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MANX

Close Air Support Aircraft
Preliminary Design

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SUMMARY

The Manx is a twin engine, twin tailed, single seat close air support design proposal for the 1991 Team Student Design Competition. It blends advanced technologies into a lightweight, high performance design with the following features:

- **High Survivability:**
  Rugged, easily maintained, with night/adverse weather capability-it is well suited for remote site based operations.

- **Highly Maneuverable:**
  Negative static margin, forward swept wing, canard, and advanced avionics result in enhanced aircraft agility.

- **Highly Versatile:**
  Design flexibility allows the Manx to contribute to a truly integrated ground team capable of rapid deployment from forward sites.

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Symbol	Definition	Dimension
A	aspect ratio	-
a	average acceleration	ft/sec^2
b	wingspan	ft
C	coefficient	-
c	chord	ft
c"	chord with flap extended	ft
c_j	specific fuel consumption	lbs/lbs/hr
D	drag	lbs
E	endurance	hour
e	efficiency factor	-
f	equivalent net parasite area	ft2
I_{xx}	mass moment of inertia	slug · ft2
I_{yy}	mass moment of inertia	slug · ft2
I_{zz}	mass moment of inertia	slug · ft2
I_{xz}	mass moment of inertia	slug · ft2
k	constant	-
L	lift	lbs
L/D	lift to drag ratio	-
M	Mach number	-
N	number of engines	-
n	load factor	-
q	dynamic pressure	lbs/ft2
R	range	nm
S	wing area	ft2
s	distance	ft
T	Thrust	lbs
T/W	thrust loading	-
V	velocity	ft/sec
W	weight	lbs
W/S	wing loading	lbs/ft2

Greek Symbols

π	constant ≈ 3.14159	-
ρ	density	slugs/ft3
μ	friction coefficient	-
λ	engine bypass ratio	-
Λ	taper ratio	-
ν	flight path angle	-

Subscripts

A	acceleration, approach	-
c/4	quarter chord	-
CREW	crew	-
D	drag	-
DO	profile drag	-
dd	drag divergent	-
E	empty	-
F	fuel	-
f	flap	-
FL	field length	-
G	ground	-
L	lift, landing	-
man	maneuver	-
max	maximum	-
mgc	mean geometric chord	-
OE	operating empty	-
PL	payload	-
r	root	-
req	required	-
SL	stall	-
TO	take off	-
TOG	take off ground roll	-
t	tip	-
tfo	trapped fuel and oil	-

wet	wetted area	-
wf	wing flap	-
0	initial condition	-
1	final	-
∞	freestream	-

Acronyms

AIAA	American Institute of Aeronautics and Astronautics
AMRAAM	Advanced Medium Range Air-Air Missile
APU	auxilliary power unit
AOA	angle of attack
ASW	aft swept wing
BIT	Built-In-Test
CAS	close air support
CFD	computaional fluid dynamics
CG	ceneter of gravity
CGR	required climb gradient, flight path angle
CRT	cathode ray tube
ECM	Electronic Countermeasure
FAA	Federal Aviation Administration
FAR	Federal Aviation Regulations
FLIR	Forward Looking Infrared
FOD	foreign object damage
FSW	forward swept wing
GD	General Dynamics
GPS	Global Positioning Satelite
HARM	High Speed Anti-Radar Missile
HIDEC	Highly Integrated Digital Engine Control
HOTAS	Hands On Throttle and Stick
HUD	heads-up display
IFF	Identification Friend or Foe
IR	infrared
JFS	Jet Fuel Starting System
LANTIRN	Low Altitude Navigation and Targeting with Infrared at Night

M	Mach Number
MGC	mean geometric chord
NACA	National Advisory Council on Aeronautics
OBOGS	On Board Oxygen GeneratingSystem
OEI	one-engine inoperative
RDTE	research, design, test, and evaluation
RFP	request for proposal
SAS	stability augmentation system
TFR	Terrain Following Radar
UHF	ultrahigh frequency
VHF	very high frequency

1. INTRODUCTION

As the turn of the century approaches the United States will require an advanced high-performance Close Air Support (CAS) fighter to replace the existing Fairchild A-10. This replacement fighter must be able to perform it's mission well into the twenty first century. The new fighter must be able to perform the required mission at much higher speeds, carry a greater load, and deliver ordinances with precise accuracy while operating in a rugged, high threat environment.

The Manx CAS fighter proposed for the 1991 Team Aircraft Design Competition is capable of high speeds at low level flight. It has excellent maneuvering qualities while at the same time carries the required ordinances. The Manx design incorporates a forward swept wing which is aeroelastically tailored with composite materials. This wing configuration gives the Manx low speed maneuverability and low wave drag. Twin engines and twin vertical tails provide the necessary survivability qualities required for the high threat environment the the plane will encounter.

2. MISSION DESCRIPTION

The Manx has been specifically designed for the primary mission specified in the design request for proposal (RFP)[32]. The profiles for this missions is shown in Figure 2.1. Two additional missions were taken into consideration and the plane was correspondingly configured to perform these two missions as well. The flight speed used for maximum military power was 500 kts. All of the combat and maneuvering phases were calculated at 350 kts.

2.1 Design Mission (Primary Mission)

1. Warm-up, taxi, takeoff, and accelerate to climb speed. Fuel for this segment was based on five minutes at intermediate power with no range credit.

2. Dash at sea level (distance to accelerate to dash speed included in this segment) at 500 knots to a point 250 nm. from take-off.

3. Combat phase: Fuel used for two combat passes at sea level, with speed equal to 450 knots. Each combat pass consists of a 360 degree sustained turn plus a 4000 ft. energy increase. Drop air-to-surface ordinance, but retain pylons, racks, and ammunition.

4. Dash at sea level at 500 knots for 250 nm. to return to base.

5. Land with fuel for 20 minutes endurance at sea level.

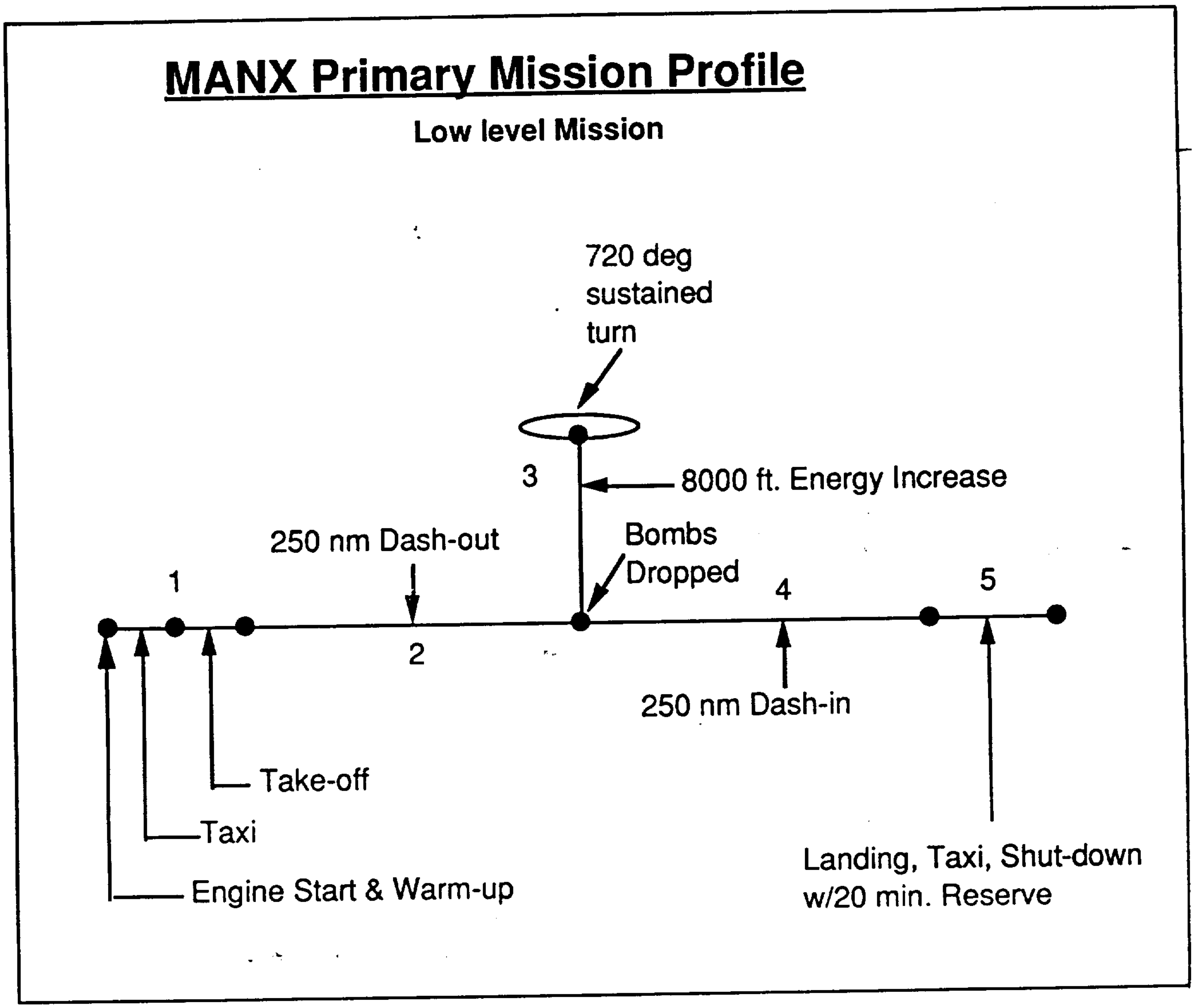


Figure 2.1

2.2 High-low-low-high mission:

1. Warm-up, taxi, takeoff, and accelerate to climb speed with fuel based on five minutes at intermediate power with no range credit.

2. Climb on course at intermediate power to best cruise altitude and speed.

3. Cruise outbound at best altitude and speed to a range of 150 nm.

4. Descend to sea level with no time, distance, or fuel used.

5. Loiter at sea level at best speed for maximum endurance for a time as determined by the fuel and payload.

6. Dash 100 nm. at sea level (distance to accelerate to dash speed included in this segment).

7. Combat phase: Fuel used for two combat passes at sea level, with speed equal to maximum speed in military power minus 50 knots. Each combat pass consists of a 360 degree sustained turn plus a 4000 ft. energy increase. Drop air-to-surface ordinance, but retain pylons, racks, and ammunition.

8. Dash 100 nm. at sea level.

9. Climb (on return course) to best cruise altitude and speed.

10. Cruise back at best altitude and speed to a total distance of 150 nm. for segments 9 and 10.

11. Descend to sea level; no time, distance, or fuel used.

12. Land with fuel for 20 minutes endurance at sea level.

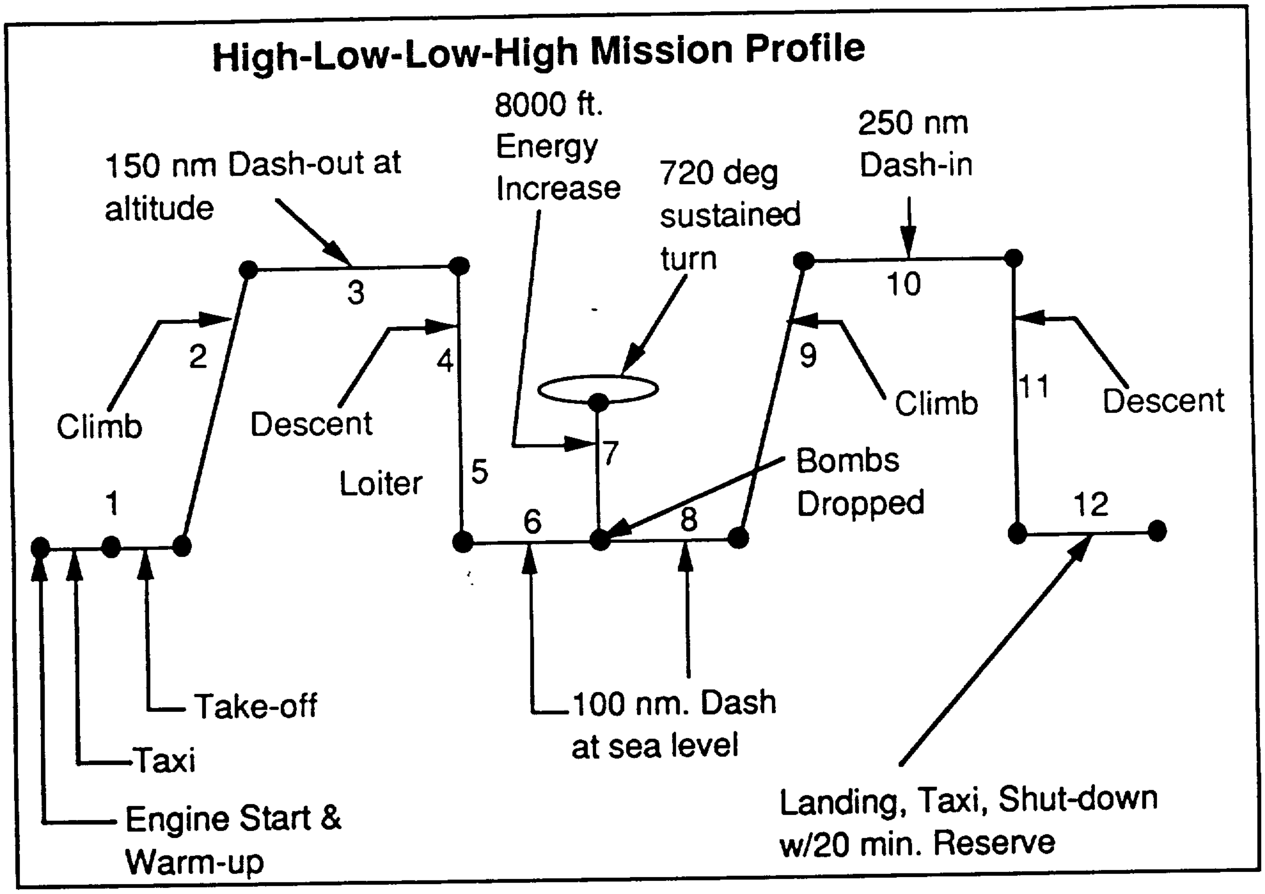


FIGURE 2.2

2.3 Ferry Mission: (Payload is replaced with fuel. No air-to-air refueling)

1. Warm-up, taxi, takeoff, and accelerate to climb speed. Fuel for this segment was based on five minutes at intermediate power with no range credit.

