Design of the Little Goose Airplane

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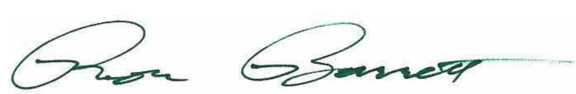

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List of Symbols

Symbol	Definition	Units
A	Altitude or Aspect Ratio	ft (m) or ---
AO_n	Ancillary objective n, where n is a positive integer value	---
C_d	Drag Coefficient	---
C_l	Lift Coefficient	---
D	Drag	lbf (N)
E	Endurance	hr
e	Oswald Efficiency Factor	---
BSFC	Brake Specific Fuel Consumption	lb/hp/hr (N/W/hr)
TSFC	Thrust Specific Fuel Consumption	lb/lb/hr (N/kg/hr)
L	Lift	lbf (N)
$M_{\&\&}$	Mission Fuel Fraction	---
$O_{!}$	Objective n, where n is a positive integer value	---
Q	Dynamic Pressure	slug/ft*s^2 (kg/m*s^2)
R	Range	nmi (m)
Rn	Requirement n, where n is a positive integer value	---
S	Distance or Surface Area	ft (m)
T	Thrust	lbf (N)
V	Velocity	ft/s (m/s) or ft^2 (m^2)
W	Weight	lb (N)

Greek Symbols

η	Efficiency	---
λ	Bypass Ratio	---
ρ	Density	slugs/ft^3 (kg/m^3)
μ	Coefficient	---

Subscripts

A	Initial Calculation	---
crew	Crew	---
cr	Cruise	---
div	Diverted	---
Fl	Field Length	---
fres	Fuel reserve	---
g	Ground	---
LG	Length of Ground	---
max	Maximum	---

ltr	Loiter	---
o	Initial	---
OE	Operational-Empty	---
p	Propellar	---
pl	Payload	---
SL	Stall	---
tent	Tentatively	---
to	Takeoff	---
tog	Takeoff ground	---
Toguess	Takeoff Estimate	---

Acronyms

ADA	Americans with Disabilities Act	---
AIAA	American Institute of Aeronautics and Astronautics	---
AO	Ancillary Objectives	
BSFC	Brake Specific Fuel Consumption	---
CONOP	Concept of Operation	---
CG	Center of Gravity	---
CGR	Climb Gradient	---
DL	Disk Loading	lbm/ft^2
FOD	Foreign Object Damage	---
HIGE	Hover in Ground Effect	---
HOGE	Hover Out of Ground Effect	---
HSVTOL	High-Speed Vertical Takeoff & Landing	---
MCP	Maximum Continuous Power	---
MEP	Mission Equipment Package	---
MMGW	Mid-Mission Gross Weight	---
MTOW	Maximum Takeoff Weight	---
MRP	Maximum Rated Power	---
MSL	Mean Sea Level	---
OF	Objective Function	---
RFP	Request for Proposal	---
ROA	Radius of Action	---
STAMPED	Statistical Time and Market Predictive Engineering Design	---
TSFC	Thrust Specific Fuel Consumption	---
VFS	Vertical Flight Society	---
VTOL	Vertical Takeoff and Landing	---

1 Introduction, Mission Specification and Profile

The New Efficient Water and Terrestrial (NEWT) Aircraft is a highly advanced and innovative aircraft designed for both water and land travel. This report aims to provide a comprehensive overview of the design and capabilities of the NEWT aircraft, its unique features and the potential benefits it brings to the aviation industry. The report will also highlight the current status and future prospects of the NEWT project.

The mission specifications and profile of the NEWT aircraft are designed to meet the demands of both water and land travel. It is capable of reaching speeds of up to 300 km/h, has a maximum range of 1,500 km and can carry up to 20 passengers. The aircraft features advanced aerodynamics and propulsion systems, allowing it to perform efficiently in both aerial and aquatic environments.

1.1 Mission Specification

The following section will cover the requirements for New Efficient Water and Terrestrial Aircrafts (NEWT). These requirements are split in the table below [1].

Table 1 :Mission Specifications of NEWT

Design Requirements	
Payload Mass	5,000 lb
Passenger Payload each passenger	193.6 lb
Mass of Crew Member Each	196.6 lb
Baggage weight per Passenger	37.4 lb
Number of Members (Crew)	1
Number of Passengers	19
Take off/Landing	HTOL
Performance Requirements	
Cruise Speed	≥200 kt
Short Take Off	At 5,000 ft
Takeoff and landing	Capable of taking off and landing from fresh and salt water
Takeoff Conditions	
Pressure	2,000 ft (609.6 m) Mean Sea Level (MSL) Pressure
Temperature	18 °F
Performance	From water (Sea)
Additional	As well as for dirt, grass, metal mat, gravel, asphalt & concrete fields

1.2 Mission Profile

For the NEWT the mission specifications and profile were given in New Efficient Water and Terrestrial (NEWT) Aircraft RFP (Ref. 1). The mission specifications listed in Table 2.1.1 can be found in Reference 1 under Section 2 and subsections 2.1 and 2.2. Additionally,

Figure 1.1 contains the general RFP requirements for the little goose Aircraft. [1]

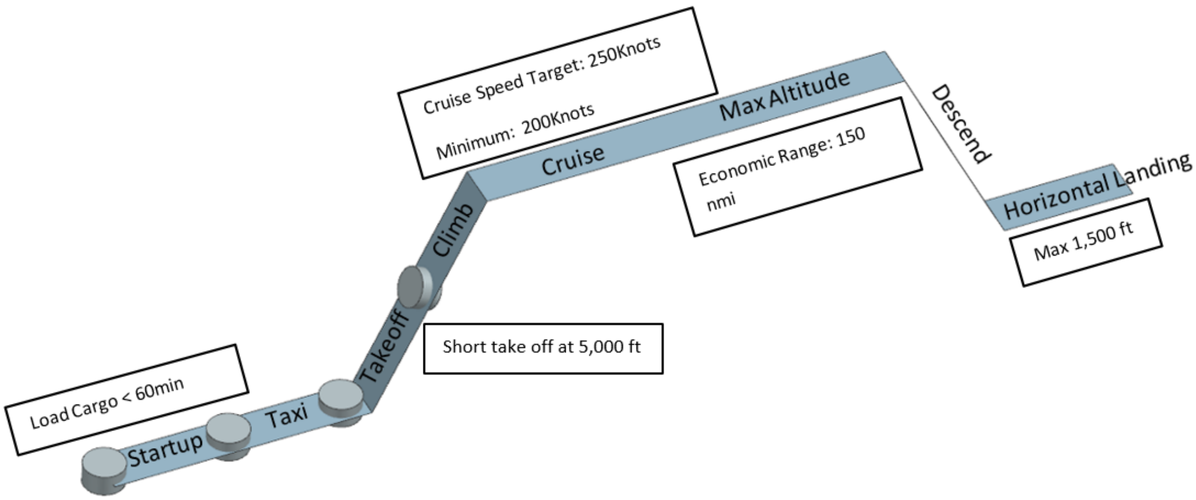


Figure 1-1 Mission Profile of NEWT

2 Chapter 2 Historical Review, Competition in the Market

provides an overview of the history of the market and the competition within it. This chapter examines the evolution of the market, highlighting key trends and developments that have shaped it over time. It also provides a comprehensive analysis of the competitive landscape, including the strengths and weaknesses of major players and market trends. The goal of this chapter is to provide a comprehensive understanding of the market and the competitive environment, which will be useful for developing effective strategies for success in the future.

2.1 Historical Review

The history of water and terrestrial (land) airplanes can be traced back to the late 19th and early 20th centuries.

The Wright Brothers, Orville and Wilbur, are credited with inventing the first successful airplane in 1903, which was a fixed-wing, powered aircraft. This marked the beginning of the aviation industry.

Meanwhile, the development of seaplanes (airplanes that can take off and land on water) began in the 1910s. The first successful seaplane was the French-built Hydroaeroplane in 1910, which was followed by the American Curtiss Model D. Seaplanes played a crucial role in naval operations during World War I and World War II, particularly for reconnaissance and patrol missions.

