	429501.	0.	0.0	0.0	0.296
CLIMB	0.	0.378	370214.	1643.	2174.	16.	16.	3.5	4.5	0.	429201.	0.	0.510	19.82	0.461
ACCEL	10000.	0.456	368571.	249.	2423.	3.	19.	0.6	5.1	0.	429201.	0.	0.423	18.43	0.492
CLIMB	10000.	0.547	368322.	6965.	9389.	170.	189.	23.2	28.3	0.	429201.	0.	0.411	17.73	0.552
CRUISE	39000.	0.800	361356.	0.	9389.	0.	189.	0.0	28.3	0.	-429101.	0.	0.574	19.90	0.547
ACCEL	39000.	0.800	361356.	0.	9389.	0.	189.	0.0	28.3	0.	429201.	0.	0.574	19.90	0.561
ACCEL	39000.	0.800	361356.	0.	9389.	0.	189.	0.0	28.3	0.	429201.	0.	0.574	19.90	0.561
CRUISE	39000.	0.800	361356.	43744.	53133.	2111.	2300.	276.0	304.3	0.	-429101.	0.	0.539	19.53	0.548
CLIMB	39000.	0.800	317612.	0.	53133.	0.	2300.	0.0	304.3	0.	429201.	0.	0.0	0.0	0.0
CRUISE	39000.	0.800	317612.	0.	53133.	0.	2300.	0.0	304.3	0.	-429101.	0.	0.504	19.09	0.549
CLIMB	39000.	0.800	317612.	0.	53133.	0.	2300.	0.0	304.3	0.	429201.	0.	0.0	0.0	0.0
CRUISE	39000.	0.800	317612.	0.	53133.	0.	2300.	0.0	304.3	0.	-429101.	0.	0.504	19.09	0.549
DESCENT	39000.	0.800	317612.	1127.	54260.	110.	2410.	15.2	319.5	0.	429301.	0.	0.361	16.42	-0.437
DECEL	10000.	0.547	316485.	55.	54315.	4.	2414.	0.8	320.4	0.	429301.	0.	0.368	17.10	-7.128
DESCENT	10000.	0.456	316429.	545.	54861.	30.	2444.	6.6	326.9	0.	429301.	0.	0.438	18.64	-2.693
CRUISE	39000.	0.800	315884.	1110.	55971.	56.	2500.	7.3	334.2	0.	-429101.	0.	0.501	19.03	0.549
LOITER	1500.	0.295	314773.	490.	56461.	0.	2500.	3.0	337.2	0.	-80101.	0.	0.769	20.05	0.625
CRUISE	1500.	0.378	314283.	383.	56844.	0.	2500.	2.0	339.2	0.	-80101.	0.	0.460	18.96	0.694
RESET	0.	0.0	313900.	0.	56844.	-2500.	0.	0.0	339.2	0.	0.	0.	0.0	0.0	0.0
CRUISE	39000.	0.800	313900.	5113.	61957.	0.	0.	33.9	373.2	0.	-429101.	0.	0.494	18.92	0.550
TAKEOFF POWER 1	0.	0.0	308787.	0.	61957.	0.	0.	0.0	373.2	0.	429601.	0.	0.0	0.0	0.944
POWER 2	0.	0.0	308787.	531.	62488.	0.	0.	1.0	374.2	0.	429501.	0.	0.0	0.0	0.296
CLIMB	0.	0.378	308256.	1308.	63796.	12.	12.	2.8	377.0	0.	429201.	0.	0.423	18.34	0.461
ACCEL	10000.	0.456	306948.	198.	63994.	2.	15.	0.[illegible]	377.4	0.	429201.	0.	0.352	16.65	0.492

CLIMB	10000.	0.547	306750.	3246.	67240.	64.	79.	9.3	386.7	0.	429201.	0.	0.301	15.09	0.541
CRUISE	30000.	0.700	303505.	484.	67724.	21.	100.	3.1	389.8	0.	-429101.	0.	0.412	17.97	0.557
DESCENT	30000.	0.750	303020.	341.	68065.	52.	151.	7.7	397.4	0.	429301.	0.	0.297	14.95	-1.253
DECEL	10000.	0.547	302679.	54.	68119.	4.	156.	0.8	398.3	0.	429301.	0.	0.352	16.64	-7.149
DESCENT	10000.	0.456	302626.	535.	68654.	29.	185.	6.4	404.7	0.	429301.	0.	0.419	18.27	-2.683
CRUISE	30000.	0.700	302090.	344.	68997.	15.	200.	2.2	406.9	0.	-429101.	0.	0.410	17.93	0.557
CRUISE	1500.	0.375	301747.	5966.	74964.	0.	200.	32.0	438.9	0.	-80101.	0.	0.444	18.69	0.700

Configuration 16

OPERATIONAL COSTS

DIRECT OPERATIONAL COST (DOC)

	C/SM***	PERCENT
FLIGHT CREW	0.44854	12.04293
FUEL AND OIL	2.11832	56.87486
INSURANCE	0.03746	1.00570
DEPRECIATION	0.59445	15.96047
MAINTENANCE	0.52576	14.11606
TOTAL DOC	3.72453	100.000

INDIRECT OPERATIONAL COST (IOC)

	C/SM***	PERCENT
SYSTEM	0.0	0.0
LOCAL	0.47800	16.07516
AIRCRAFT CONTROL	0.01317	0.44284
CABIN ATTENDANT	0.44143	14.84536
FOOD AND BEVERAGE	0.16735	5.62799
PASSENGER HANDLING	0.63674	21.41362
CARGO HANDLING	0.17677	5.94475
OTHER PASSENGER EXPENSE	0.83200	27.98022
OTHER CARGO EXPENSE	0.00860	0.28909
GENERAL + ADMINISTRATION	0.21948	7.38106
TOTAL IOC	2.97353	100.000