2. Climb on course at intermediate power to best cruise altitude and speed.

3. Cruise outbound at best altitude and speed to a total accumulated range of at least 1,500 nm.

4. Descend to sea level; no time, distance, or fuel used.

5. Land with fuel for 20 minutes endurance at sea level.

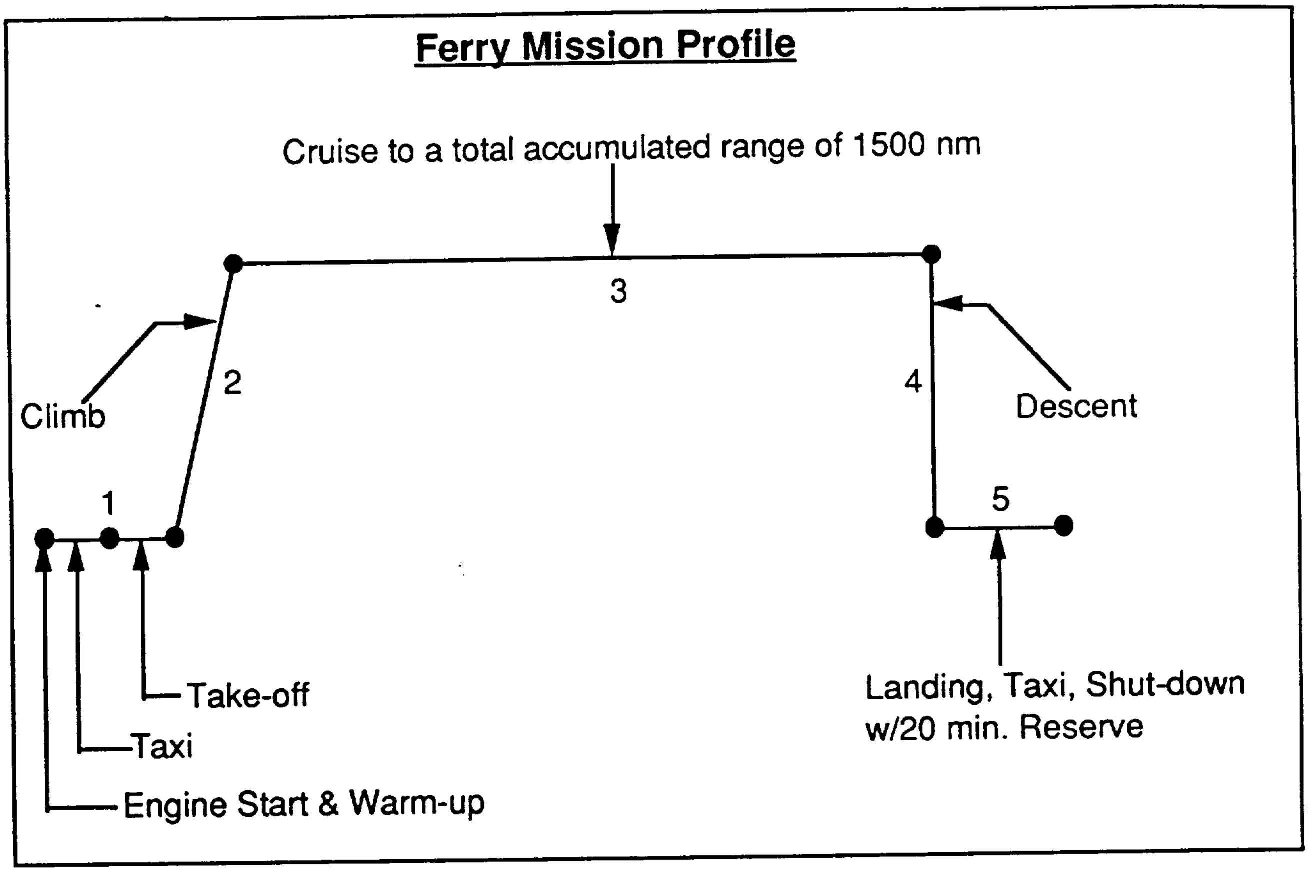


FIGURE 2.3

2.4 Additional Performance Requirements

In addition, the aircraft must comply with the following performance requirements which include a payload of standard stores with 50% of internal fuel.

I. The ability to accelerate from Mach 0.3 to 0.5 at sea level in less than 20 seconds.

II. Turn rates:
Sustained g's at 500 knots, on a standard day at sea level: 4.5
Instantaneous g's at 500 knots, on a standard day at sea level: 6.0

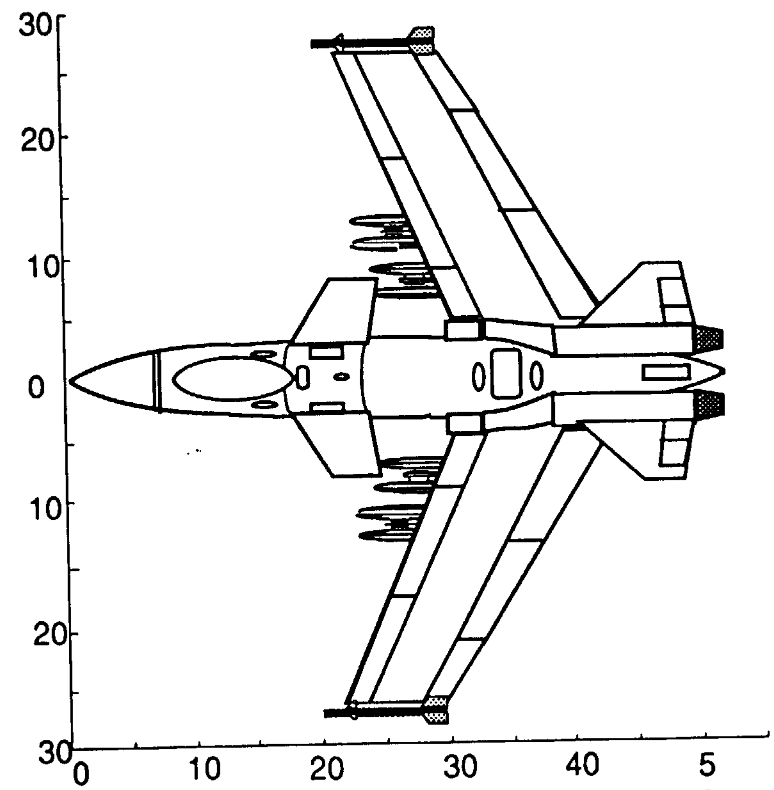
III. Re-attack time of less than 25 seconds (time between first and second weapons release passes in combat phase).

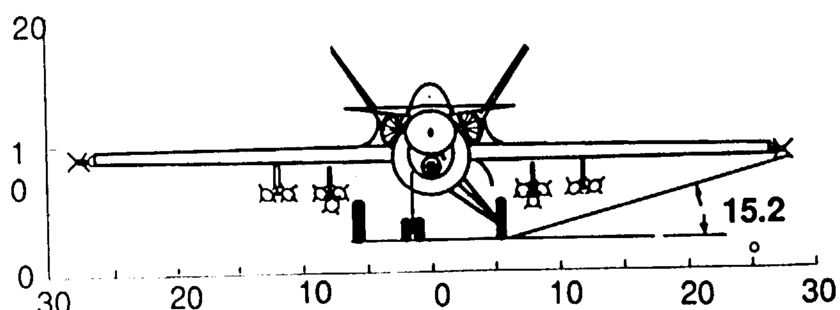
3 DESIGN RESULTS

The design results for the Manx fighter follow. The Manx three-view and tabulated geometry can be found in Figure 3.1. The performance curves for excess power, rate-of-climb and engine fuel consumptions are also presented in this section.

Manx Tabulated Geometry

	Wing	Vertical Tails	Canard
Area (sq ft)	558	120	60
Span (ft)	53	8	16.5
MGC	10.75	5.7	4.75
Aspect Ratio	5	0.2	2
Sweep C/4	-35	40	26
Root Chord	13.5	9	6.1
Tip Chord	7.5	3	4.8
Dihedral (deg)	0	55	0
Incidence	0	0	-
(deg)	65-21	0009	000
	0		8
	Fuselage	Cockpit	Overall
Length (ft)	52	7.25	52
Max. Height (ft)	12.4	12.4	15.6
Max. Width (ft)	6.25	3.2	53





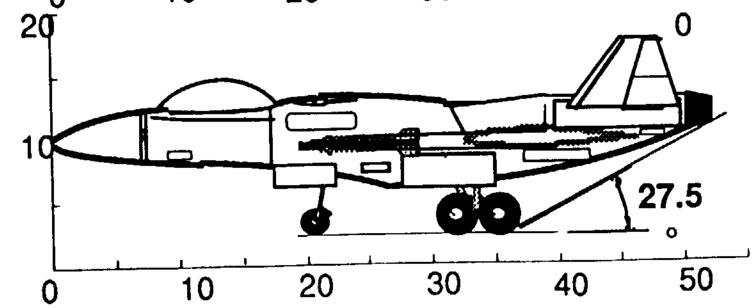


Figure 3.1 Manx Three-view

3.1 Excess Power Performance

Reference 28 outlines the method used to determine the excess power requirements for the Manx. Figures 3.1.1a thru 3.1.1c illustrates excess power versus the Mach number for three flight altitudes. From these figures a plot of maximum rate of climb versus altitude was constructed (Figure 3.2.1), in order to establish the absolute ceiling of the Manx. The Manx design achieved an absolute ceiling of 31,000 ft, and a maximum rate of climb at sea level of 3147 ft/min.