Over the years, both types of aircraft have advanced significantly. Land-based aircraft now feature advanced technologies such as turbofan and turboprop engines, fly-by-wire systems, and composite materials, making them faster, more fuel-efficient, and safer.

Similarly, seaplanes have also evolved, with the development of amphibious aircraft (airplanes that can operate both on water and land) and floatplanes (airplanes that are designed to land on water and are equipped with floats for buoyancy). Today, seaplanes are used for a variety of purposes, including tourism, transportation, and military operations.

Here is a list of some aircraft that are capable of taking off and landing from both fresh and salt water:

Table 2 Land-based aircraft

Grumman Gosse	DHC-3 Otter	Quest Kodiak 100	Beechcraft King Air
Cessna 208 Caravan	Pilatus PC-6 Porter	AW109	Bell 429
AS365 Dauphin	Robinson R44	Sikorsky S-76	AW139

there are other aircraft that have been designed for amphibious operations. These aircraft are equipped with floats or other features that allow them to take off and land on water.

Here is a list of some well-known amphibious aircraft:

Table 3 Amphibious Aircraft

Grumman Albatross	DHC-2 Beaver	Short SC.7	Beriev Be-200
Consolidated PBY Catalina	BN-2 Islander	Pierre Robin 100	EMB 120Brasilia
Airbus H135	Piaggio P.180 Avanti	Yakovlev Yak-40	HS-125

This list is not exhaustive, and there are many other amphibious aircraft that have been developed and used over the years. Some of these aircraft have been designed specifically for military operations, while others have been used for civilian purposes such as air ambulance, search and rescue, and passenger transportation.

2.2 Market Competition

2.2.1 The 19 Passenger Light Passenger/Commuter Market

There are two major types of aircraft that will be discussed in this section which are the turbo propellers and the turbojets.

2.2.1.1 Turboprop aircraft

The engine's turbine drives a propeller, providing efficient and reliable power for takeoff and cruise flight. Turboprop aircraft are commonly used for regional and short-haul flights, as well as military and utility purposes, due to their ability to operate in remote areas with rough runways. They are also known for their fuel efficiency and low operating costs compared to turbojet and turbofan aircraft.

The De Havilland Canada DHC-6 Twin Otter is a popular and versatile aircraft that has been used for a variety of purposes, including regional passenger transportation, cargo transport, and military and humanitarian operations. A total of 844 aircraft were delivered from 1965 to 1988 before they officially shut down.

Figure 2-2 DHC 6

Metro III/23 The Metro III/23 is a type of regional airliner produced by the US aerospace company, Fairchild Aircraft. It was introduced in the 1970s and is known for its reliability, versatility, and low operating costs. there was a total of 291 units sold.

Figure 2-1 Metro 23

Jetstream 32 They are popular for short-haul flights and known for their ease of handling, fuel efficiency, and low operating costs. The Metro III and Metro 23 are twin-engine turboprop aircraft, with a Aerospace Engineering Department C-7 seating capacity of up to 19 passengers. They are commonly used for regional passenger transportation, as well as corporate

Figure 2-2.3 JetStream 32

and utility transport. A total of 386 units were sold over the years. Beechcraft 1900D The Beechcraft 1900D is a popular twin-engine, turboprop regional airliner that was widely used for short-haul flights. The Beechcraft 1900 is a widely popular regional airliner, having achieved the title of bestselling 19-passenger aircraft in history with a total production number of 695 units. This remarkable feat showcases the airliner's immense popularity and widespread use in the aviation industry.

Figure 2-3 B 1900D

2.2.1.2 <u>Turbojet aircraft</u>

Turbojets are known for their high speed and altitude capabilities but are less fuel efficient and have higher operating costs compared to turbofan and turboprop engines. They are mainly used in military and supersonic aircraft applications where high performance is a priority.

Gulfstream G700 The Gulfstream G700 is a state-of-the-art, long-range business jet produced by Gulfstream Aerospace. It features advanced technology, including a spacious cabin, cutting-edge avionics, and a highly fuel-efficient engine. With its sleek design, advanced technology, and impressive range, the Gulfstream G700 is considered one of the best business jets on the market. Since it is a new aircraft only 12 units were sold.

Figure 2-4 G700

Figure 2-5 G600

Gulfstream G600 The G600 features advanced technology, including a spacious cabin, cutting-edge avionics, and a highly fuel-efficient engine. With its impressive range of up to 6,500 nautical miles and Aerospace Engineering Department C-8 top speed of Mach 0.925, the G600 is capable of connecting major cities around the world with ease. 55 units were sold. Global 7500 The Global 7500 is considered one of the best business jets on the market, providing a truly remarkable travel experience for its passengers, it is a long-range, ultra-luxury business jet produced by Bombardier Aviation (now known as Longview Aviation Capital). It features a spacious cabin, advanced technology, and a highly fuel-efficient engine. More than 50 units were sold.

Figure 2-6 G7500

2.2.2 Regional Aircraft Payload-Range Data and Operating Expenses

This section will present the payload-range diagrams of different small aircraft with less than 20 passengers.

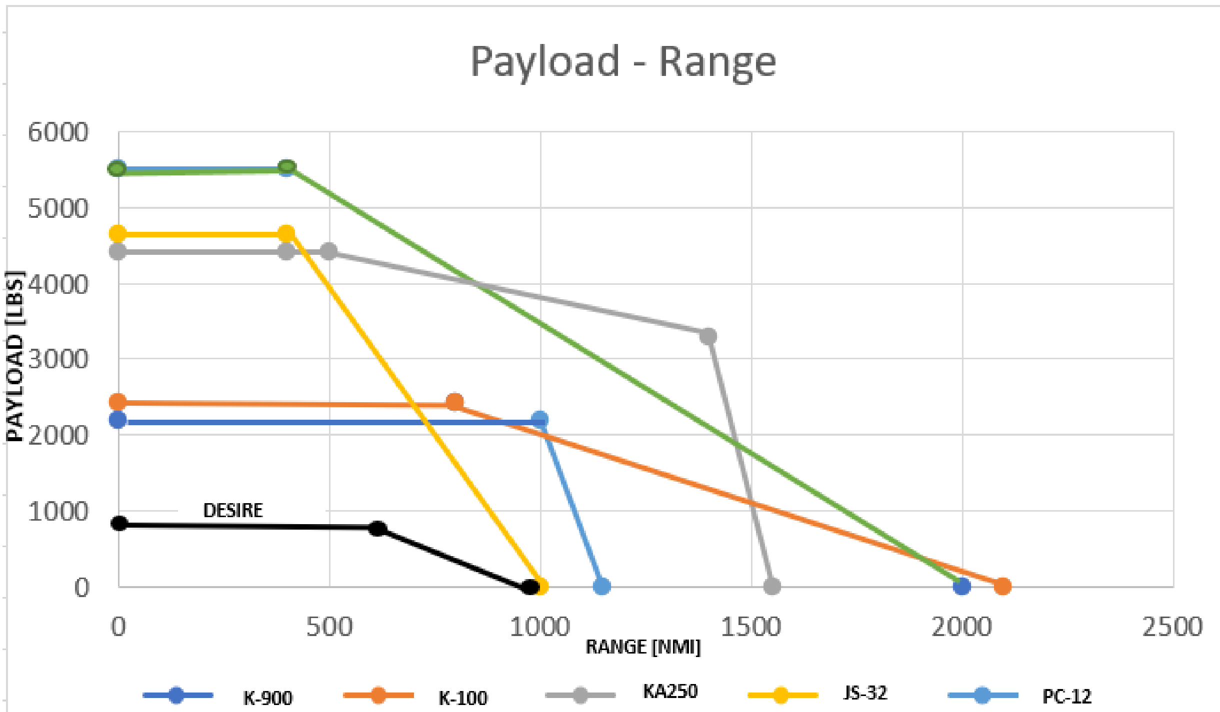


Figure 2-7 Payload vs Range Comparison

2.2.3 19 Passenger Regional Aircraft Fleet Operation Norms

Regional airlines typically utilize aircraft, such as regional jets and turboprops, with a seating capacity ranging from 19 to 130 passengers, for short to medium-distance flights.