MISC. DATA

FLIGHT DISTANCE (N. MI.)	2500.00
BLOCK FUEL (LBS)	57928.04
BLOCK TIME (HRS)	5.99
FLIGHT TIME (HRS)	5.65
AVG STAGE LENGTH (N. MI.)	2500.00
AVG CARGO PER FLIGHT	13695.72
UTILIZATION (HRS PER YR)	4141.97
FLIGHTS PER A/C PER YEAR	691.77
FARE ($)	374.96
FUEL COST ($/LB)	0.31600

*** - CENTS PER SEAT N. MILE

RATE OF RETURN ON INVESTMENT

YEAR	AVG NO AIRCRAFT DURING YEAR	AIRCRAFT ADDED DURING YEAR	AVERAGE INVESTMENT DURING YEAR	CUMULATIVE DEPRECIATION	AVERAGE BOOK VALUE OF FLEET	REVENUE	INTEREST EXPENSE	OPERATING EXPENSE	CASH FLOW	ROI
			$M	$M	$M	$M	$M	$M	$M	PERCENT
1	5.0	8.0	332.97	18.73	314.24	304.47	39.96	202.72	-99.54	22.55
2	13.0	8.0	865.72	67.43	798.29	791.63	97.49	527.06	-59.55	22.68
3	20.4	7.0	1356.85	143.75	1213.10	1240.74	143.64	826.07	-3.93	23.01
4	23.0	0.0	1531.65	229.90	1301.75	1400.59	146.24	932.50	124.55	23.60
5	23.0	0.0	1531.65	316.06	1215.59	1400.59	127.86	932.50	133.74	24.51
6	23.0	0.0	1531.65	402.21	1129.44	1400.59	109.48	932.50	142.93	25.57
7	23.0	0.0	1531.65	488.37	1043.28	1400.59	91.10	932.50	152.12	26.80
8	23.0	0.0	1531.65	574.53	957.13	1400.59	72.72	932.50	161.31	28.25
9	23.0	0.0	1531.65	660.68	870.97	1400.59	54.34	932.50	170.50	29.99
10	23.0	0.0	1531.65	746.84	784.82	1400.59	35.96	932.50	179.69	32.11
11	23.0	0.0	1531.65	832.99	698.66	1400.59	17.58	932.50	231.50	34.76
12	23.0	0.0	1531.65	919.15	612.51	1400.59	5.59	932.50	280.11	38.67
13	23.0	0.0	1531.65	1005.30	526.35	1400.59	-0.00	932.50	320.20	44.47
14	23.0	0.0	1531.65	1091.46	440.20	1400.59	-0.00	932.50	320.20	53.17
15	23.0	0.0	1531.65	1177.61	354.04	1400.59	-0.00	932.50	320.20	66.11
16	23.0	0.0	1531.65	1263.77	267.89	1400.59	-0.00	932.50	320.20	87.37

AVG ROI OVER THE 16 YEAR PERIOD = 31.16 PERCENT

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1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
NASA CR-3586		

4. Title and Subtitle

INTEGRATED TECHNOLOGY WING DESIGN STUDY

5. Report Date
August 1982

6. Performing Organization Code

7. Author(s)

A. P. Hays, W. E. Beck, W. H. Morita, B. J. Penrose, R. E. Skarshaug, and B. S. Wainfan

8. Performing Organization Report No.
LR-30000

10. Work Unit No.

9. Performing Organization Name and Address

Lockheed California Co.
P.O. Box 551
Burbank, CA 9150

11. Contract or Grant No.
NAS1-16273

13. Type of Report and Period Covered
Contractor Report
November 1979–December 1980

12. Sponsoring Agency Name and Address

National Aeronautics and Space Administration
Washington, DC 20546

14. Sponsoring Agency Code

15. Supplementary Notes

Langley Technical Monitor: Dennis W. Bartlett
Final Report

16. Abstract

This report describes a study to determine the technology development costs and associated benefits in applying advanced technology associated with the design of a new wing for a new or derivative trijet with a capacity for 350 passengers and maximum range of 8519 km (4600 n.mi.), entering service in 1990.

The areas of technology are: (1) airfoil technology, (2) planform parameters, (3) high lift, (4) pitch active control system, (5) all-electric systems, (6) E^3 propulsion, (7) airframe/propulsion integration, (8) graphite/epoxy composites, (9) advanced aluminum alloys, (10) titanium alloys, and (11) silicon carbide/aluminum composites. These technologies were applied to the reference aircraft configuration both individually and concurrently; payoffs were determined in terms of block fuel reductions and net value of technology. These technologies were then ranked in terms of the ratio of net value of technology (NVT) to technology development costs.

For a fleet of 400 aircraft, the application of all advanced technologies yields an NVT of 72 billion (in 1980 dollars), for a total technology development cost of $639 million. Reduction in block fuel in 40 percent for the all-advanced configuration.

Technology development in airfoil and planform offers the largest benefit in NVT per unit technology development cost, yielding $17 billion increase in NVT (achieved with 11.3 percent reduction in block fuel) for $28 million technology development cost. However, E^3 propulsion technology with airframe/propulsion integration gives the greatest single benefit in NVT of $19 billion, but with a technology development cost of $243 million.

17. Key Words (Suggested by Author(s))

Aircraft Design
Wing Design
Development Cost

18. Distribution Statement

FEDD Distribution

Subject Category

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	464	

Available: NASA's Industrial Applications Centers