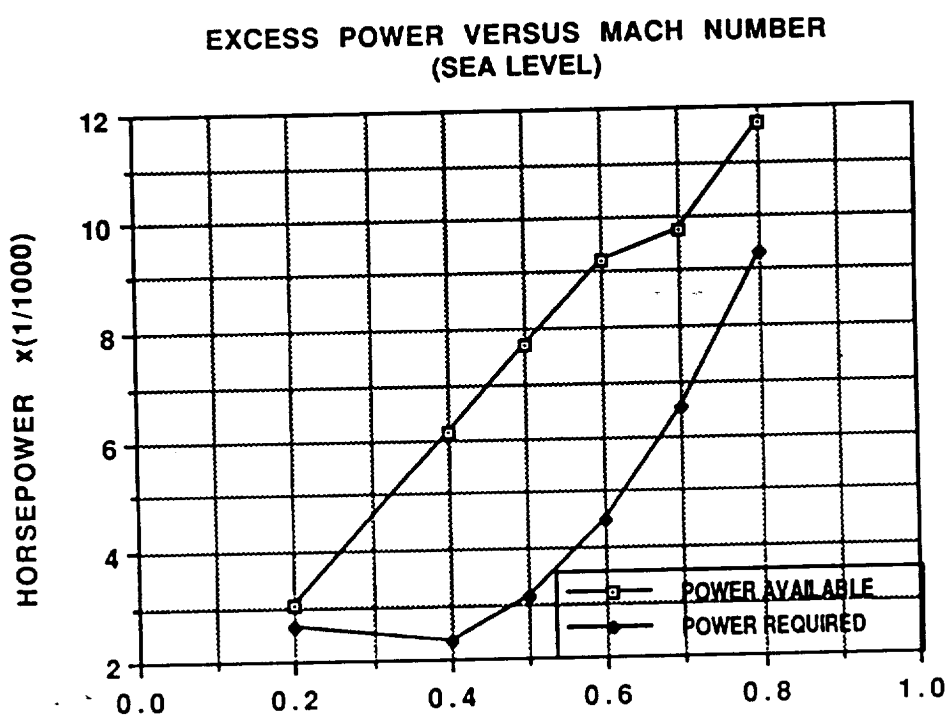


FIGURE 3.1.1a

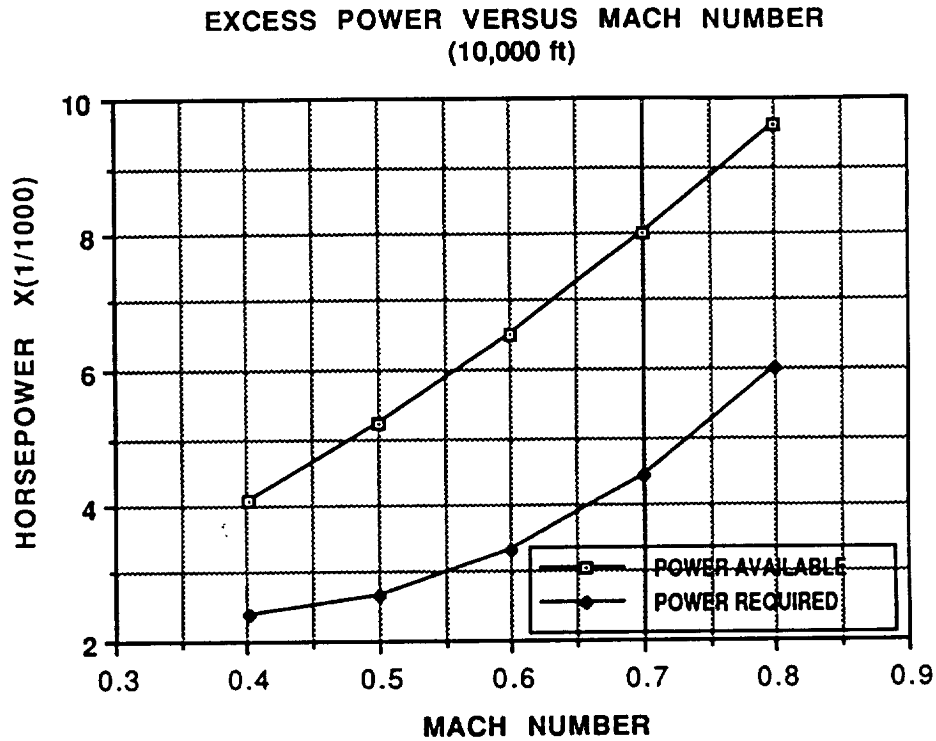


FIGURE 3.1.1b

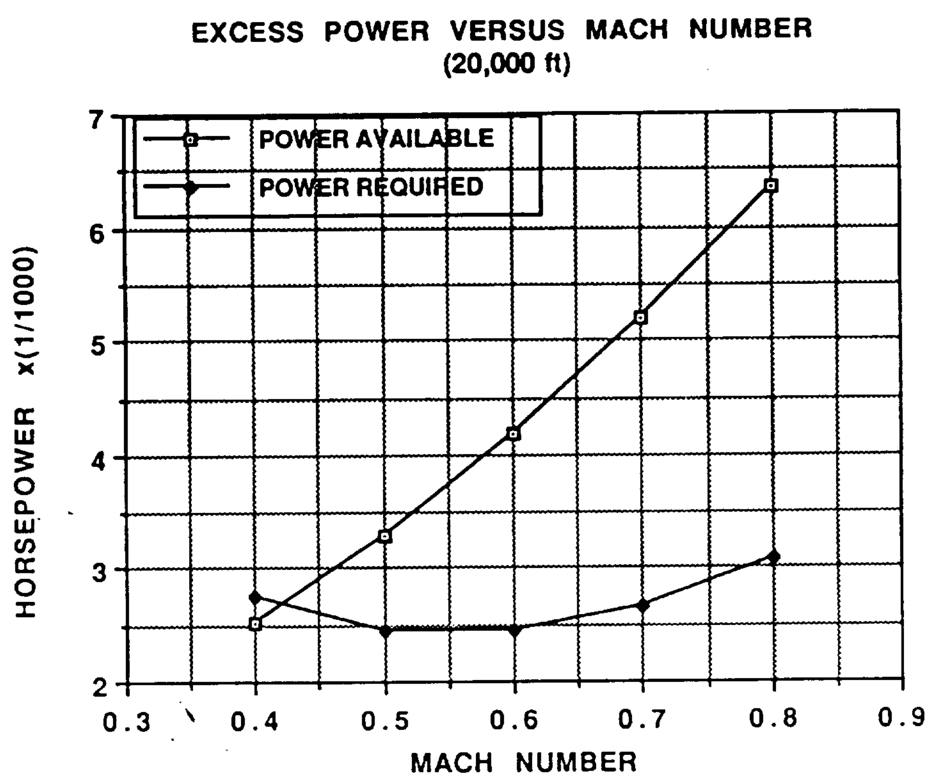


FIGURE 3.1.1c

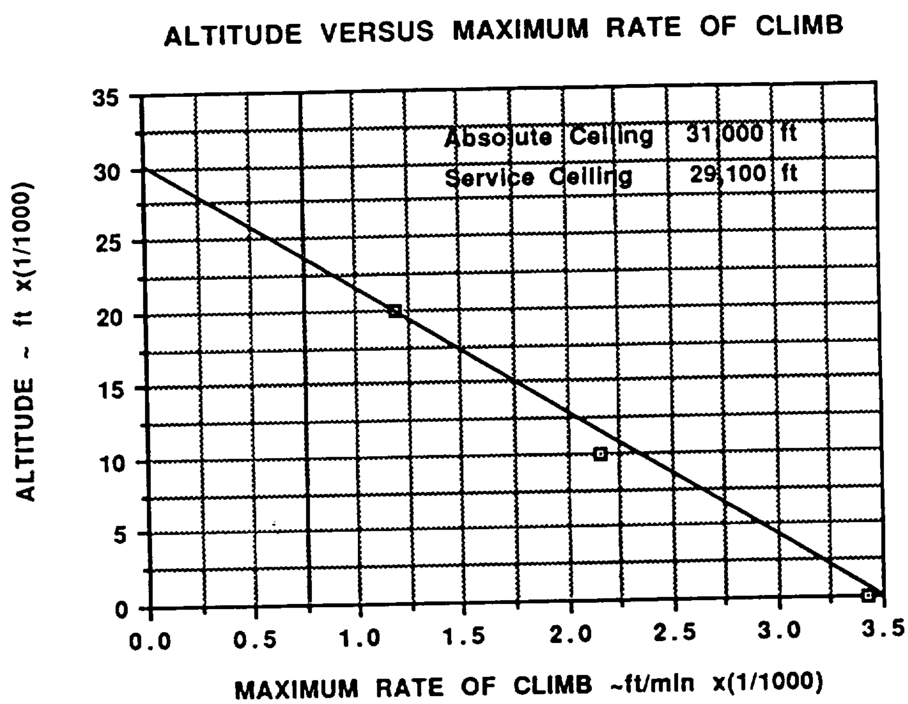


FIGURE 3.2.1

3.2 Engine Fuel Consumption

A further consideration of engine performance is the design engine's thrust specific fuel consumption, c_j. The Manx is evaluated for the low-level mission and the ferry mission using the design engine cycle data, for climb, cruise and best cruise altitude (Table 3.2.1).

Table 3.2.1 Fuel Consumption

Mission	Condition	CJ
Low Level	Climb	0.64 - 0.72
	Cruise	0.65
Ferry	Best cruise Altitude	0.68

3.3 Take-off and Approach Performance

The Manx was designed from its early conception to be suited for remote site based operations. This requires it to takeoff and land within 2000 ft. after clearing a 50 ft. obstacle on runways that are difficult to maintain. As a result, design considerations were performed to meet these objectives.

The landing gear was designed for use on dirt or grass strips with tire sizing done to accommodate these surfaces. The capability to land and takeoff within 2000 ft. after clearing a 50 ft. obstacle is a function of the aircraft's design point characteristics. The stall speed of the aircraft was computed to be 114 knots at takeoff and 104 knots at landing, in a fully loaded configuration. Using Reference 23 (ch5.1), the Manx's take-off ground roll distance to clear a 50 ft. obstacle was computed to be 1512 ft. which adequately fulfills the 2000 ft. requirement with a 500 ft. safety margin.

4. AIRCRAFT SIZING

4.1 Specifications

The Federal Aviation Administration requires that sizing data for all military aircraft must comply with FAR 25 specifications . Reference 1 provides methods for the preliminary sizing estimations which are in compliance with FAR 25.

4.2 Weight Sizing Requirements

Estimating the gross take-off weight, W_{TO} , empty weight, W_E , and the mission fuel weight, W_F , is dependent upon the mission range, endurance, speed and payload-carrying requirements of the design mission. These requirements are outlined in the Mission Specifications.

Reference 1 develops the iterative method which was employed in this study to determine W_{TO} , W_E , and W_F . This method utilized empirical data obtained from similar aircraft and the Breguet's range and endurance equations, which in turn were used to calculate the fuel fractions of each phase of the mission in terms of W_{TO}. The results of these calculations are found in Table 4.1.

Table 4.1 Mission Weight Sizing Requirements

Gross Take-Off Weight, W_{TO}	48,820 lbs.
Operational Empty Weight, W_{OE}	25,423 lbs.
Empty Weight, W_E	24,954 lbs.
Fuel Weight, W_F	9855 lbs.

Using the weights from Table 4.1, the remaining sizing requirement were calculated.

4.3 Weight Sizing Results

The final weight sizing for the close air support aircraft combined with the thrust loading (T/W) and wing loading (W/S) give the aircraft its characteristics. These characteristics are derived by combining all of the sizing graphs onto one graph (Figure 4.3). This graph shows all of the operating ranges of the aircraft for a range of maximum wing lift coefficients (C_{Lmax}). The design condition is the one point on the graph that sufficiently meets or exceeds the performance requirements of the design mission specifications [1].

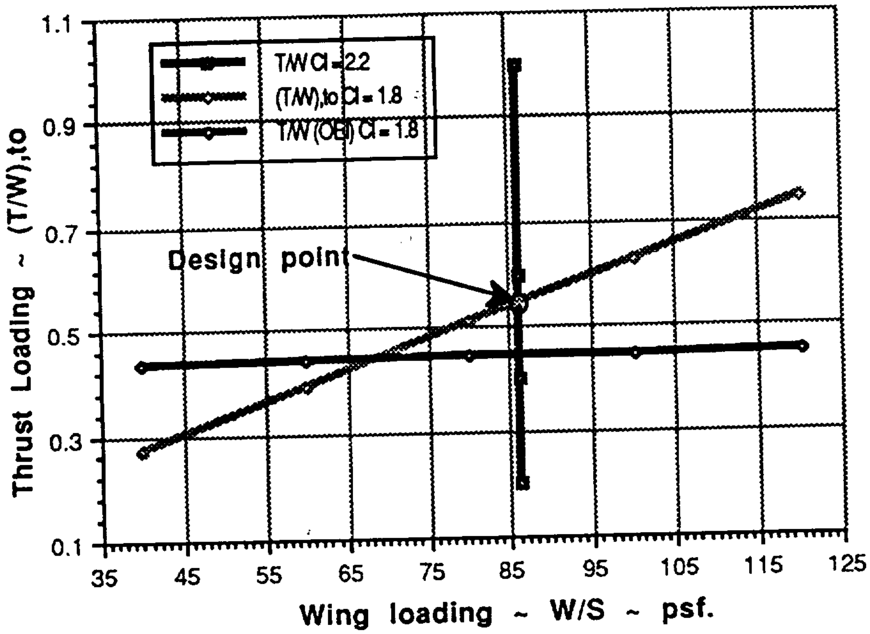


Figure 4.3 Design Point Graph

4.4 Selection of Design Point

The region above and to the left of the curves on Figure 4.3 meet the requirements for a C_{Lmax} of 2.2. The point that is chosen takes into consideration the ability of the design to meet the requirements, while at the same time allows simplified construction with light weight, maintainable and affordable materials

There are other very important considerations involved in the selection of the design condition. Wing loading, W/S, directly affects the performance of any aircraft. The ability of the aircraft to maneuver depends upon the W/S of the aircraft. The lower the W/S, the better the plane's maneuverability. However, a lower wing loading does not permit good turbulence penetration. Since maneuverability is not the strictest design consideration for this mission and the design mission is to take place at very low altitudes where turbulence is high, the turbulence penetration of the aircraft is an important design consideration. For this reason a high wing loading is favorable [1].

Another consideration is the engine sizing. The thrust to weight, T/W, parameter specifies that the engine of the aircraft must provide a certain amount of thrust in relation to the weight of the plane. For a given aircraft weight, a large T/W implies a larger, heavier and more expensive power plant. A larger engine would use more fuel thus reducing the maximum range or requiring more fuel capacity. For these reasons, it would be beneficial to have a lower thrust to weight ratio [1].

The design point was chosen from Figure 4.3 by taking into consideration the previously mentioned criteria. A C_{Lmax} of 2.4 was specified by the design group for each regime of the flight envelope. Each C_L for a flight condition was selected based upon the design groups expectation of the design to achieve that C_L. This criteria was used to systematically remove all of the curves which were below or to the left of the design C_l for a particular flight regime. Figure 4.1 shows the operational flight envelope of the aircraft, with all of the points above and to the left of the curves meeting the performance requirements [1].

Applying the criteria for a high W/S and low T/W to this graph, it can be seen that the best point for the design lies where the landing performance and take-off performance curves intersect. This point corresponds to a W/S = 87.5 psf. and T/W = 0.54. Although these points optimize the aircraft for the design mission, it does not take into consideration the performance and maneuvering capabilities of the Manx. These added performance requirements dictated a higher T/W. For this reason, for the final configuration, a T/W of 0.635 was used to meet all performance parameters.

5. CONFIGURATION SELECTION

The Manx CAS fighter was designed to meet all of the performance requirements of the RFP. Using these requirements, a number of critical design parameters were identified which are listed below:

1. High subsonic Mach Numbers. M= 0.76
2. High maneuverability at low speeds
3. Survivability in high threat environment

Many different designs were considered for the proposed close air support role. These different design configurations are compiled in Table 5.1. The advantages and disadvantages are stated for each design.

Table 5.1 Configuration Comparison

Configuration	Advantages	Disadvantages
Helicopter	no runway required good maneuverability good stealth capabilities	inadequate speed high maintenance complex expensive
Tilt-rotor	no runway required good for rough terrain good speed range	low survivability high maintenance complex expensive
Conventional tail	contributes to aircraft stability good downward visibility	larger control surfaces, heavier
Rearward sweep	low wave drag good downward visibility	higher take-off speed higher landing speed poor stall characteristics
Canard	smaller control surfaces vortex coupling with main wing	contributes to aircraft instability

Table 5.1 Configuration Comparison (continued)

High wing	good lateral visibility good downward visibility	high interference drag
Mid wing	low interference drag good accessibility to stores	higher weight penalty
Low wing	low interference drag good accessibility to stores	poor lateral stability
Inlets above wing	good for rough terrain low chance of FOD	fuselage boundary layer ingestion
Inlets below wing	no runway required good for rough terrain good speed range	low survivability high maintenance complex, expensive
Single engine	low maintenance low weight	poor survivability
Twin engine	good survivability	higher weight higher maintenance

5.1 CONFIGURATION DESCRIPTION

Using the comparison study of Table 5.1, and keeping in mind the critical design parameters, the following configuration resulted:

- Forward Swept Wing
- Canard configuration
- Twin vertical tails and engines
- Over-wing inlets location
- Mid-wing location

A complete three-view drawing of the Manx configuration can be found in Figure 4.1. as well as the tabulated geometry for all of the airframe components. A more in depth description of the Manx configuration follows.

5.1.1 Wing

The forward swept wing was chosen because of its capability of high subsonic flight speed with low drag rise due to compressibility. It also exhibits excellent maneuverability at high angle-of-attack (AOA), and good low speed lateral control capabilities [14]. The disadvantages of weight and structural divergence are to be eliminated by the use of aeroelastically tailored composites. The wing is swept forward 25 degrees at the quarter-chord. A mid-wing position was chosen to minimize the wing/fuselage interference drag. It also allows for the wing box to be carried through the fuselage thus taking advantage of weight saving synergism as well as simplifying the construction. Fowler flaps and a leading edge slat are to be deployed during take-off and landing to achieve the required Cl_{max}. Ailerons are located at the wing tips for the lateral control of the aircraft. The wing has been constructed to allow for the incorporation of spoilers if they are needed for additional roll control.

5.1.2 Canard

A canard was selected primarily due to smaller required control surface areas resulting in lower skin friction drag on the Manx. The canard provides a downward force at trimmed conditions and provides the instability required for increased maneuverability. The chord line of the canard is placed two feet above the main wing chord line. This has been done in order to take advantage of the canard tip vortices interacting with the main wing boundary layer,providing increased lift at high AOA [13]. A smaller control surface is possible with a canard because it is not being down-washed by the main wing as are conventional tails. The canards are full moving surface devices that act as high lift devices on take-off and landing. They are differential as well to add to the lateral control of the aircraft in flight, and can be employed as speed brakes to decrease landing distance[ ].

5.1.3 Twin Vertical Tails

Twin tails were selected for redundancy, increasing the survivability aspect of the plane. They are also effective in providing good lateral control qualities at high AOA. In addition, the twin tails serve to reduce the airplane's side profile lessening the chance of visual detection. They are canted 55 degrees to reduce the radar image and to position them out of the wake of the fuselage for increased directional control at high AOA [20]. Also, since the thrust lines of the two engines are off-set from the aircraft center line, the two tails provide good directional control in a one-engine-out-operation configuration.

5.1.4 Engines and Inlets

It was determined that two engines would adequately meet the thrust requirements for the Manx. The twin engine configuration also allows for the flexibility of being accepted for use as a Navy based fighter. A one engine configuration would make it necessary to develop a high thrust, light weight engine and would reduce the survivability of the fighter. The engine used was designed from parameters taken from a thrust augmented rubber engine [29](see Appendix). The inlets have been placed above the wing with the opening one foot in front of the leading edge. Over-wing inlets reduce the possibility of foreign object damage (FOD) that may result from the plane operating from undeveloped airfields. The placement also makes it difficult for hostile ground fire to be ingested by the engines. The inlets are also canted down 6 deg. in order to maximize uniform inlet flow and to decrease the possibilities of flow separation from the inlet lip at high AOA flight.

6. COMPONENT DESIGN

6.1 Fuselage

The fuselage has been design to enhance the high subsonic flight capabilities of the Manx. For this reason, a fineness ratio of 8 was chosen. This provides the lowest fuselage drag [19]. A detailed drawing of component placement can be seen in Figure 6.1.1 (System inboard profile). The large fuselage cross section was necessary to contain the large 30 mm. GAU-8a cannon. This gun has been placed so that the C.G. of the ammunition lies very close to the C.G. of the Manx. This minimizes C.G. travel as the ammunition is used. The firing barrel of the gatling gun has been placed along the center-line of the fuselage which eliminates the control problems associated with the gun recoil when firing. The major electronic components are placed behind the pilot. These along with the pilot are enclosed in a Kevlar cockpit shield. This cockpit shield is designed so that the pilot is protected from small arms ground fire and shrapnel from anti-aircraft fire. The nose cone contains the Radar and Forward Looking Infrared units. The Auxiliary Power Unit is contained in between the two engine inlets in front of the engines and on top of the wing. The climate control system is located below the cockpit.