At the beginning of 2020, the regional aviation fleet consisted of approximately 9300 aircraft, with the majority being regional turboprops with an average age of 23 years, and the rest being regional jets with an average age of 12 years. The number of passengers a regional airline can carry depends on the specific aircraft used by the airline. However, some regional airlines may operate aircraft that can accommodate 19 passengers or less, although this is relatively rare, and many regional airlines operate aircraft that can accommodate larger passenger capacities. The size of the aircraft and passenger capacity can vary depending on the specific needs of the airline and the regional market it serves.

The following are some of the regional airlines that use 19-passenger airplanes.

Aerocardal: Dornier 228

Alliance Air: Dornier 228

Continental Airlines: Beechcraft 1900D

Twin Jet: Beechcraft 1900D

Island Aviation: DHC-6-300 Twin Otters

Samoa Airways: DHC-6-300 Twin Otters

Nordic Seaplanes: DHC-6-300 Twin Otters

Sierra West Airlines: Metro III

Key Lime Air: Metro III

Paraclete Aviation: Short SC-7 Skyvan

Command Airways: Short SC-7 Skyvan

around the world there are a lot of different airlines that have in their fleets, floatplanes or amphibious airplanes, but these have few units, this is because most amphibious airplanes are used for fun and in strategic places, some countries with large coastlines, such as the United States, Canada, Australia, and Russia, may have a higher demand for amphibious aircrafts due to their need for access to coastal and island communities.

The percentage of airplanes that are amphibious is very small compared to the total number of aircraft in operation, it’s difficult to determine the exact percentage of amphibious aircraft in operation, but it's likely to be less than 1% of the total number of aircraft.

3 Objectives, Requirements and Design Optimization Function

From reference 1 as objectives and will now be used to determine the most important factors in the aircraft design. The objective function will be used as a tool to compare different design options and make decisions on which design is best suited to meet the requirements and objectives stated in the RFP, as well as any additional relevant objectives identified by the author.

3.1 Requirement

The requirement specifications listed as R1, R2, ..., Rn are found in Reference 1 and can be viewed in Section 2.1 Table 2.1.1. It is important to note that some requirements have restrictions or limitations outlined. To fully understand these requirements, it may be helpful to refer to Table 2.1.1 while reading the requirements listed in this section. The cargo dimensions must be precisely as specified and cannot be smaller. This is because the RFP in Reference 1 does not specify whether smaller dimensions are allowed. The following are the requirements taken from Reference 1, along with their corresponding values.

Requirement Number	Requirement	Values
R_1	>200 Knots	$R_1 = \begin{cases} 1\ if\ R > 200 Knots \\ 0\ if\ R \leq 200 Knots \end{cases}$
R_2	≥200 nmi	$R_2 = \begin{cases} 1\ if\ R \geq 200\ nmi \\ 0\ if\ R \leq 200\ nmi \end{cases}$
R_3	≥ 5,000 lb.	$R_3 = \begin{cases} 1\ if\ R > 5{,}000\ lb \\ 0\ if\ R \leq 5{,}000\ lb \end{cases}$
R_4	=19 Passenger	$R_4 = \begin{cases} 1\ if\ R = 19\ pass \\ 0\ if\ R \neq 19\ pass \end{cases}$
R_5	≥150 nmi economic mission	$R_5 = \begin{cases} 1\ if\ R > 150\ nmi \\ 0\ if\ R \leq 150\ min \end{cases}$
R_6	Crew = 1	$R_{6=} \begin{cases} 1\ if\ R = 1 \\ 0\ if\ R \neq 1 \end{cases}$
R_7	VR capability	$R_{7=} \begin{cases} 1\ if\ R = Yes \\ 0\ if\ R = No \end{cases}$

R_8	Passenger Weight $\leq$ 3,678 lb.	$R_8 = \begin{cases} 1\ if\ R \leq 3{,}678\ lb \\ 0\ if\ R \geq 3{,}678\ lb \end{cases}$
R_9	Baggage Weight $\leq$ 710 lb.	$R_9 = \begin{cases} 1\ if\ R \leq\ 710\ lb \\ 0\ if\ R \geq 710\ lb \end{cases}$
R_{10}	IFR capability	$R_{10} = \left\{\begin{cases} 1\ if\ R = Yes \\ 0\ if\ R = No \end{cases}\right.$

3.2 Objectives

The objectives listed as O1, O2, ..., On are not explicitly stated in Reference 1. However, it was assumed that exceeding the minimum requirement would be considered an objective. although these are not directly stated as requirements. These aspects are therefore considered as objectives in this report.

Objective Number	Objective	Values
O_1	Cruise speed >250 knots	$O_1 = \begin{cases} 1\ if\ > 250\text{ knots} \\ \frac{W_{pl}-250}{200}\ if\ Cruise < 250\ Knots \end{cases}$
O_2	Energy Cost $\leq$ 80%	$O_2 = \begin{cases} 1\ if\ Energy \leq\ 80\% \\ \frac{Ec-80\%}{80\%}\ if\ Energy > 80\% \end{cases}$
O_3	Inspection time <60min.	$O_3 = \begin{cases} 1\ if\text{ Inspection time} < 60\text{min.} \\ \frac{Inspection\ time-60min}{60min}\ if\ Seat\ pitch \leq 28in \end{cases}$
O_4	Max take off $\leq$ 1,900 ft	$O_4 = \begin{cases} 1\ if\text{ take off } \leq 1{,}900\text{ft} \\ \frac{take\ off-1{,}900}{1{,}900} > \ if\ not \end{cases}$

3.3 Ancillary Objectives

These ancillary objectives were deemed significant by the author and are focused on in the RFP. The five proposed objectives include ADA compliance for the crew, reduced inspection time between flights, reduced engine noise, reduced payload loading time, and implementation of redundancy systems. Compliance with ADA allows for a wider pool of potential crew members. The decrease in inspection time increases the aircraft's maintainability and allows for quick identification of any issues. Reducing engine noise protects the health of the crew. A faster payload loading process improves the aircraft's efficiency. Implementing redundancy systems enhances safety.

Most of these supplementary objectives have a value of either 1 or 0, but future research may use a linear scale after further analysis has been conducted in each category. The following are the ancillary objectives and their corresponding values.

Ancillary Number	Ancillary Objective	Values
AO_1	ADA compliant	$AO_1 = \begin{cases} 1\ if\ ADA\ compliant \\ 0\ if\ not\ ADA\ compliant \end{cases}$
AO_2	Max View Angle > 15°	$AO_2 = \begin{cases} 1\ if\ \text{View Angle} > 15° \\ 0\ if\ not\ \text{View Angle} > 15° \end{cases}$
AO_3	Low Operating cost	$Ao_3 = \begin{cases} 1\ if\ Low\ Operating\ Cost \\ 0\ if\ not\ Low\ Operating\ Cost \end{cases}$
AO_4	Stage Five Noise	$Ao_4 = \begin{cases} 1\ if\ Stage\ Five\ Noise \\ 0\ if\ not\ Stage\ Five\ Noise \end{cases}$
AO_5	Load Payload$\leq 1\ hr$	$Ao_5 = \begin{cases} 1\ if\ AO \leq 1 \\ 0\ if\ AO \geq 0 \end{cases}$
AO_6	Interoperability	$Ao_4 = \begin{cases} 1\ if\ Interoperability \\ 0\ if\ not\ Interoperability \end{cases}$

4 Statical Timer and Market Predictive Engineering Design (STAMPED) Analysis

In this section, we will introduce the method of Statistical Time and Market Predictive Engineering Design (STAMPED) analysis, which is a tool designed to forecast future product characteristics based on the historical and evolving trends of the characteristics being predicted. The STAMPED techniques enable accurate forecasting of any engineering design variable at any given time. The primary objectives of the STAMPED analysis are to establish the development timeline of a product, which allows for correlating significant project milestones, such as project initiation and initial operational capability (IOC) dates, with the product's market dominance based on its evolving characteristics. Additionally, the STAMPED analysis assesses the impact of the variability in design parameters on the product's market share.