6.2 Wing

The Manx utilizes a tailless, forward swept wing (FSW), and canard configuration. The wing is cantilevered to avoid the drag of external bracing. A mid wing was chosen to allow for better engine placement above the wing, less interference drag, good lateral stability, good visibility from the cockpit, and a lower landing gear weight. A forward swept wing was chosen, because of the superior maneuverability capabilities at transonic Mach numbers. The construction of the FSW will utilize composites to take advantage of the aeroelastic tailoring capabilities. This will allow the wing to bend under load, which will delay the flutter and divergence associated with the FSW. The FSW creates a higher swept shock at the trailing edge, resulting in lower pressure drag. This allows for a lower sweep angle than an Aft Swept Wing (ASW) resulting in a higher lift curve slope, and lower subsonic induced drag. The spanwise flow component of the FSW is directed toward the root, promoting root stall as opposed to tip stall, which occurs with an ASW, allowing for greater use of the ailerons at higher AOA and thus greater maneuverability. [6]

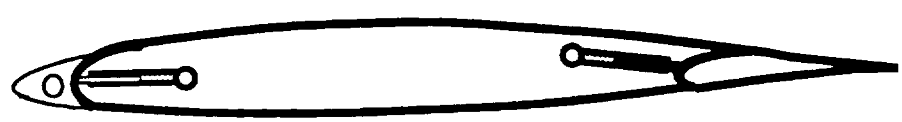
For the planform design, initial values for wing thickness ratio, taper ratio, and sweep angle were chosen referencing existing aircraft. The airfoil was then selected for the predicted required lift coefficients at various configurations. The wing employs a series of airfoils; a NACA 65-210 at the root, down linearly to a NACA 65-208 at the tip. The high lift device sizing took several iterations to achieve the required space for the desired control surfaces. Smaller flaps were achieved with the added penalty of higher complexity and cost. Table 6.2.1 shows the resulting wing planform parameters while Figure 6.2.1 shows the high-lift -devices layout and operation. [18]

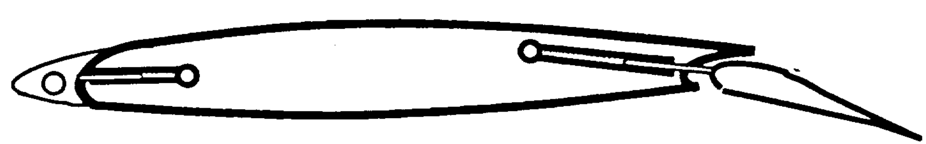
Table 6.2.1 Wing Planform Sizing

b	53 ft.
S	558 sq. ft.
A	5.0
$\Lambda_{c/4}$	-25 deg.
c_t	7.5 ft.
c_{mac}	10.75 ft.
λ	0.55
Fuel volume	230 cu. ft.

Table 6.2.2 Airfoil and High Lift Devices

Airfoil	root: NACA 65-210 tip: NACA 65-208
Fowler flap	c_f/c = 0.3 S_{wf}/S = 0.68
Leading edge slat	c"/c = 1.126
Flap deflection	takeoff: 20° land: 40°
Maximum lift coefficient	takeoff: 2.0 land: 2.4


Clean Configuration: Cruise


Take-off Configuration: 20 deg. Fowler flaps

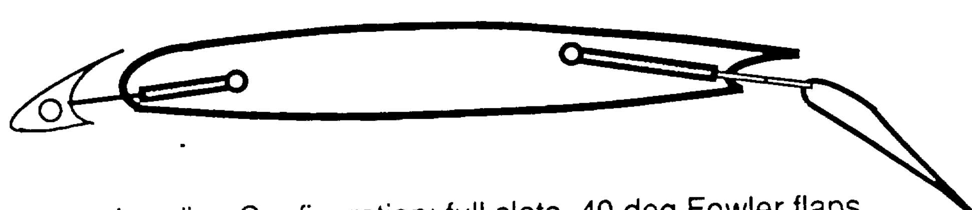

Landing Configuration: full slats, 40 deg Fowler flaps

Figure 6.2.1 Wing High-Lift-Devices

6.3 Cockpit Layout

The aircraft controls are the standard center stick and side throttle configuration based on that of the McDonnell Douglas F-15 Eagle. The control layout employs the Hands On Throttle and Stick (HOTAS) philosophy which allows the pilot to operate vital combat functions without removing his hand from the the aircraft controls. The HOTAS system allows a decreased work load for the pilot and also a faster response time in combat situations. This system has proven itself valuable in actual combat. The control stick and throttle arrangement for the Manx can be seen in Figure 6.3.1a,b. [33]

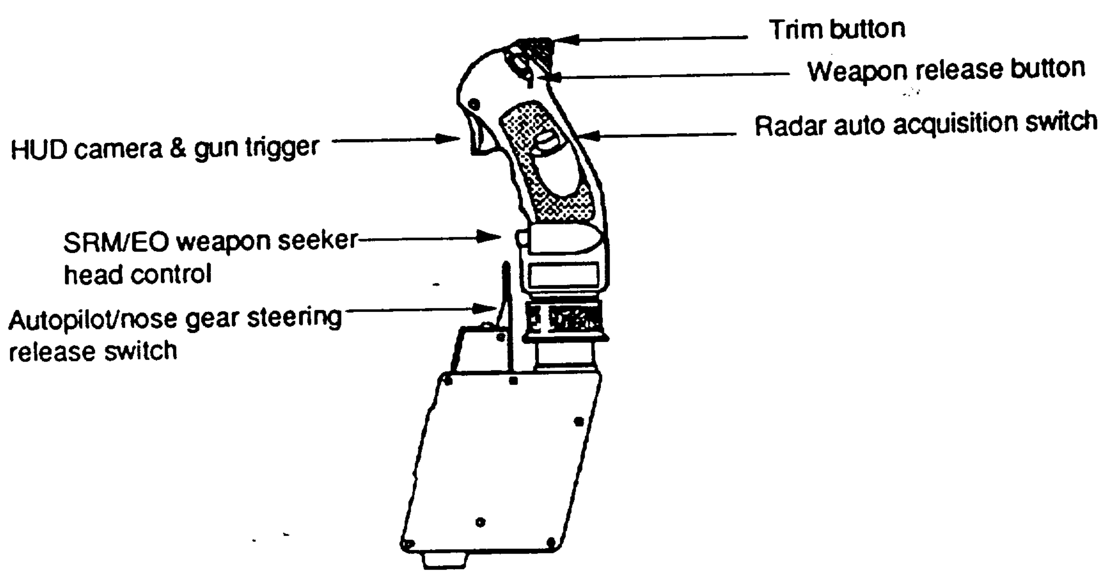


Figure 6.3.1a HOTAS Control Stick

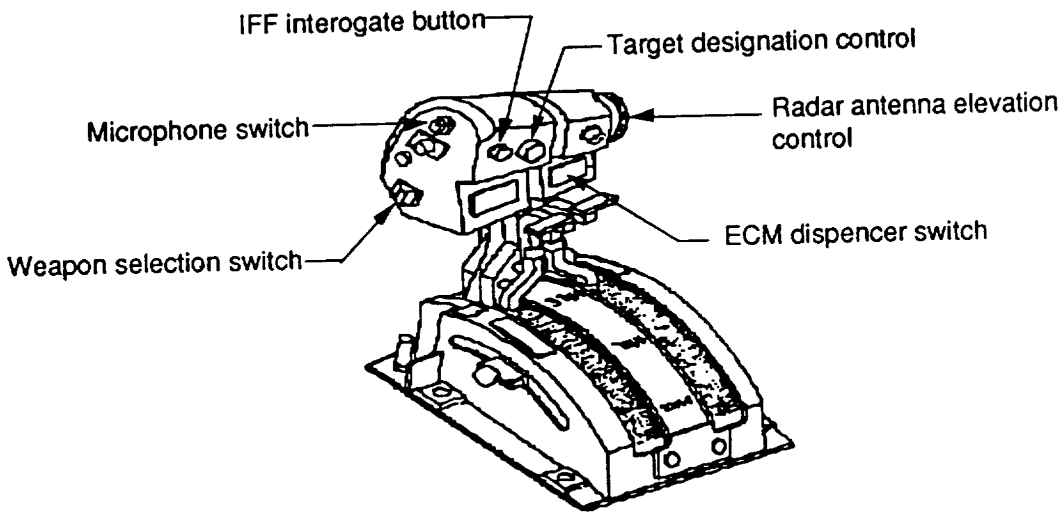
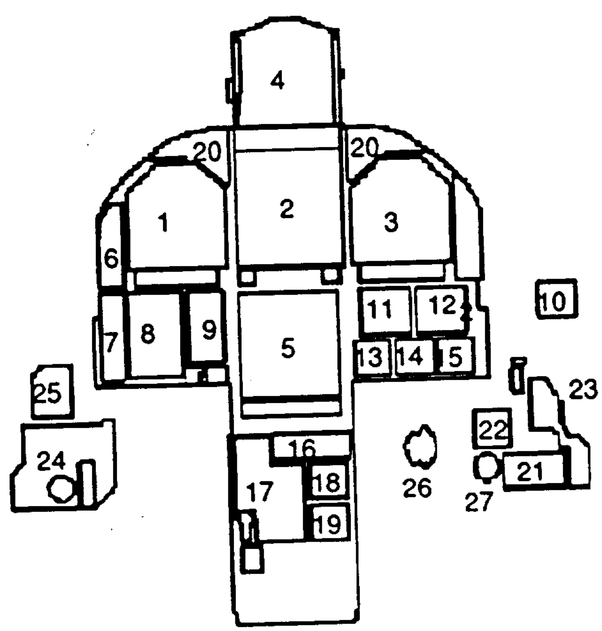


Figure 6.3.1b HOTAS Throttle

Instrumentation is arranged in a display format similar to that of the McDonnell Douglas/Northrop F/A-18 Hornet (see Figure 6.3.2). This display takes advantage of the multifunction CRT displays as well as a fully integrated HUD. The system is designed to lower the pilots combat work load by placing only the most important information in front of the pilot as it is needed. The CRT displays are programmable so that they can act as different displays are needed for particular missions. Not only does this allow more flexibility for the aircraft configuration but it allows a more efficient use of the instrumentation displays. The cockpit orientation and pilot position can be seen in Figure 6.3.3. The arrangement allows for the pilot to have good 360° visibility.



1 Master monitor display (CRT)
2 Up-front control panel
3 Multi-function display (CRT)
4 Integrated head-up display (HUD)
5 Horizontal situation display (CRT)
6 Master armament panel
7 Stores jettison indicators
8 Digital engine monitor display
9 Fuel quantity indicator
10 Standby magnetic compass
11 Attitude referrence indicator
12 Radar warning display
13 Stanby airspeed indicator
14 Standby altimeter
15 Vertical speed indicator
16 ECM monitor panel
17 ECM control panel
18 Clock
19 Cabin pressure altimeter
20 Warning panel
21 Caution light panel
22 Altitude indicator
23 Landing light plate
24 Brake pressure indicator
25 Landing gear controls
26 Static pressure source selector
27 Hydraulic pressure indicator

Figure 6.3.2 Manx Cockpit Instrumentation

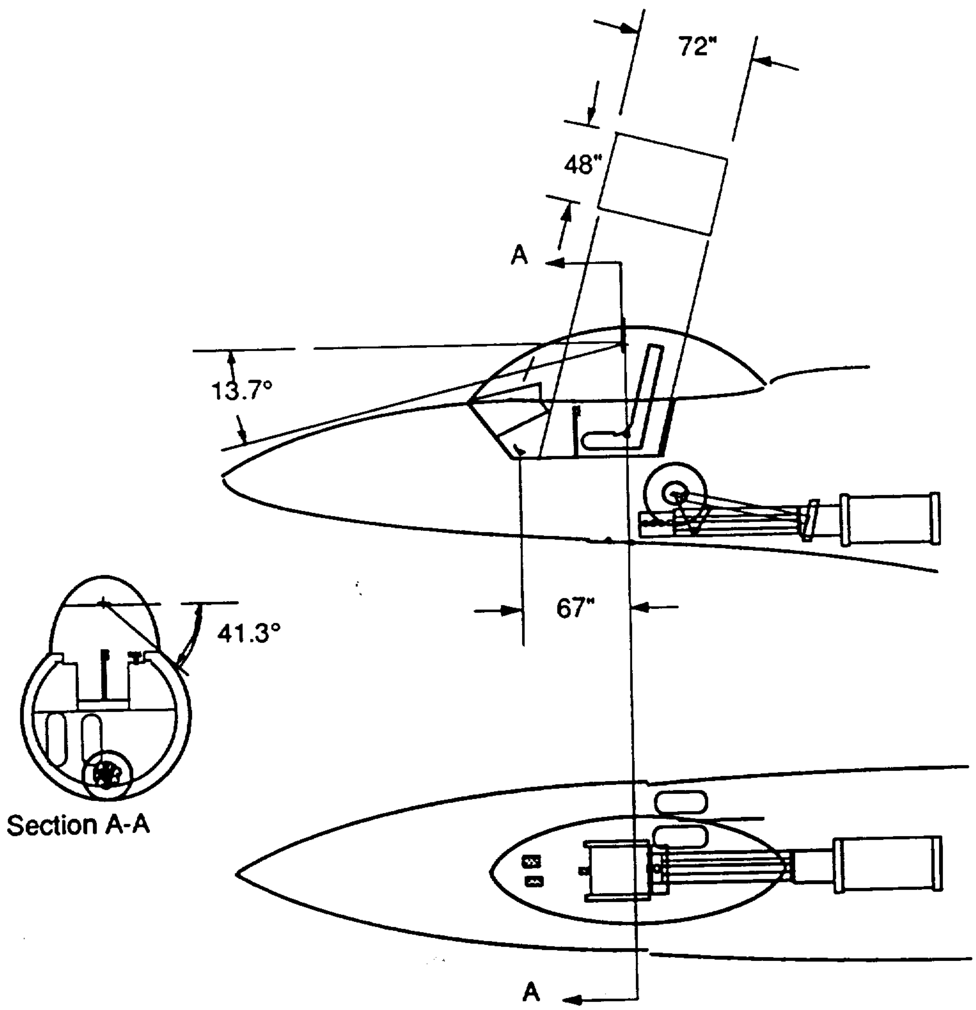


Figure 6.3.3 Cockpit Layout

6.4 Propulsions Integration

6.4.1 Engine Selection

The engine parameters for the Manx is based on a design engine. This design engine meets the mission requirements specified in the RFP, for Mach number, altitude, thrust, mass airflow, fuel flow, and specific fuel consumption.