4.1 Empty Weight to Takeoff Weight Ratio Market Analysis

The empty weight to takeoff weight ratio of a 19-passenger propeller airplane can vary depending on the specific model and design of the aircraft. However, as a general guideline, the empty weight of a typical 19 passenger propeller airplane can range from around 4,000 to 10,000 pounds, while the takeoff weight can range from around 10,000 to 25,000 pounds.

Therefore, the empty weight to takeoff weight ratio for such an airplane can range from around 0.16 to 0.4. However, it's important to note that these are just approximate values and the actual empty weight to takeoff weight ratio can vary based on a variety of factors, such as the design of the aircraft, the materials used in construction, and the intended use of the airplane.

Below a plot of similar airplanes W_e/W_{to}.

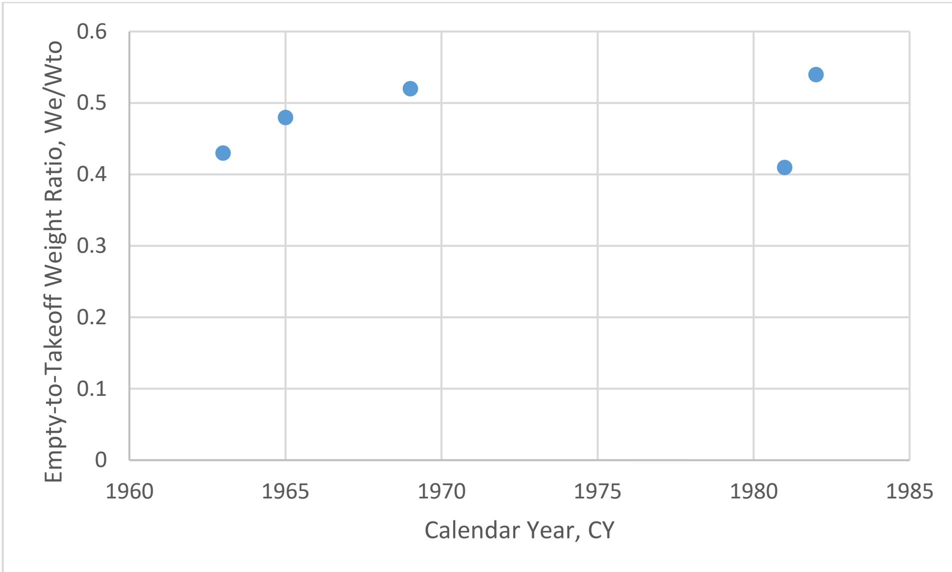


Figure 4-1 We/Wto Ratio Through Time

5 Weight Sizing

5.1 Weight Sizing Code Generation

In this chapter the author will discuss the following parameters:

- We
- Wto
- Wpl
- Geometries
    - Wing Area (S)
    - Aspect Ratio (AR)
- Mission Fuel Weight (Mf)

5.2 Weight Sizing Code for Fuel Burn and Iteration of We, Wf, and Wto

To determine the weight of the aircraft the following steps were followed per Reference guidance. First the sum of the payload (WPR) and crew (Wcrew) weight was found which both are given in Section 2.1 in Table 2.1.1 yielding 5750 lb. Next a guess was made that the takeoff weight (Wtoguess) was 18150 lb which was in the previous tables showing most aircraft analyzed congregated around this region. The third step is to determine the weight of the fuel (Wf) which relies on knowing the fuel burned during each step of the mission profile. Figure 2.2.1 in Section 2.2 shows the mission profile, and it should be noted that there is no specified loiter sections and two cruise sections. For climb the value of 0.96 was used however, Reference 5 gives the range 0.96 to 0.9 so more research may be needed to validate whether this value is the most appropriate to select. Additionally, it was considered by the author that mission phases which give an allotted time could be treated as loitering and an endurance Equation could be used to find the fuel burn value. This calculation was shown in Appendix A and it was found that these values were very close to the values given in Reference.

Table 4 Engine Fuel Fraction

W_{i+1}/W_i	**Segment**	**Fuel Fraction**
W_2/W_1	Engine warm	**0.995**
W_3/W_2	Take off	**0.99**
W_4/W_3	Climb	**0.98**
W_5/W_4	Cruise	**0.88**
W_6/W_5	Descent	**0.98**
W_7/W_6	Landing	**0.99**
M_{ff}	Mission Fuel Fraction	**0.87**

`

The table above was produced using the average empty weight to take-off shown previously.

Take-off weight is comprised of payload, fuel weights (for a specific range at a specific payload).

5.3 Weight Estimations

Average values were obtained to estimate weight of aircraft components. Finally, preliminary weights of the wing and empennage were obtained using stress analysis to increase accuracy of the estimation. The following tables show weight breakdown for the given design. Weights obtained from structural analysis show close similarity compared to statistical values.

Table 5 General Weight Data

	Weight (lb)
Max Take off Weight	22000
Max Landing Weight	21000
Empty Weight	11500
Fuel Weight	5600
Payload Weight	5000
Crew Weight	384

Table 6 Empty Weight Breakdown

Component	Weight %	Weight lb
Wing	20.15	2317.25
Horizontal Tale	2.85	327.75
Vertical Tale	1.26	144.9
Fuselage	28.98	3332.7
Landing Gear	4.72	542.8
Engine	15.86	1823.9
Fuel System	0.94	108.1
Avionics	9.51	1093.65
Flight Control System	3.18	365.7
Hydraulics	0.19	21.85
Electrical	4.23	486.45
Furnishing	8.13	934.95
Total	1	11500

6 Wing and Powerplant Sizing

Wing and powerplant sizing are critical aspects of aircraft design that must be carefully balanced to ensure optimal performance and safety. The size of the wings determines the amount of lift generated, which must be sufficient to support the weight of the aircraft during takeoff and flight. The powerplant must be sized to provide enough thrust to overcome drag and achieve the desired speed and altitude. Factors such as the intended use of the aircraft, environmental conditions, and regulatory requirements must all be taken into account when determining the optimal wing and powerplant sizing. Additionally, advancements in technology and materials can allow for more efficient and effective wing and powerplant designs, leading to improved performance and fuel efficiency.

6.1 Takeoff and Landing Sizing

Performance analysis is a critical aspect of aircraft design, as it helps to determine the capabilities and limitations of the aircraft in different operating conditions. For the current proposal, several cases are being considered to assess the performance of the aircraft in various mission scenarios.

The first case involves a short takeoff and landing (STOL) runway mission of 250 nautical miles with 20 passengers. The takeoff and landing will be performed from the ground at sea level and 5000ft at ISA +18oF. The performance will be evaluated for different runway profiles, which can affect the aircraft's takeoff and landing distances and other performance metrics.

The second case involves a similar STOL mission, but with takeoff and landing from water instead of the ground. Again, the mission is 250 nautical miles with 20 passengers, and the takeoff and landing will be performed at sea level and 5000ft at ISA +18oF. This case will help to assess the aircraft's performance in water-based operations, which can present different challenges and opportunities compared to ground-based operations.

The third case involves a longer 1000 nautical mile mission with the maximum amount of passengers. The takeoff and landing will be performed both on the ground and on water at sea level and 5000ft at ISA +18oF. This case will provide insights into the aircraft's performance over longer distances and with a higher passenger load.

Finally, a 500 nautical mile cargo mission with takeoff and landing on both ground and water at sea level and 5000ft at ISA +18oF will be analyzed. This case will evaluate the aircraft's cargo-carrying capabilities and its ability to operate in a variety of environments and conditions.

Throughout these cases, a payload-range relationship will be discussed, which helps to determine the optimal payload and range for the aircraft in different mission scenarios. Overall, the performance analysis will provide important insights into the capabilities and limitations of the proposed aircraft design and help to inform key design decisions.