6.4.2 Inlet Integration

The preliminary design process for inlet sizing is dependent on several important factors. These factors are as follows:

- Subsonic Performance
- Pressure Recovery
- Landing Gear/ Fuel Storage
- Foreign Object Damage
- Gun Exhaust Gas Ingestion
- Undisrupted Flow Into Inlets
- Reduce Spillage Drag

The Manx inlets are constructed such that the engine airflow requirements can be met. This includes determining the inlet area and the geometric configuration of the duct leading to the engine compressor face, which is essential for minimizing the total stream tube wetted-area and the viscous pressure losses. The inlet geometry is designed for a range of flight modes; specifically, for the required range of flight Mach numbers and engine performance requirements specified by the Manx's design engine.

The Manx incorporates internal-compression subsonic inlets which are semi-circular in cross section at the cowl and diverge in circular cross-sections to the compressor face. The inlet stream tubes are 9.0 ft. long, which allows for a gradual area transition from the inlet face to the fan face. This avoids severe angle deflections in the stream tube, which eliminates flow separation in the inlet duct which can induce diffuser stall, and reduces the energy losses in the internal-compression inlet. Consequently, the positive pressure-gradient along the diffuser length is kept small. Table 6.4.2.1 lists the inlet pressure losses for variations in Mach number and altitude. Turbofan engine performance analysis has determined these values to be highly favorable for high pressure recovery at the compressor face, which minimizes the turbine work required to compress the air flow.

The above-wing disposition of the inlets and engines, along with the straight through configuration aide in maximizing fuel and landing gear storage volume. In addition, the risk of FOD to the turbofan engine is greatly reduced as well as the risk of gun exhaust gas ingestion during weapons deployment. To maximize the freestream flow ingestion at high AOA, the inlet cowl is oriented 6 degrees down from the horizontal.

References 22 and 27 develop relationships for inlet sizing, in order to maximize performance during critical flight conditions. Table 6.4.2.2 summarizes the results for determining the inlet area for three critical flight conditions.

Table 6.4.2.1 Inlet Pressure Losses (psf.)

Altitude (ft.)	Sea Level	5000	10000	20000	30000
Mach					
0.2	0.177	0.148	0.122	0.082	0.053
0.4	0.709	0.593	0.489	0.327	0.212
0.5	1.109	0.926	0.764	0.511	0.331
0.6	1.596	1.333	1.101	0.736	0.477
0.7	2.173	1.815	1.498	1.002	0.649
0.8	2.838	2.370	1.957	1.309	0.848

Table 6.4.2.2 Inlet Area per Engine

Take-off	4.258 sq. ft.
M = 0.4 at 20,000 ft.	2.957 sq. ft.
M = 0.4 at sea level	2.344 sq. ft.

To meet the take-off flight condition the Manx is designed with inlet area of 4.258 sq. ft. per engine.

The Manx inlets incorporate boundary layer splitters to avoid consumption of the boundary layer which develops along the fuselage upstream of the inlets. This improves flow conditions to the turbofan engine, greatly reducing the occurrence of disrupted flow entering the inlets, and maximizing engine performance.

6.4.3 Engine Performance

The performance of the Manx is based on the following requirements:

- Thrust/Power Available
- Thrust/Power Required
- Altitude Effects on Thrust/Power Required and Available
- Rate of Climb/Maximum Rate of Climb
- Absolute and Service Ceilings

The Manx design engine cycle data provided the available uninstalled thrust data. Reference 22 outlines the method used to obtain the available installed thrust values. Considerations for the available thrust included Mach number effects, and power extraction from the engine for operation of electrical, mechanical, and pneumatic equipment on board the Manx. Table 6.4.3.1 lists power extraction requirements, however, the Mach number is the main variable for available installed thrust.

Table 6.4.3.1 Power Extraction Requirements

Electrical

Radar
Navigation
Weapons Deployment
Control Surface Deflection

Mechanical

Fuel Pumps
Hydraulic Pumps
Cooling Fans
Pressurization Systems
Air conditioning/Heating Systems

Pneumatic

Anti-icing Systems
Engine Starting Systems
Fuel Tank Pressurization
Flap/Control Surface Deployment

Thrust and power required are based on the drag polar calculations of Section 9 for the Manx. Reference 28 outlines the method used to calculate thrust/power required, which are primarily a function of the aircraft drag coefficient and the flight Mach number. The aircraft is assumed to be in level and unaccelerated flight for this analysis.

Altitude effects on thrust/power required and available are only a function of density. Specifically, they are a function of the ratio of standard sea level density to the density at altitude. This analysis assumes a standard day.

For rate of climb it is assumed that the Manx is in steady, unaccelerated climbing flight. For this assumption, the rate of climb is determined for the power available/required curves versus velocity curves, where rate of climb is the ratio of the excess power to the aircraft weight. Based on this analysis, the maximum rate of climb is obtained from the maximum excess power.

Absolute and service ceilings are listed in Figure 3.2.1 for maximum rate of climb versus altitude. Refer to the results section of this report for a complete presentation of the performance curves.

6.5 Empennage Sizing

The empennage parameters for the Manx are summarized in the geometry table of Figure 3.1.

6.5.1 Canard

The canard sizing was determined by the level of instability of the Manx and its effect on take-off trim. With the aircraft highly unstable, a symmetric airfoil was chosen for the canard so that lift could be provided equally in either direction. Positioning the canard as far forward of the wing as possible while keeping it behind the pilot to provide good visibility, provided the smallest required canard area. The resulting longitudinal feedback gain, $K\alpha$, was not a limiting factor for the canard sizing.

The canard was designed as a fully movable surface. This feature allows the canard to serve as an effective brake when landing. The canard is also fully differential which allows for synergism with the ailerons to enhance roll capability. A high vertical positioning of the canard was chosen to minimize inlet air flow disruption during level and positive angle of attack flight. This position also provides the pilot with minimal vision obstruction. Existing canard aircraft of similar configurations were examined for aid in designing the planform of the canard.

6.5.2 Vertical Tail

Vertical tail sizing for the Manx was determined primarily by the yaw recovery requirement for the one engine inoperative (OEI) condition during take-off. In placing the tails 3 ft. from the fuselage centerline, the flow disruptions from the fuselage wake which become significant at high AOA are reduced. This characteristic was further enhanced by canting the tails outward 55 degrees. Twin vertical tails also provide redundancy in the event one tail is damaged, and serves to reduce the overall airplane height. With the directional response increased by the added moment arms provided by twin tails, the sideslip-to-rudder feedback gain was not a restrictive sizing parameter.

6.6 Landing Gear

The Manx landing gear is designed to withstand the loads placed on it by rough, unimproved landing strips such as grass strips and hard packed sand. In order for the fully loaded plane to taxi on these unimproved fields, two wheels are provided for each strut to allow for better weight distribution. The nose gear is a dual arrangement while the main gear is a tandem arrangement. The tricycle landing gear arrangement allows for good stability and ample clearance for take-off rotation. Both the main gear and nose gear retract forward so that the gear can be deployed by gravity and locked in place by dynamic pressure if the hydraulic system fails due to damage or power failure. The wheel sizing can be found in Table 6.6.1.

Table 6.6.1 Landing Gear Tire Sizing and Rating

	Nose gear	Main gear
Size (in.)	25.65 x 8.7	37.5 x 12.75
Dynamic load (lbs.)	8,000	12,800
Number of plys	12	12
Tires per strut	2	2
Infl. pressure (psi)	100	75
Max. speed (kts)	120	160

7. AIRCRAFT STRUCTURE

The aircraft structure was designed to take full advantage of synergistic component mating and construction. Examples of this are the ammunition cannister mount, main landing gear strut mounts and forward wing box all use the same fuselage frame mounting point.

7.1 Wing Structure

The forward swept wing of the Manx fighter is to be constructed from composite materials. The use of composite materials allows for aeroelastic tailoring of the structure. The aeroelastically tailored wing uses a stressed composite skin which is laid up so that the wing angle of attack is decreased as the wing load is increased. This is needed due to the tendency of the structure of the forward swept wing to diverge and fail. This tendency can be overcome with a large weight penalty if conventional materials are used (i.e. aluminum alloys) or with aeroelastic tailoring using composite materials. A typical composite wing structure can be found in Figure 7.1.1. Due to the complex problems of composite structural design, a detailed rib and spar drawing was not constructed. The ribs in Figure 7.1.1 have been placed at key hard point locations where the loads are carried on pylons. [34]

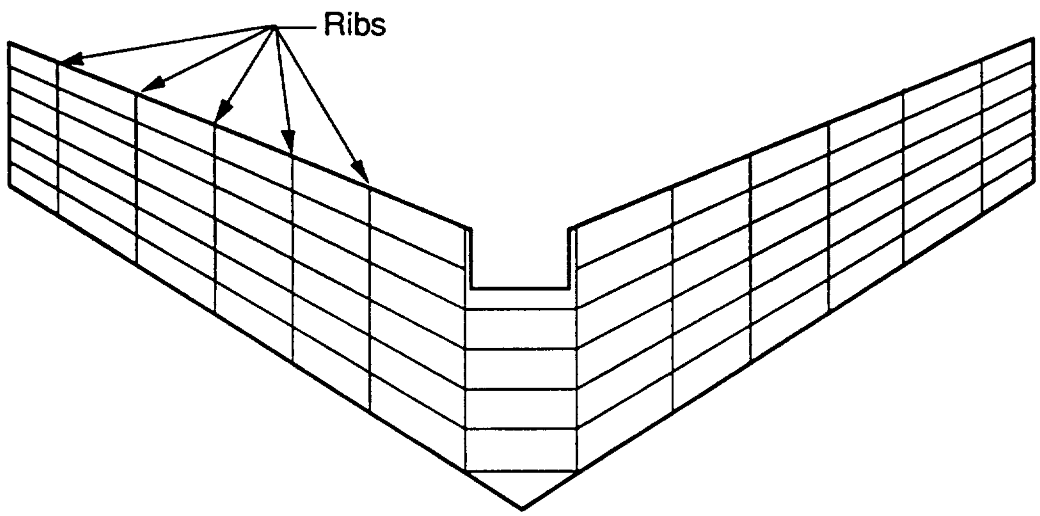


Figure 7.1.1 Manx Wing Structure

7.2 Fuselage Structure

The fuselage structure is constructed of aluminum-lithium frames and aluminum-alloy longerons. The spacing is typical for fighters [19]. The skin is unstressed graphite composite material. The fuselage structure with typical cross-sections can be seen in Figure 7.2.1. The wing box passes through the center of the fuselage and the frames at those intersection stations are bolted to the wing.

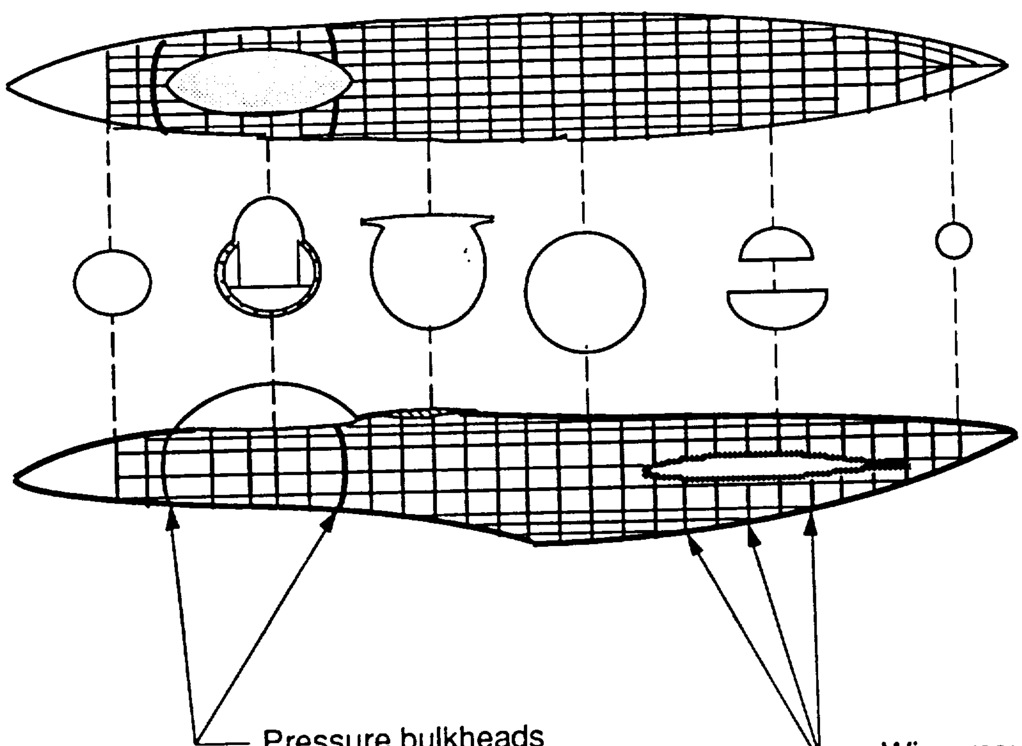


Figure 7.2.1 Fuselage Structure

7.3 Canard Structure

The canards are superplastically formed from six flat titanium sheets. these sheets are diffusion bonded together at 900 deg C. Next the sheets placed in a die and molded to the airfoil shape using argon gas to physically expand it to the shape of the die. The construction method is similar to that used for the Eurofighter being constructed by British Aerospace [30]. The construction method is designed to decrease production costs and increase the durability of the canard.

8. C.G. and Moment of Inertia Analysis

8.1 Component Weight and C.G. Locations

The component weights for the Manx were determined using the methods of Reference 8 and 21. Weights for the internal cannon and ammunition, external stores, and pilot were specified in the RFP. The engine weights were arrived at based on the given design engine that was modified as needed to meet the specified requirements.

Table 8.1.1 lists the Manx component weights and individual locations from the aircraft c.g. Component locations are presented visually in Figure 8.1.1. The longitudinal C.G. excursion for the range of loading conditions is shown in Figure 8.1.2 and the corresponding mission phases are provided in Table 8.1.2.