Climb and Ceiling Sizing

6.2 Take off and Landing

Short take-off and landing (STOL) operations are characterized by the need to take off and land in confined spaces or on short runways. This requires an aircraft with specific design features and capabilities.

One of the key requirements for STOL operations is the lowest possible aircraft weight. This is because the lighter the aircraft, the less runway distance is required for takeoff and landing. To achieve this, the design must make use of lightweight materials, such as composites, and minimize the weight of all components, including the structure, systems, and furnishings.

Strong aerodynamic characteristics are also critical for STOL operations. This means that the aircraft must be designed to provide the necessary lift at low speeds, as well as to maintain stability and control during takeoff and landing. This can be achieved through the use of high-lift devices, such as flaps and slats, and careful attention to the aircraft's overall aerodynamic design.

Take-off			Landing		
	Requirement	Speed (KCAS)		Requirement	Speed (KCAS)
V_{SR}	$V_{SR} > V_{CLMAX}$	67	V_{SR}	$V_{SR} > V_{CLMAX}$	60.0
V_{MC}	$V_{MC} > 1.3V_{SR}$	72.0	V_{FLR}	$V_{MC} > 1.3V_{SR}$	75.0
V_R	$V_{MR} > 1.05V_{SR}$	75.0	V_{TD}	$V_{MR} > 1.05V_{SR}$	68.0
V_{LOF}	$V_{LOF} = 1.1V_{SR}$	78.0	V_{BR}	$V_{LOF} = 1.1V_{SR}$	65.0

Figure 2 Speed requirements and Values

6.3 L/D

Since these aircraft are propellers, the values needed to solve for L/D in cruise is the thrust specific fuel consumption (cj) and mission fuel fraction (Mff). The other values which will be in the mission profile given in the initial RFP (Ref. 1). The thrust specific fuel consumption was easily found by noting what engine each aircraft used and then looking up the manufacturer's claimed cj values. The following Table concisely summarizes the found values.

To solve for the mission fuel fraction the following equations below can be used. Note that the weight (W) of the maximum takeoff weight (MTOW) must be subtracted from the passengers ferried (ferry pax) to get the takeoff weight (Wto).

$$M_{ff} = \frac{W_{to} - W_f}{W_{to}}$$

Using the previous equations listed above the mission fuel fraction can be calculated and tabulated in the Table below.

Table 7 Mission Fuel Fraction Results

Aircraft	$W_{MTOW}(lbf)$	$W_{ferry}(lbf)$	$W_f(lbf)$	M_{ff}
KA 250	110,500	12,500	13,420	0.698

PC 12	105,000	13,000	14,000	0.679
Kodiak 100	180,200	15,200	15,630	0.680

6.4 Market Leader Performance Estimation

These aircraft are used for various purposes such as leisure, tourism, rescue operations, and military applications. Key players in this market include companies such as ICON Aircraft, Seabird Aviation, and Waco Classic Aircraft. The market demand for amphibian aircraft is influenced by factors such as the growth of tourism and the increase in demand for utility and multirole aircraft.

7 Design Philosophy and Configuration Constraint Establishment

The design philosophy provides the guiding principles for the design process, while the establishment of configuration constraints helps to ensure that the design is feasible and practical within the given limitations and restrictions. Both are critical elements of the design process and should be considered simultaneously to ensure that the final product or system meets the desired objectives.

7.1 Motto

The author wants to highlight the aircraft's ability to reach new and exciting destinations, both near the coast and further inland.

"Connecting the Coast and Beyond"

7.2 Design Philosophy

'Our airplane is designed to operate effectively in both water and land environments, with features that allow for easy transition between the two. It is designed to operate efficiently, both in terms of fuel consumption and operational costs, to provide cost-

effective transportation options for regional routes, providing access to a wider range of destinations and opportunities for regional travel.'

By emphasizing these key design principles, the regional amphibious aircraft can deliver a high-quality, cost-effective, and versatile transportation option for regional travel, providing comfort and reliability for its passengers and efficiency and versatility for its operators.

8 Candidate Configuration Matrix Establishment

The RFP from the VFS (as outlined in Reference 1) features several design configurations that have already been proposed. Many of the chosen designs were directly taken from the aforementioned reference. Some other designs were selected by the author based on notable regional prop vehicles that meet the requirements specified in the RFP. The remaining designs not listed in Reference 1 were inspired by historic aircraft with documented high-performance records.