The C.G. travel as well as the tip-over angles of the Manx were found to meet or exceed accepted limits according to guidelines listed in Reference 19 and are given as follows:

	Acceptable	Obtained
C.G. Range for Design Mission	≤ 0.20c	0.05c
Longitudinal Tip-Over Angle	≥ 15°	23°
Lateral Tip-Over Angle	≤ 55°	55°

Table 8.1.1 Component Weights and C.G. Locations

		Weight(lbs)	X(in) from nose	Y(in) from centerline	Z(in) from ground
Structures					
1	wing	4850	443	0.0	89.2
2	canard	385	198	2@ +-26.1	125.0
3	vertical tails	855	542	2@ +-69.2	150.0
4	fuselage	5475	269	0.0	91.7
5	main gear	1235	386	2@ +-38.5	43.3
6	nose gear	665	230	-18.0	37.5
7	engine mounts	143	518	2@ +-33.7	112.7
8	firewall	116	518	0.0	99.2
9	engine section	106	518	2@ +-33.7	112.7
10	air induction sys	568	410	2@ +-41.7	108.3
Propulsions					
11	engines	4637	510	2@ +-33.7	112.7
12	engine cooling	291	518	2@ +-33.7	112.7
13	furnishings	385	126	0.0	101.7
14	tail pipes	52	602	2@ +-33.7	117.0
15	oil cooling	138	470	0.0	102.5
16	engine controls	73	490	0.0	120.0
17	starter	68	490	0.0	110.8
Equipment					
18	fuel sys. & tanks	477	420	0.0	88.3
19	flight controls	1031	86	0.0	108.4
20	instruments	181	86	0.0	112.5
21	hydraulics	201	170	0.0	69.2
22	electrical	497	370	0.0	111.6
23	avionics	1375	194	0.0	103.2
24	gau-8a cannon	1840	240	0.0	84.0
25	air cond/anti-ice	256	270	0.0	96.0
Total Empty Weight		25900			
Useful Load					
26	trapped fuel/oil	244	474	0.0	81.6
27	fuel	9855	366	0.0	88.3
28	pilot	225	126	0.0	111.6
29	ammo	2106	354	0.0	116.7
30	missiles	390	303	2@ ±316	87.5
31	12 bombs	6060	382.5	12@ ±91.6	45.0
32	8 bombs	4040	364	8@ ±140	48.8
Take-off Weight		48820			

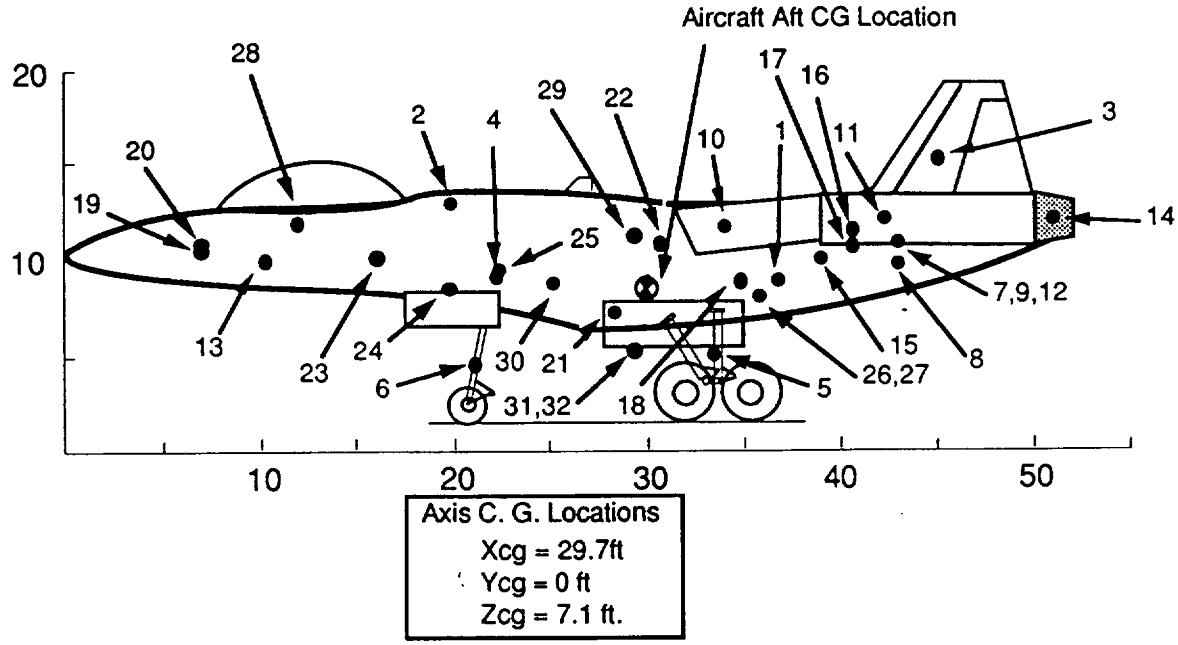


Figure 8.1.1 Manx Component C.G. Locations

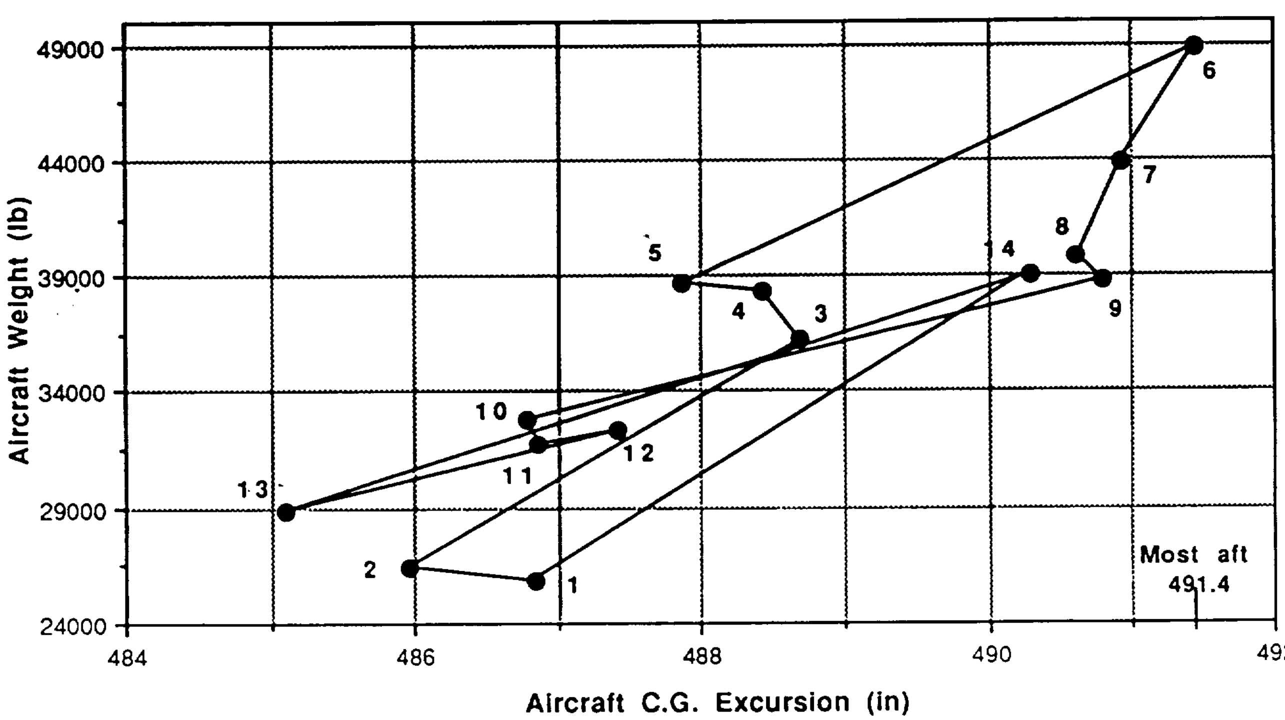


Figure 8.1.2 Manx C.G. Excursion Envelope

Table 8.1.2 C.G. Excursion for Range of Loadings		
Loading Condition	**Weight (lbs)**	**C.G. (in)**
1 Empty	25,900	486.84
2 +TFO+Pilot	26,369	485.95
3 +TFO+Pilot+Fuel	36,224	488.68
4 +TFO+Pilot+Fuel+Ammo	38,330	488.43
5 +TFO+Pilot+Fuel+Ammo+Missiles	38,720	487.87
6 +TFO+Pilot+Fuel+Ammo+Missiles+Bombs	48,820	491.43
7 +TFO+Pilot+1/2Fuel+Ammo+Missiles+Bombs	43,893	490.92
8 +TFO+Pilot+1/2Fuel+Ammo+Missiles+1/2Bombs	39,853	490.61
9 +TFO+Pilot+1/2Fuel+1/2Ammo+Missiles+1/2Bombs	38,800	490.79
10 +TFO+Pilot+1/2Fuel+1/2Ammo+Bombs	31,687	486.77
11 +TFO+Pilot+1/2Fuel+Missiles	32,350	486.86
12 +TFO+Pilot+1/2Fuel+1/2Ammo	28,865	487.42
13 +TFO+Pilot+Ammo+Missiles	38,965	485.09
14 +TFO+Pilot+Ammo+Missiles	25,900	490.28

8.2 Mass Moments of Inertia

The aircraft moments of inertia were obtained using the guidelines in Reference 21, and formulas for estimating the individual component inertias were taken from References 34 and 35. The smallest components, totalling under 4% of the full aircraft weight, were assumed to have negligible inertia moments about their own C.G. and were therefore considered to be point masses. The centroidal moments of inertia for the Manx when fully loaded for the design mission are given below:

$$I_{xx} = 98{,}176 \text{ slug} \cdot \text{ft}^2$$
$$I_{yy} = 144{,}200 \text{ slug} \cdot \text{ft}^2$$
$$I_{zz} = 226{,}458 \text{ slug} \cdot \text{ft}^2$$
$$I_{xz} = 2{,}347 \text{ slug} \cdot \text{ft}^2$$

9. AERODYNAMICS

The following reference data was used in the aerodynamic analysis of the Manx.

•S	=	558 sq. ft.
•MGC	=	10.75 ft.
•b	=	53 ft.

9.1 Lift Analysis

The lift calculations performed for the Manx considered lifting contributions from the wing, canard, and vertical tails. Figures 9.1.1 and 9.1.2 are presented to show the aircraft's lift performance for takeoff, cruise, and approach flight regimes. All calculations pertaining to the prediction of incompressible flight parameters were performed using the methods of reference 22. For prediction of compressibility effects, the incompressible data was modified using Laitone's Rule.

Figure 9.1.1 Airplane Lift Curve: TO/Approach, M=.24, sea level

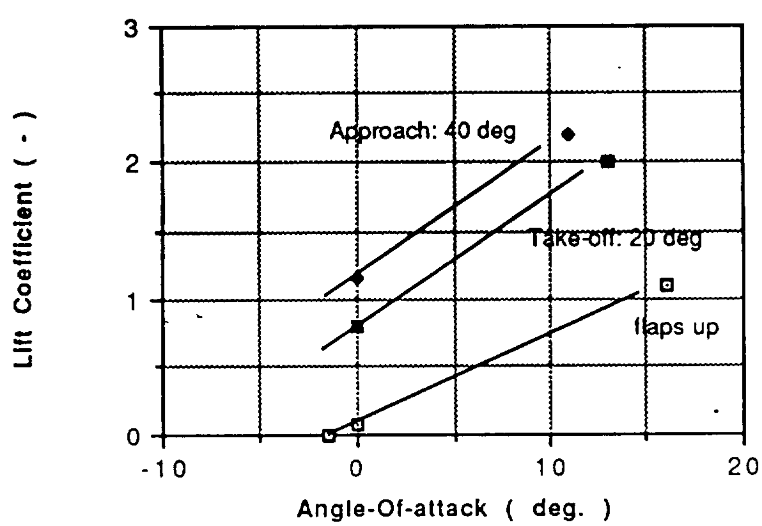
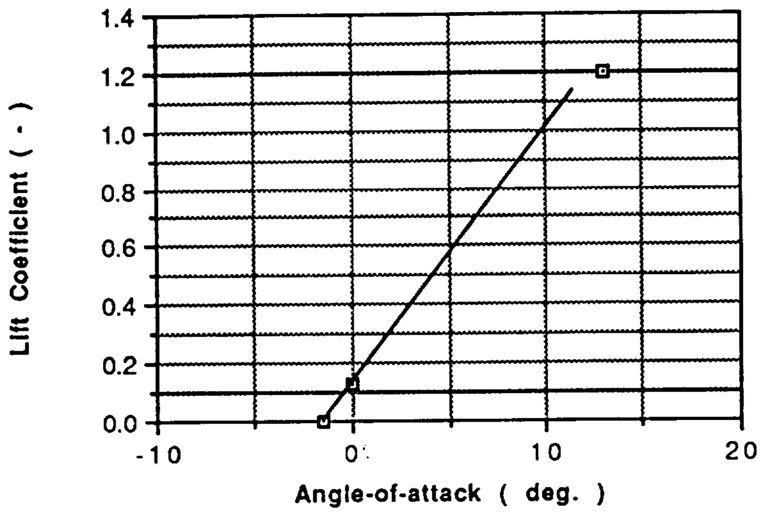


Figure 9.1.2 Airplane Lift Curve: Cruise, M=.76, sea level



9.2 Drag Analysis

Drag polars have been determined for the Manx for various flight regimes using the method of Reference 22. Parasite drag terms were based on the following wetted areas.

Table 9.2.1 Wetted Areas of Manx Components

Item	Wetted Area (sq. ft.)
Wing	916.8
Fuselage	674.7
Vertical Tails	120.1
Engines	183.1
Total	2018.8

The drag for each component of the Manx was determined for various flight regimes as seen in Figures 9.2.1- 9.2.4. Based on the performed profile drag calculations and the skin friction coefficient of the aircraft taken as .004, the Manx's equivalent flat plate area was computed to be 9.31 sq. ft. which places it among similar aircraft of this type and helps to confirm the validity of the drag polars presented. [6]

The influence of the canard vortices on the wing could not be accounted for with the methods used in the computation of the drag polars. Accurate prediction of the lift contributions due to vortex coupling must be determined using either a computational fluid dynamics code or wind tunnel testing.

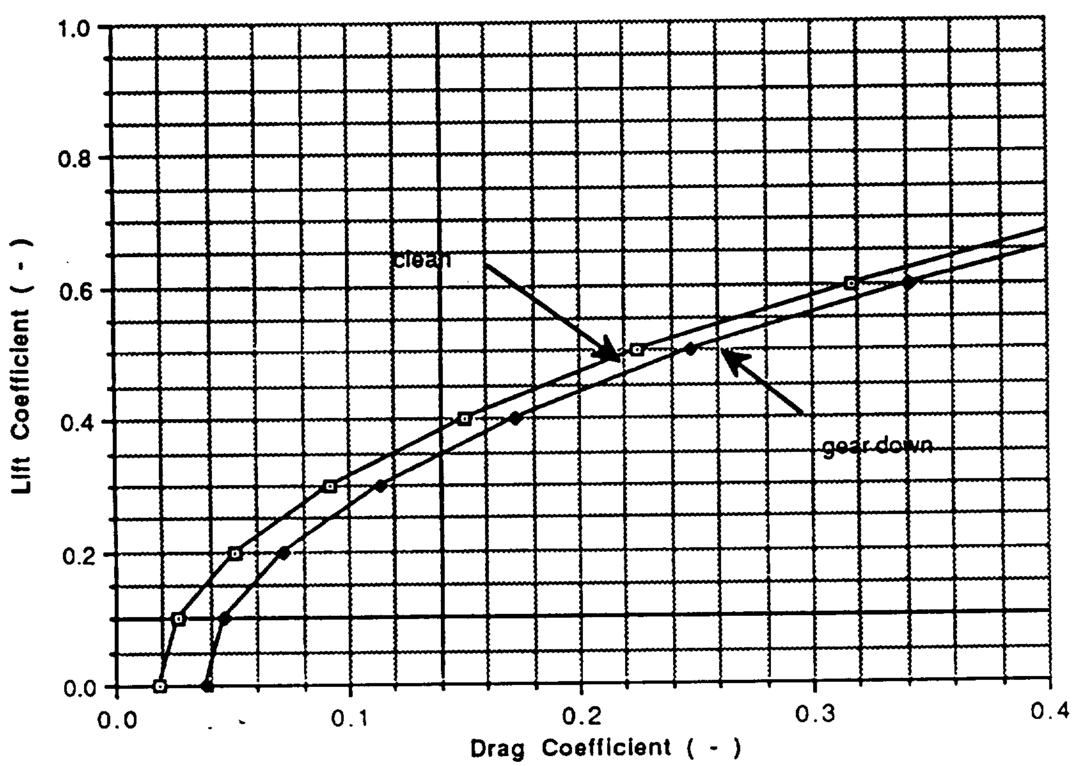


Figure 9.2.1 Drag Polar: Take-off, M=.24, sea level

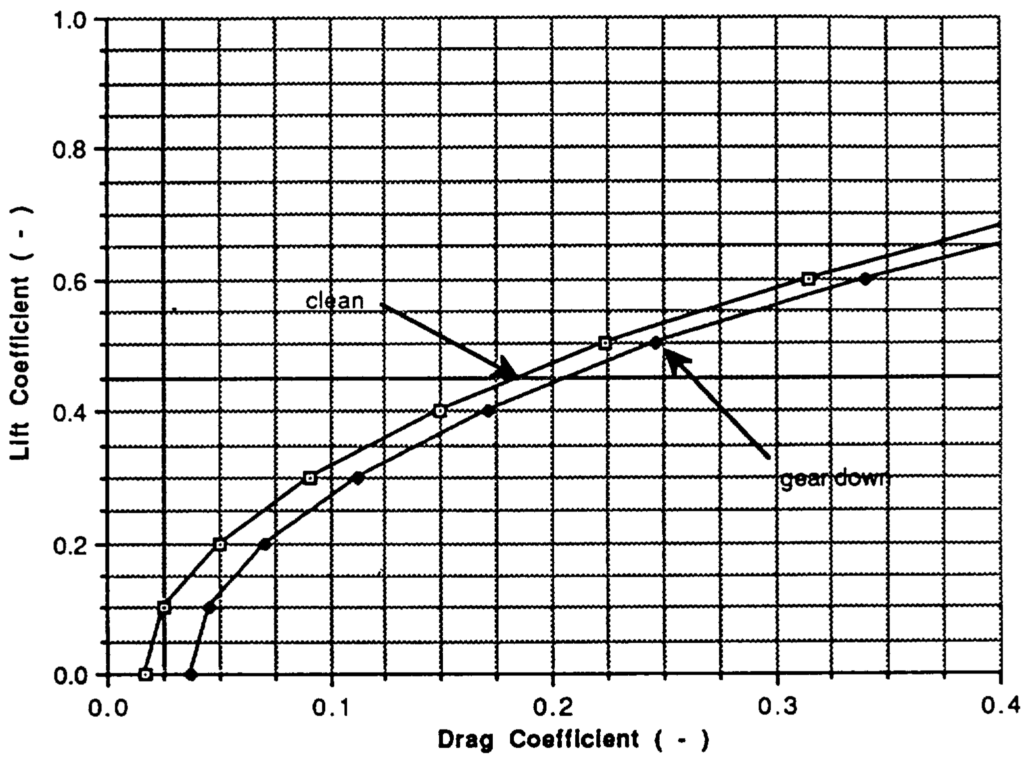


Figure 9.2.2 Drag Polar: Approach, M=.24, sea level

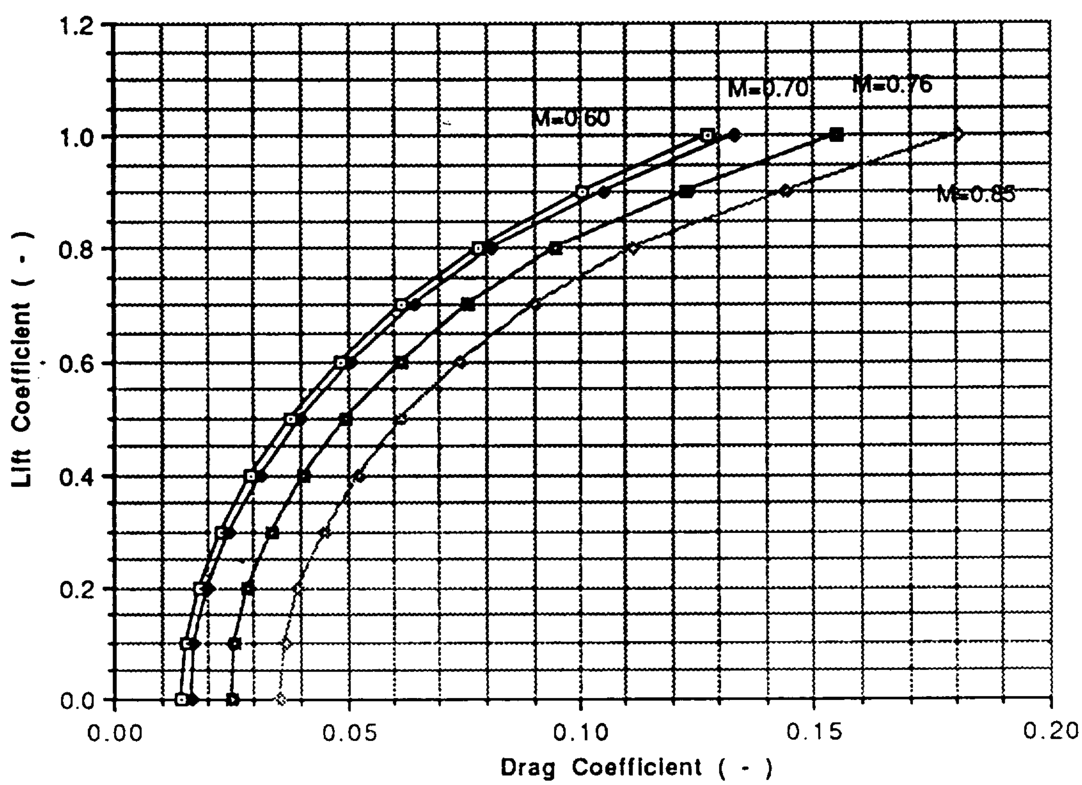


Figure 9.2.3 Drag Polar: Cruise, sea level

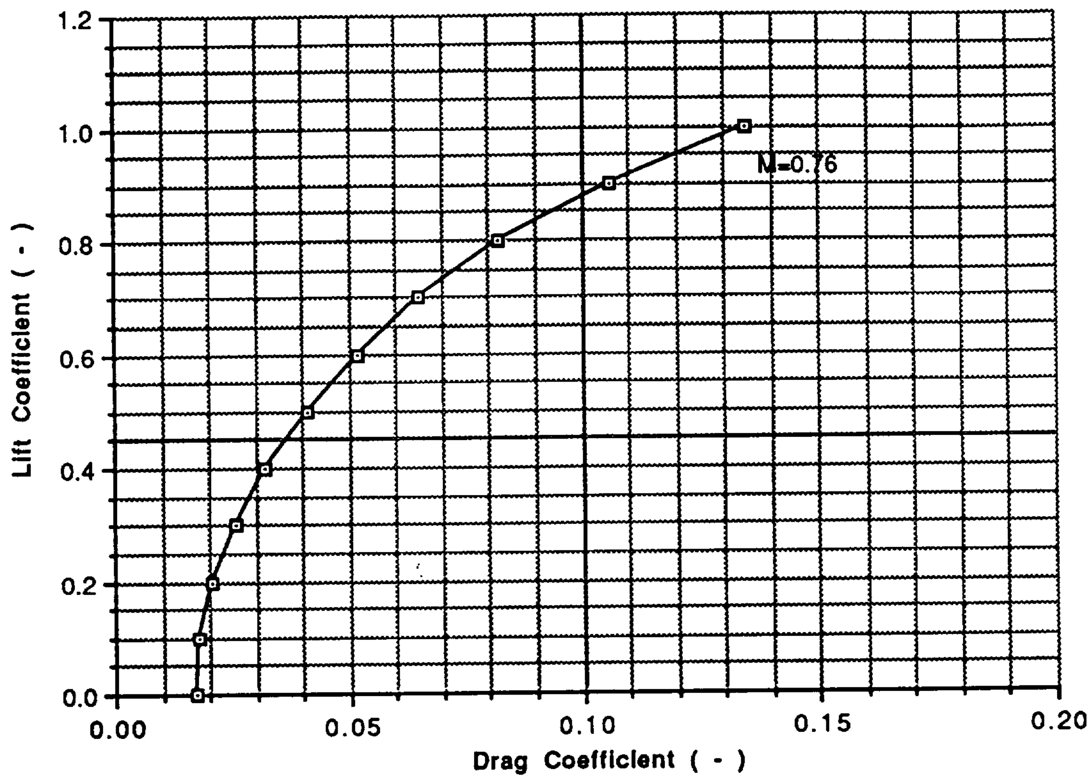


Figure 9.2.4 Drag Polar: Cruise, 20,000 ft.

10. STABILITY AND CONTROL

After conducting a preliminary longitudinal and directional static stability analysis an unstable static margin of -17.8 % was chosen for the Manx.

This level of instability will result in an aircraft that meets or exceeds the maneuverability characteristics of existing fighter aircraft. While having this capability may mean higher complexity and cost, this added maneuverability will enhance the aircraft's survivability as well as the plane's multi-role capability and could thereby eliminate the need for specialized aircraft. Furthermore, the Manx design team philosophy is designing for prevention rather than cure. Therefore, the capability to out maneuver ground-to-air ordinance and air-to-air interdiction is cost effective.

The Manx's relatively high level of instability requires the employment of a stability augmentation system (SAS). Although a more costly flight control system, the overall benefits it provides will outweigh the cost. The purpose of SAS is to take an aircraft which is difficult or impossible to fly, and enable the pilot to maneuver the aircraft to its fullest potential, while maintaining a low pilot work load. [12]

A list of the stability derivatives follows in Table 10.1

Table 10.1. Static Stability Derivatives

$C_{Y\delta_r}$	0.168 rad^{-1}
$C_{Y\beta_v}$	-0.393 rad^{-1}
$C_{n\delta_r}$	0.036 rad^{-1}
$C_{n\beta_v}$	0.084 rad^{-1}
$C_{n\beta_f}$	-0.074 rad^{-1}
$C_{n\beta_w}$	0.0 rad^{-1}
$C_{n\beta}$	0.024 rad^{-1}
$C_{m_{i_c}}$	0.445 rad^{-1}
$C_{L\alpha_c}$	4.17 rad^{-1}
$C_{L\alpha_{wf}}$	3.72 rad^{-1}
$C_{L\alpha}$	4.23 rad^{-1}

11. Avionics

The avionics system of the Manx increases its effectiveness to deliver close air support while at the same time being relatively simple thus decreasing pilot workload. It is assumed that the avionics will also be no more than 25% of the total airplane cost .

The avionics were selected based on research conducted on existing aircraft with similar mission capabilities [2]. It was determined that the Manx requires the following avionics systems:

- •Stability Augmentation System (SAS)
- •Navigation (GPS)
- •Terrain Following/Avoidance (Radar/IR)
- •Target Detection and Identification
- •Heads-up-display (HUD)

Due to the relaxed static stability of the Manx, a stability augmentation system (SAS) in conjunction with fly-by-wire technology will be required. Hard point accommodations will be provided for a ALQ-131 Electronics Counter Measure (ECM) Pod, FLIR Pod and Low Altitude Navigation and Targeting with Infrared at Night (LANTIRN) pod. These avionics packages fulfill Manx's navigation sensing requirements by providing night and adverse weather operational capability by means of a terrain following radar (TFR) and a wide angle forward looking infrared imaging system (FLIR) on a head-up display. The TFR and FLIR will also function to assist the Manx in effective target detection, identification, and ordinance delivery. The design mission is dominated by low level terrain, therefore a Global Positioning Satellite (GPS) navigation system will be integrated to enhance the accuracy of the weapon delivery and navigation. [33]

The following avionics components have also been included:

- •Flight Control System
    - - flight computer
    - - artificial horizon
    - - heading reference
    - - airspeed indicator

•UHF/VHF antenna

•IFF transponder

•Central Air Data System

The triple-redundant flight computer will be utilized with the fly-by-wire technology for signal transferring and multiplexing of the data. The air data system should be integrated into the flight control system so that the engines operate in the most efficient manner possible. A heads-up display (HUD) system will utilize a CRT to provide a real time presentation of TFR and FLIR information on range and angle tracking, real beam ground mapping, Doppler beam sharpening, and target detection.

All of the avionics will be selected with Built-In-Test (BIT) capability to reduce the maintenance and ground support requirements thus increasing its suitability for remote site operations. For a description of BIT functioning, refer to the Ground Support Requirements section of this report. [5]

12. FLIGHT CONTROL SYSTEMS LAYOUT

The flight control system primary flight control system layout can be found in Figure 12.1. The flight controls are irreversible. Signals are sent to the actuator controller from the digital flight control computer through shielded lines. The flight control computer is triple-redundant with second best information reversion. The signal paths are double-redundant with the secondary paths placed away from the primary paths for protection. There are two electrohydrostatic actuators for each control surface and the control surfaces are divided into at least two sections for redundance and safety.