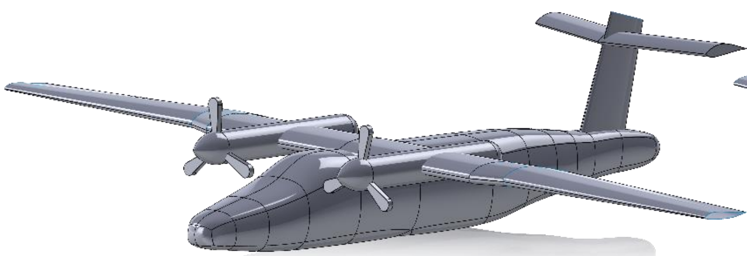


Figure 8-2 Design I

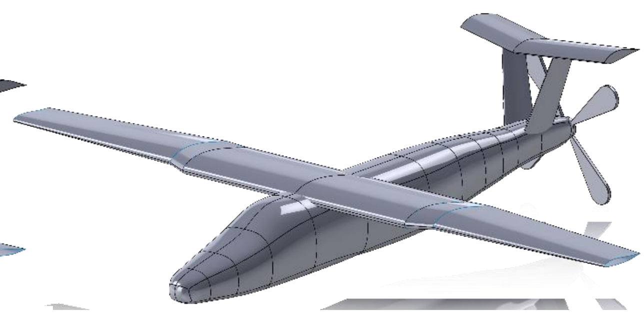


Figure 8-1 Design II

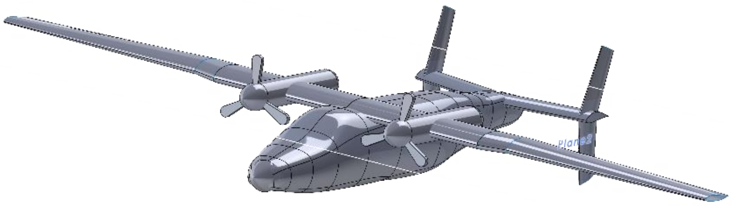


Figure 8-4 Design III

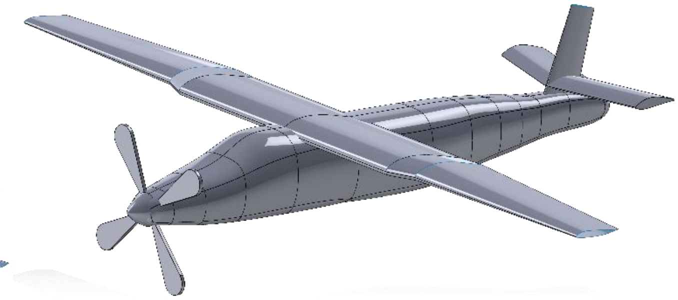


Figure 8-3 Design IV

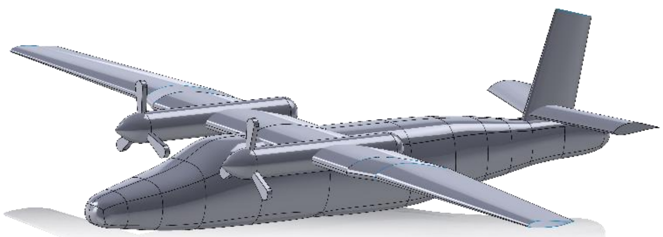


Figure 8-6 Design V

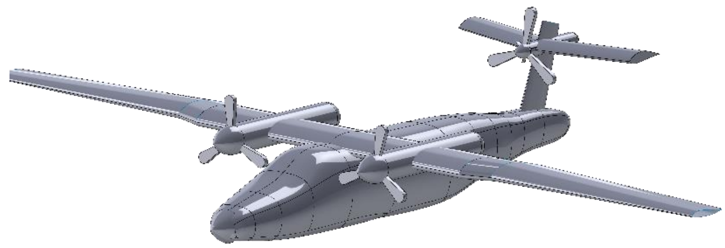


Figure 8-5 Design VI

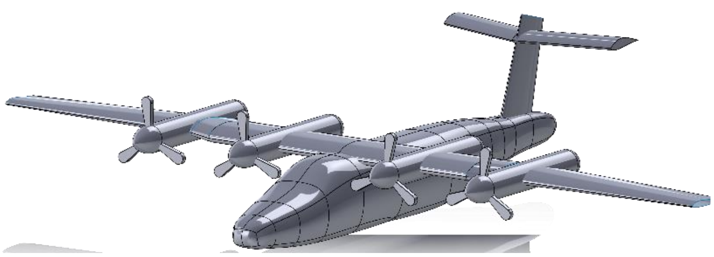


Figure 8-8 Design VII

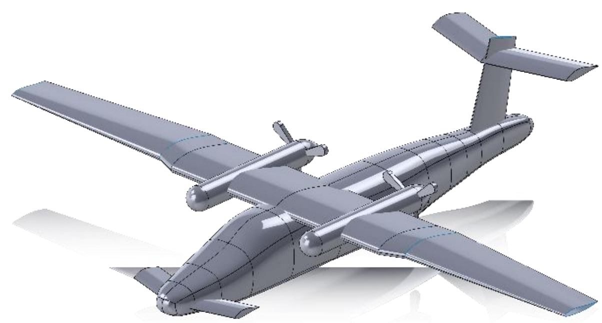
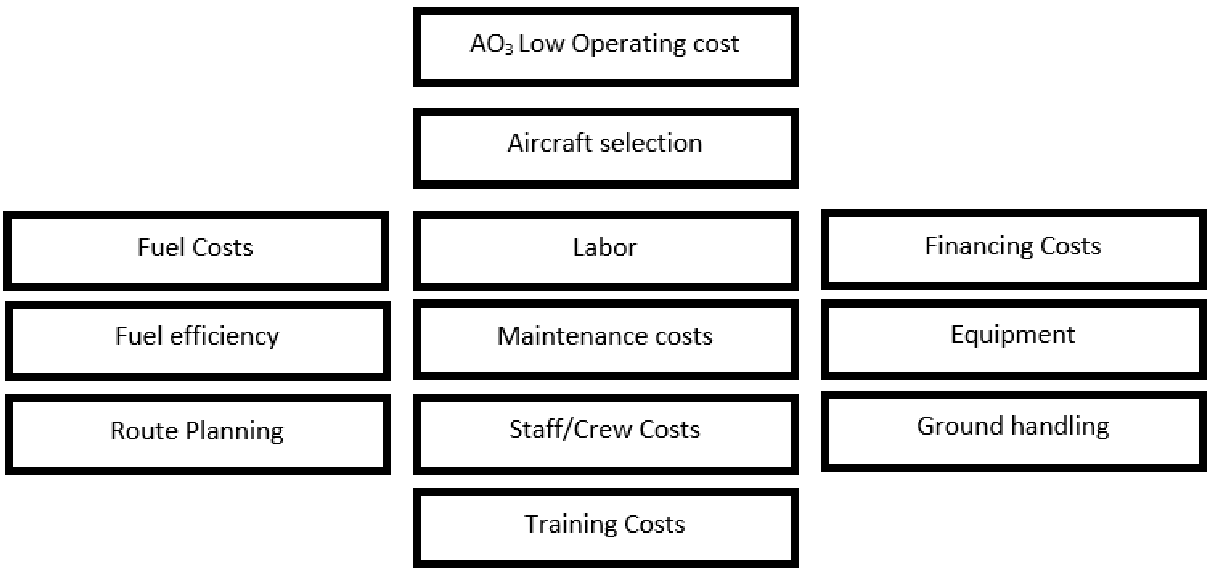


Figure 8-7 Design VIII

9 Application of Optimization Function and Requirements Flowdown Charts to Configurations and Downselection

A low operating cost for a regional aircraft is achieved by selecting an efficient and cost-effective aircraft model, optimizing operations and maintenance procedures, and reducing unnecessary costs wherever possible.

Table 8 Ao3 Low Operating Cost



Achieving ADA compliance for a regional aircraft requires designing the cabin and procedures with accessibility in mind, providing accommodations for passengers with disabilities, and ensuring that crew members are trained to provide assistance as needed.

Table 9 Ao1 ADA Compliant

	AO_1 ADA Compliant	
Aircraft Design	Boarding and Deplaning	Crew Training
Seating Accommodations	Wheelchair Ramps	Communication access
Assistive devices	Service animals	

Achieving Stage 5 noise compliance for a regional aircraft requires designing the aircraft with noise reduction features, selecting engines that meet Stage 5 noise standards, optimizing flight and ground operations to minimize noise, properly maintaining the aircraft, and obtaining certification from regulatory authorities.

Table 10 Ao4 Stage Five Noise

	AO_4 Stage Five Noise 5	
Aircraft Design	Flight operations	Ground operations
Engine Selection	Noise monitoring	Maintenance and repair
Certification	Noise abatement procedure	

Loading payload in less than an hour for a regional aircraft requires pre-flight planning, standardized cargo containers and pallets, specialized ground handling equipment, trained personnel, clear communication, and effective time management.

Table 11 Ao4 Load Payload less than 60 min

AO_4 Load Payload $\leq 1\ hr$

Pre-flight planning

Time management

Ground handling equipment

Communication

Trained personnel

Cargo containers

Prioritization

Door to load Payload only

9.1 Initial Down selection

This Section summarizes the results from previous sections into a comprehensive table listed below.

	Config. 1	Config. 2	Config. 3	Config. 4	Config. 5	Config. 6	Config. 7	Config. 8
O1 Cruise speed >250 knots	0.8	0.7	0.8	0.7	0.8	1	1	0.8
O2 Energy Cost ≤ 80%	0.88	0.98	0.86	1	0.896	0.656	0.556	0.8
O3 Inspection time <60min	1	1	1	1	1	0.8	0.7	1
O4 Max take off ≤ 1,900 ft	0.755	0.928	0.81	0.99	0.8	0.788	0.611	0.92
Sum	3.435	3.608	3.47	3.69	3.496	3.244	2.867	3.52
AO1 ADA compliant	1	1	0	1	1	1	1	0
AO2 Max View Angle > 15	1	1	1	1	1	1	1	1
AO3 Low Operating cost	1	1	1	1	1	0	0	1
AO4 Stage Five Noise	1	1	1	1	1	0	0	1
AO5 Load Payload≤1 hr	1	1	1	1	1	1	1	0
AO6 Interoperability	1	0	1	0	1	1	1	1
Sum	6	5	5	5	6	4	4	4
Total Score	9.435	8.608	8.47	8.69	9.496	7.244	6.867	7.52

Figure 11 Initial Down Selection

To select which configurations are superior the first step is to eliminate configurations which scored considerably low. The author decided to eliminate any configuration with an objective score equal to or below .8 which got rid of configuration 6,7 and 8.

10 V-n Diagram

To ensure the successful design and accurate calculations for the structure of an airplane, the first step is to obtain a V-n diagram. The V-n diagram is developed using the load requirements specified in FAR Part 25. Based on the estimations, the minimum ultimate positive load factor for the aircraft is determined to be 2.87. However, to provide an additional safety margin, this value is increased to 3.

The negative load factor is estimated to be -1.5, which is based on the typical load factors for transport aircraft as described in Raymer. Additionally, gust speeds of 25ft/s and 50ft/s are also considered, based on the estimations from FAR Part 25 requirements.