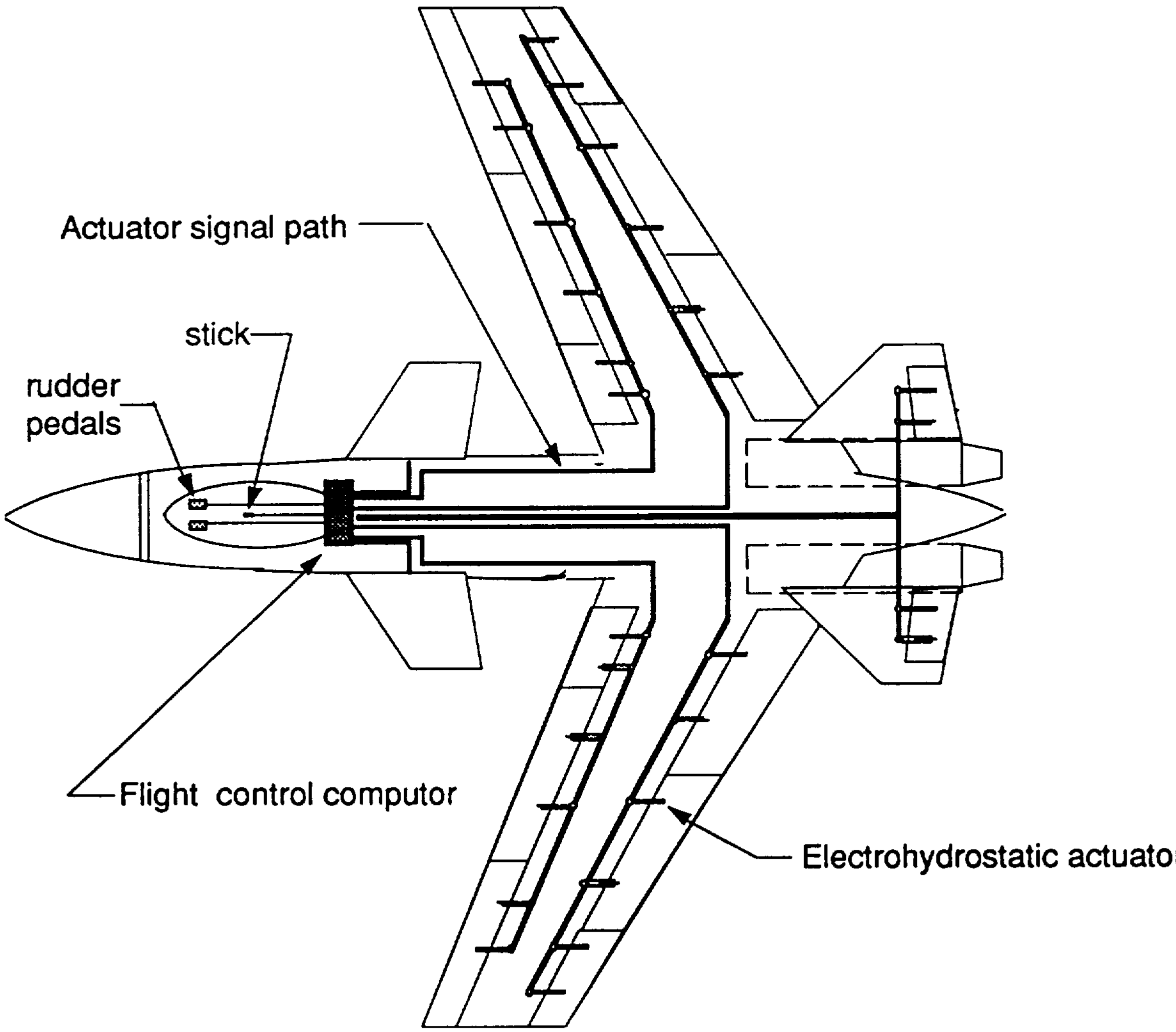


Figure 12.1 Flight Controls System Layout

13. WEAPONS INTEGRATION

The Manx has been designed primarily for the CAS mission. In this configuration the plane carries twenty 505 lb. Mk-82 bombs externally on four pylons. In addition, there are two AIM-9 Sidewinder, located at each wing tip. The four additional hard points are available on the Manx in order to accommodate additional missions and weapon integration. The weapon placement and configuration can be seen in Figure 13.1. [4]

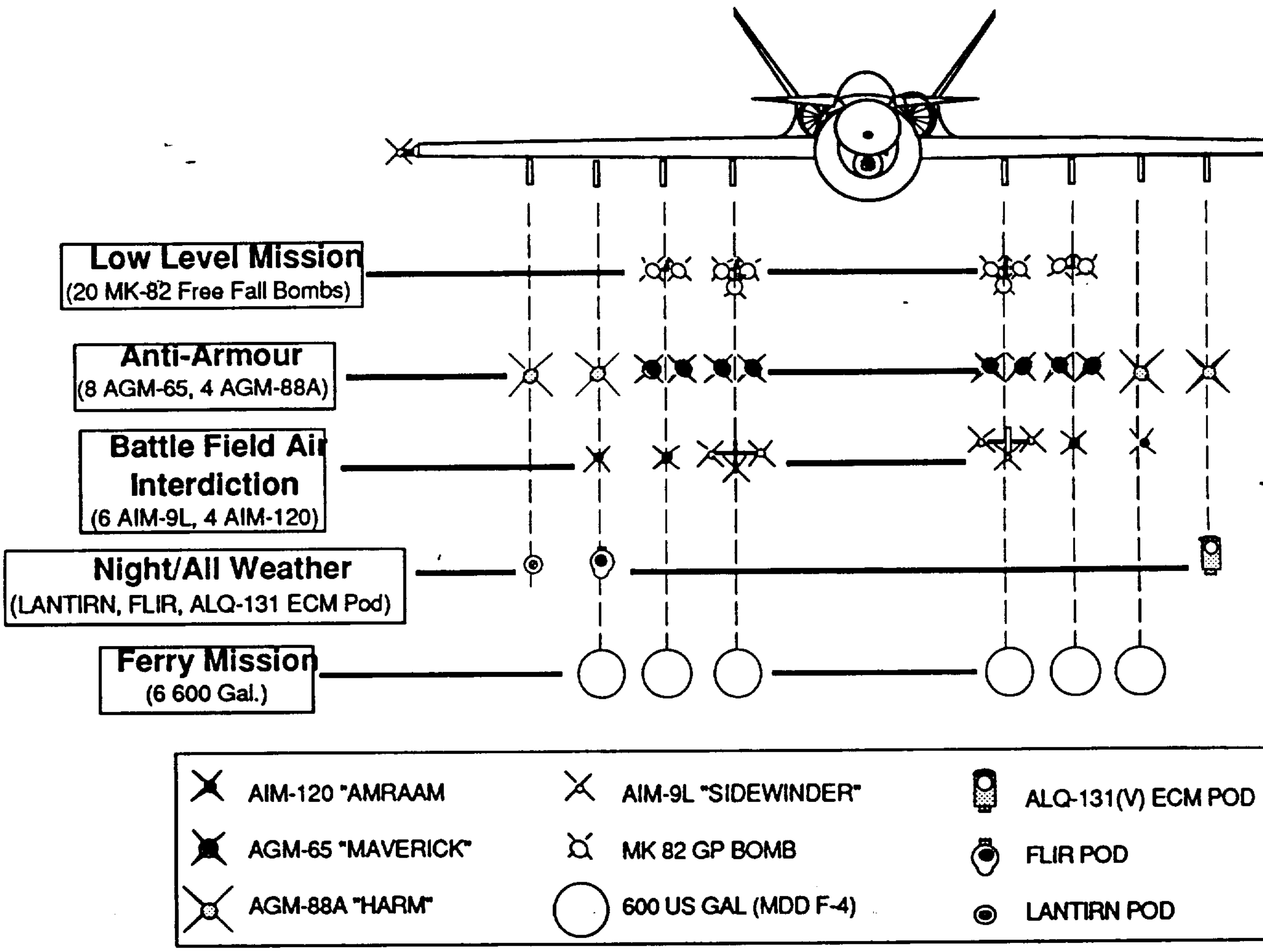


Figure 13.1 External Stores Arrangement

14. GROUND SUPPORT REQUIREMENTS

The Manx was designed for reduced maintenance requirements and increased reliability such that it could be utilized in remote site based operations. Consequently, minimal ground support requirements are necessary to achieve this capacity.

The capability of the Manx to perform various mission profiles requires it to be armed suitably and thus, the need for a weapon loading system is evident. For a high sortie rate and fast reattack time, a mobile refueling system is also necessary. The Manx possesses an Auxiliary Power Unit (APU) therefore, no external power supplies are necessary.

Inherent to the design of the Manx are built in features to assist in the reduction of its ground support requirements. These come in the form of an On Board Oxygen Generating System (OBOGS) and Jet Fuel Starting system (JFS) which eliminate the need for separate starters and oxygen replenishment. In addition, the Manx will carry self-sealing fuel lines, sealed batteries, and will utilize electrohydrostatic actuators for all primary flight controls surfaces. Other design features contributing to low maintenance include over wing engine placement for reduced susceptibility to FOD and a hydraulic system that will service only the landing gear for reduced chances of leakage. The lowered FOD susceptibility is crucial for remote site based operations where runways are difficult to maintain.

The ability of the Manx to provide effective close air support, however, relies heavily on its on board avionics technology. As a result, the importance that its avionics system be functioning properly with a high degree of reliability and low maintenance can not be too highly stressed. For these reasons, avionics systems will be selected with Built-In-Test (BIT) capability [5]. Avionics systems provided with BIT will utilize the BIT capabilities of the avionics equipment and multifunctional capabilities of the mission computer and CRT as the primary mechanisms. Consequently, no special monitoring, storage, or control equipment is required in providing:

- Complete operational readiness test capability without equipment test sets
- In-flight periodic BIT fault detection and automatic reversion to next best available data
- Initiated BIT fault isolation
- Complete functional test with repair verification capability

The BIT capability is a key feature in keeping the aircraft in the air with minimal ground support requirements so that its high sortie rate may be achieved.[5]

15. Life Cycle Cost Analysis

A life cycle cost analysis was performed for the Manx using the method in Reference 23 which spans the program from its initial stages of research, development, test, and evaluation to acquisition and manufacturing. This analysis also includes operation, support, and disposal costs with all costs expressed in 1992 dollars.

The research, development, test, and evaluation (RDTE) phase consists of aircraft's planning and conceptual design. It is during this phase that the aircraft's mission requirements research is conducted and preliminary design activities performed. Also during this phase, trade studies are performed to assess what combinations of technology are important to the aircraft's performance. The final leg of this phase consists of systems integration, detailed design, and prototype testing involving flight and structural testing. It was assumed that due to the nature of military contracts, the Manx will be a high security program and as such will have a slightly higher cost in this phase for security reasons. The RDTE cost was computed as being a function of airframe engineering and design costs, development support and testing cost, flight test and operations cost, test and simulation facilities cost, RDTE profit, and costs to finance the RDTE phase.

The programs acquisition costs include the manufacturers cost with a 10% profit margin for 500 aircraft. This cost is defined as arising from airframe engineering and design, airplane production, flight test operations, and the financing of the manufacturers program. During the programs duration, costs from operations arising from fuel, oil, and lubricants, aircrew, maintenance crews, and other associative direct and indirect personnel have been allotted for as well as spares, depots, and miscellaneous expenses. Finally, the disposal phase has been predicted assuming the life cycle of the aircraft will run 25 years.

Table 15.1 present a breakdown of these associative costs and the Manx unit cost. The calculated operational cost is $1549 per flight hour. Figure 15.2 shows a qualitative beakdown of how the life cycle cost is comprised.

Table 15.1 Life Cycle Cost Breakdown
(expressed in 1992 dollars for a 25 year span*)

RDTE Phase	
Airframe engineering and design	187.4
Development support and test	678.5
Flight test	2676.4
Flight test operations	14.9
Test and simulation facilities	524.9
Profit	262.5
Finance charges	262.5
Total RDTE Cost	4607.1

ACQUISITION PHASE	
Manufacturing	
Airframe engineering and design	433.9
Aircraft production	8043.9
Flight test operations	62.5
Program financing	360.6
Prototype	1041.2
Total Acquisition Cost (500 airplanes)	9942.1

MANX UNIT COST	**28.8**

*All values are in millions of dollars.

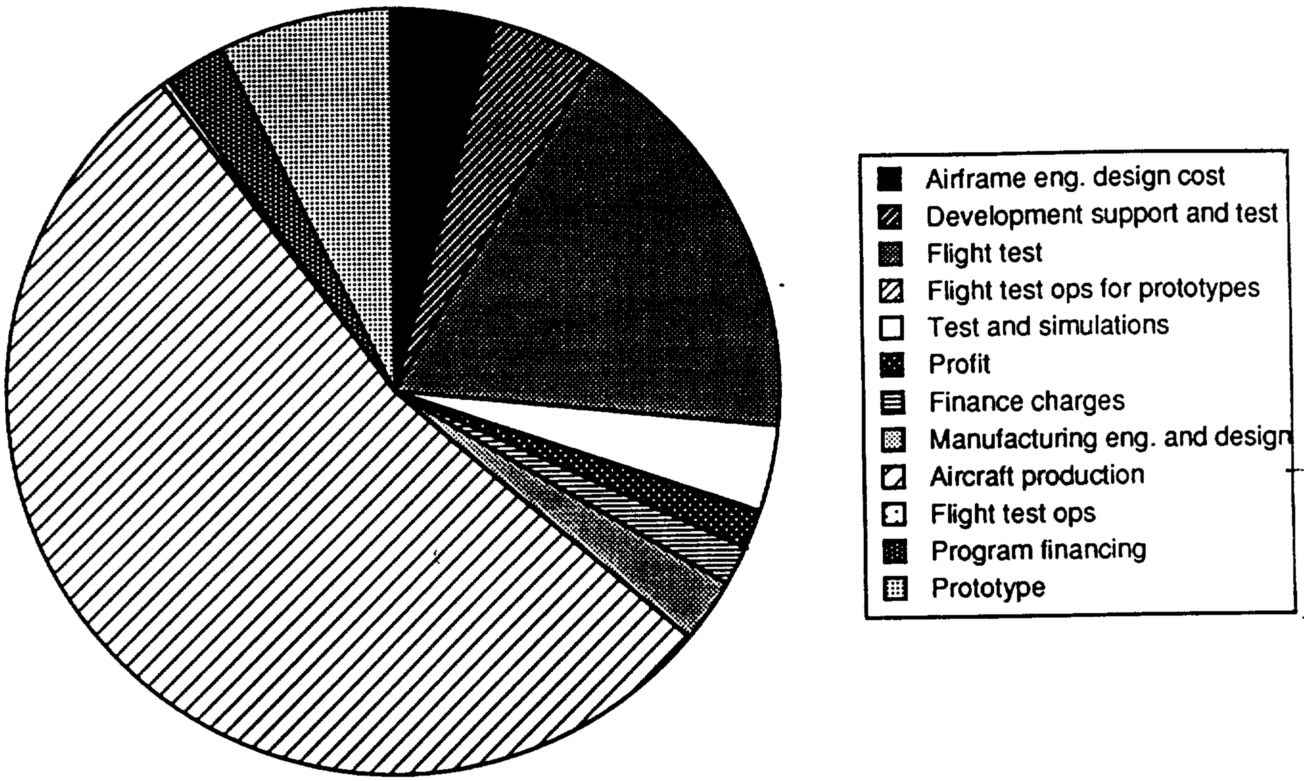


Figure 15.1: Life Cycle Cost Breakdown

16. Conclusions and Recommendations

The Manx is an advanced, high performance design capable of meeting the needs of a close air support fighter that will operate into the twenty first century. The design of the aircraft incorporates proven technologies giving it unmatched capabilities in maneuverability and survivability with relatively low maintenance requirements enhancing its suitability for the close air support role. The design is flexible allowing it to contribute to a truly integrated ground team capable of rapid deployment from forward sites making it highly attractive in the third world theatre, while increasing its chances of acceptance as a Navy based fighter.

The Manx has the capacity to outperform the aging Fairchild A-10. It can perform the close air support mission at higher speeds, carrying a greater payload, having lower take-off and landing distances, and excellent maneuvering qualities which enable it have a limited air-air interdiction capacity. In short, it has all of the necessary qualities to make it the obvious replacement aircraft.

With the completion of the preliminary design, there are still areas which require further research as listed below:

- Thrust vectoring capabilities
- Integration of HIDEC (Highly Integrated Digital Engine Control)
- Optimization of the engine for efficient high speed cruise
- Optimization of the flight computer
- Structural analysis of the composite structure of the wing

Further analysis in these areas is suggested to complete the design process for the Manx. Equipped with these additional capabilities, the Manx will be a formidable force to contend with in the twentieth century.

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