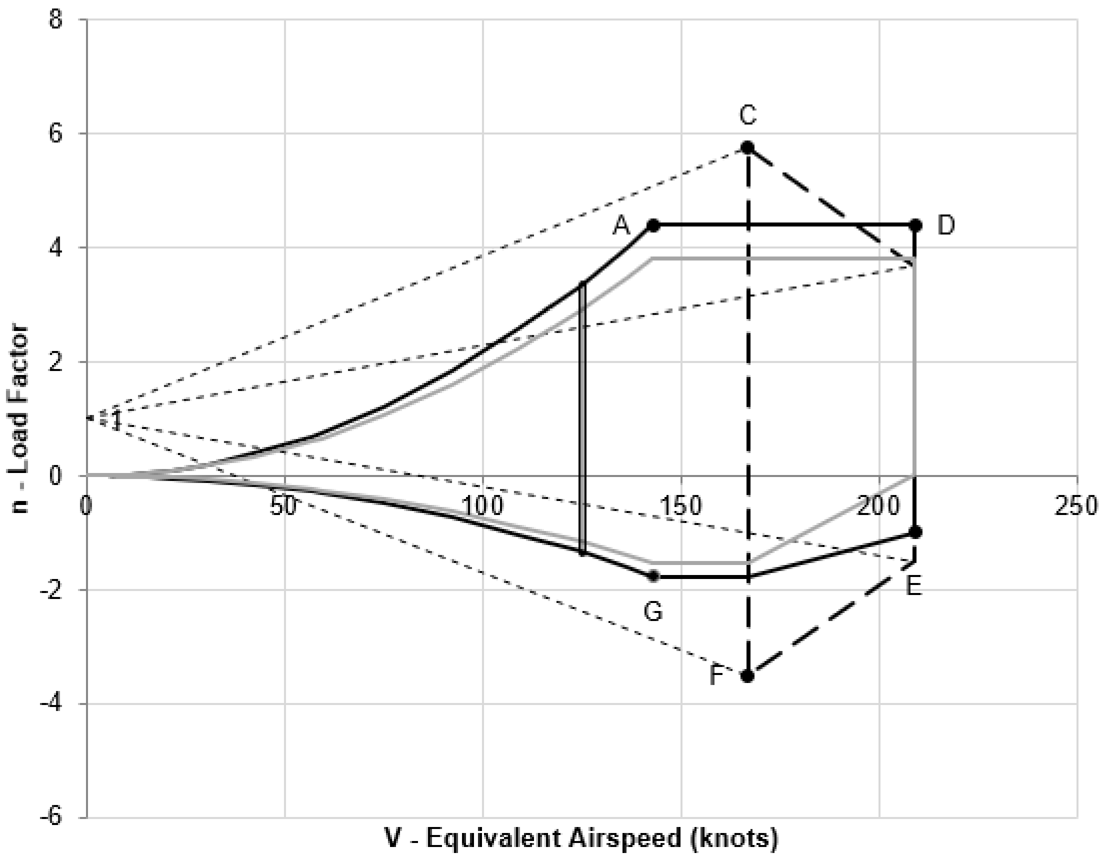
Once the aircraft reaches its design cruise speed, the positive load factor starts decreasing until it reaches a value of two at the dive speed. This decision is made to decrease the maximum possible loads developed by the structure, which in turn reduces the weight of the aircraft.

To illustrate the V-n diagram, we can plot the stall speeds at sea level, cruise altitude, and service ceiling. The V-n diagram will show the relationship between the load factor (n) and the velocity (V). The stall speeds at different altitudes are important because they affect the maximum load factor that the aircraft can withstand at that altitude.

Overall, the V-n diagram is a crucial tool in designing an aircraft's structure and ensuring its safe operation during flight.

V-n Diagram of Little Goose

v_A =	143.0	kts (EAS)
v_C =	167.0	kts (EAS)
v_D =	209.0	kts (EAS)
v_{S1} =	125.0	kts (EAS)



11 Payload-Range Diagram

The Payload Range Curve was acquired through the application of the Breguet range formula. The diagram consists of four main points, with point zero representing the maximum payload capacity of the aircraft without any fuel. Point one denotes the maximum range attainable by the aircraft while carrying a full payload, while point two indicates the maximum range achievable with full fuel tanks. Finally, point three indicates the maximum range that can be achieved with no payload.

It is important to note that all points on the payload diagram meet the mission range requirements. Furthermore, the maximum range achieved by the aircraft is significantly higher than that of its competitors.

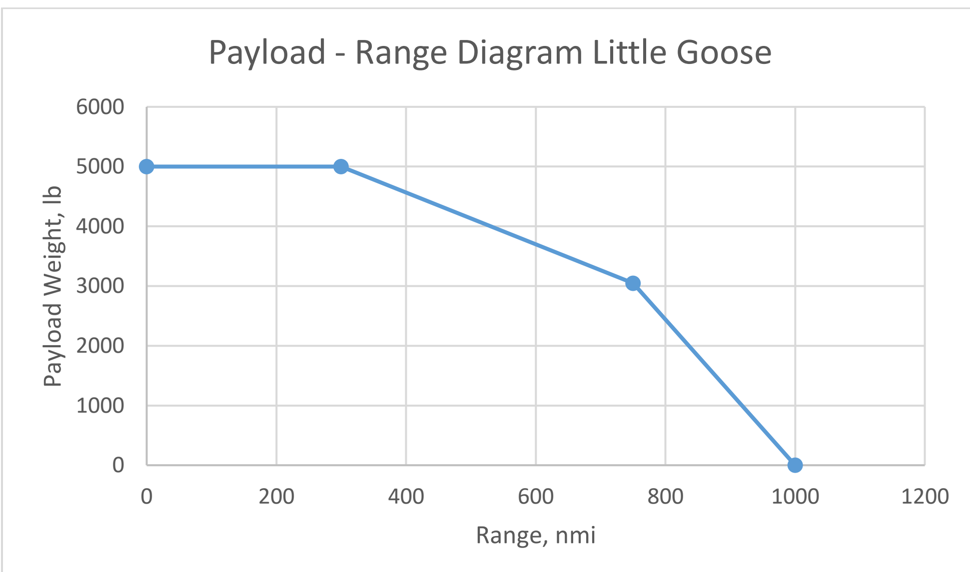


Figure 11-1 Payload - Range Diagram

Table 12 Payload, Range, and Range for critical points of the Payload Range Curve

Point	Payload Weight (lb)	Fuel Weight (lb)	Range (nmi)
0	5000	0	0
1	5000	4985	300
2	3050	6936	750
3	0	6936	1000

11.1 Fuel Burn

Fuel burn refers to the amount of fuel consumed by an aircraft's engines during a specific period of time, usually measured in pounds or gallons per hour. Fuel burn is a critical factor in aircraft design and operation, as it directly impacts fuel efficiency, range, and operating costs. The amount of fuel burn depends on various factors such as the type of engine, the size and weight of the aircraft, and the altitude and speed of flight. Modern aircraft engines and designs are continually being developed to increase fuel efficiency and reduce emissions, which can have significant benefits in terms of both cost savings and environmental impact. As such, fuel burn is an important metric that is closely monitored and optimized in the aviation industry.

The Request for Proposal (RFP) required the aircraft design to achieve a minimum 20% reduction in fuel consumption per passenger on a mission of similar length. To assess the fuel efficiency, three aircraft were evaluated on a 300 nautical mile mission, namely the Beechcraft 1900D, Dornier 228, and DHC-6 Twin Otter. Based on initial design specifications and performance analysis, the fuel efficiency of the KR-1 was computed using the passenger weight stipulated in the RFP and compared against the fuel economy of the two-reference aircraft.

Table 13 Fuel economy comparison

Aircraft Name	Fuel per seat (miles per gal)
Beechcraft 1900D	35.8
Dornier 228	37.8
DHC-6 Twin Otter	34.6
Little Goose	30

12 Design and Sizing

Table 14 Fuselage Characteristics

Fuselage Characteristics			
Length (ft)	59.1		
Max Height (ft)	19		
Max Width (ft)	6		
Planform Characteristics			
	Wing	Horizontal Tale	Vertical Tale
Area S (ft^2)	280	89.3	46.5
Span b (f)	50.5	20.5	6.5
Aspect Ratio (AR)	9.1	4.71	.91
Inboard Sweep	25	35	40
Outboard Sweep	20	40	35
Taper Ratio (λ)	0.37	0.57	0.5
Airfoil	NACA 23018	NACA 0012	NACA 0012
Anhedral Angle Γ (deg)	2	-	-
Incident Angle I (deg)	0	0	0

12.1 Powerplant Sizing

The PT6A-68C is a turboprop engine designed and manufactured by Pratt & Whitney Canada. It is part of the PT6A family of turboprop engines, which are widely used in a variety of aircraft, including business jets, regional airliners, and military transport aircraft. The PT6A-68C is one of the most powerful engines in this family, with a flat-rated power of 1600SHP.

One of the advantages of the PT6A-68C is its fuel efficiency. It has a fuel consumption rate of 0.542lb/h/hp, which means that it can produce 1 horsepower of output while consuming only 0.542 pounds of fuel per hour. This makes it an efficient choice for aircraft that require long-range capabilities and low operating costs.

Parameter	Value
Flat-rated power	1600 HP
Fuel consumption	0.542 PPH
Shaft rotation at max RPM	1700

12.2 Powerplant Placement

There were three primary factors that influenced the positioning of the engine on our aircraft. Firstly, sufficient clearance was necessary to avoid interference with the propeller. This was especially critical because the aircraft was designed to operate in Sea State 3 conditions, which typically involve waves between 0.5 to 1.25 meters high. To reduce the risk of damage to the engines and propellers, we opted to position the propulsion system at a sufficient height to avoid potential wave-strikes.

Secondly, our team wanted to position the propulsion system in a location that would provide optimal lifting benefits through augmented lifting solutions. This was important for ensuring that the aircraft had sufficient lift to operate efficiently and safely, especially in challenging conditions.

Finally, we also considered ease of maintenance when selecting the engine placement. It was important to ensure that the engines were accessible and easy to maintain, in order to minimize downtime and reduce maintenance costs.

12.3 Compartment Layout

12.3.1 Cockpit layout

The design of the cockpit was specifically intended to offer the pilots an optimal field of view, enabling them to efficiently operate the aircraft. The pilot location and windshield were therefore positioned with great care to ensure that the pilots had a clear and unobstructed line of sight. The accompanying image illustrates the angle of pilot visibility, and it is worth noting that the angle of 130 degrees conforms to the widely accepted standard for transport aircraft.

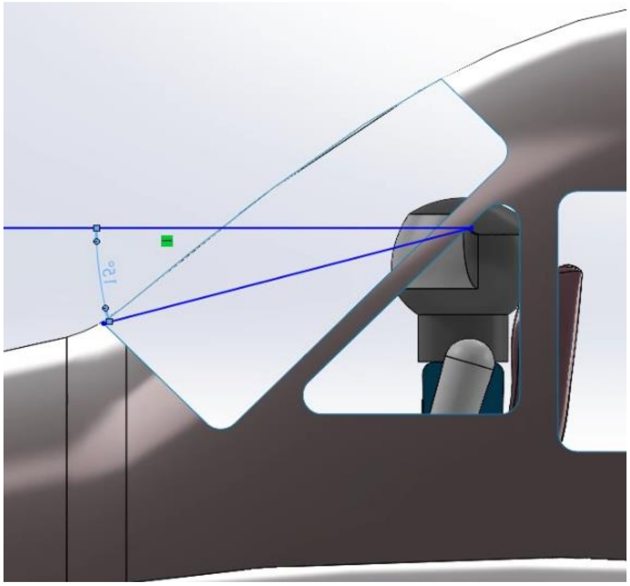


Figure 12-1 Pilot Sight

12.3.2 Fuselage

The placement of the passenger cabin and its doors were carefully considered to ensure easy boarding and cargo loading, particularly when the aircraft is on the water. To provide sufficient clearance from the waterline, the doors were elevated relative to the hull bottom. The cabin was designed to accommodate up to 19 passengers and provide ample space for cargo in the cargo configuration. A roller system was integrated into the cabin to facilitate efficient distribution of cargo.

In the passenger configuration, the seating arrangement was designed such that the rows near the aft door did not impede passenger access to the door. This was done to ensure that passengers could easily embark and disembark the aircraft.

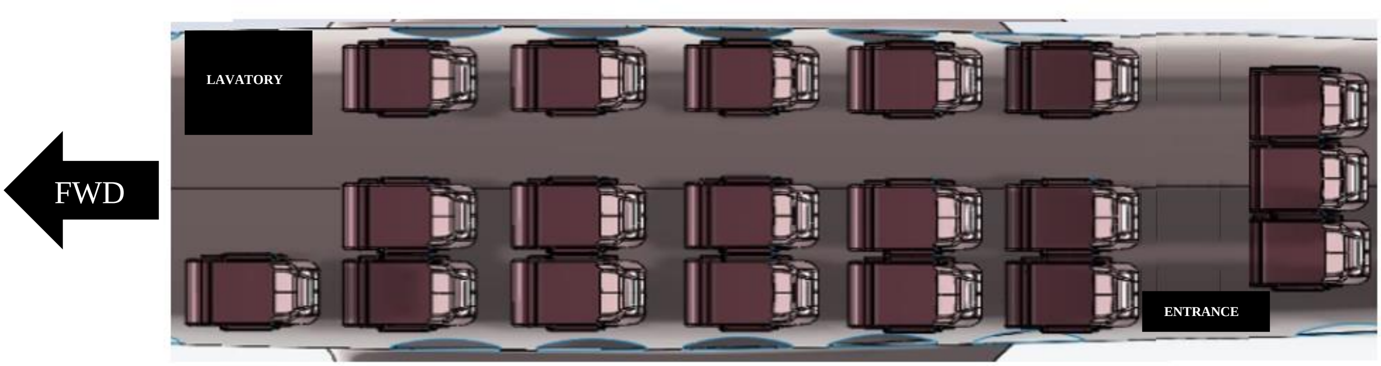


Figure 12-2 Seats Distribution

In an aircraft with three-row seats, the seating arrangement is typically designed to maximize passenger comfort and space efficiency. The seats are arranged in rows with a narrow aisle in between, and there may be two seats on one side and one seat on the other side of the aisle. The placement of seats also takes into account factors such as emergency exit access, legroom, and overhead storage compartments.

Figure 12-3 Seats Distribution

13 Engine Installation

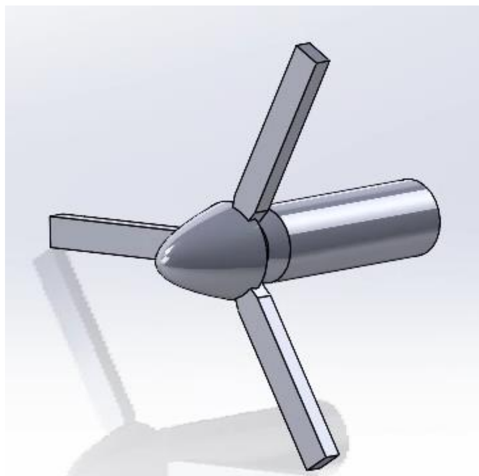


Figure 13-1 Engine

To optimize the engine's performance throughout the entire mission, a metal propeller with the ability to reverse-thrust and maintain a constant speed was selected. The propeller diameter is a crucial factor in converting the engine's power into thrust. When selecting the appropriate diameter of the propeller, two important considerations must be taken into account. Firstly, it's important to avoid high tip speeds to prevent losses caused by shocks at the tips. For a metal propeller, the maximum Mach number should be between 0.7 and 0.8. Secondly, the use of a spinner can have a significant impact on the propeller's performance, which should be taken into account when evaluating the overall effectiveness of the propeller.

The location of the engine was chosen after careful consideration of various factors. First and foremost, the position of the engine had to comply with the FAR Part 25 regulations, which stipulate a minimum distance of one inch between the blade tip and the aircraft structure and 18 inches between the tip and the water. Additionally, the location of the propeller with respect to the cabin doors was determined based on the danger zones of the propeller. Other factors such as water spray, clearance above the water line, and static stability were also taken into account. Furthermore, the engine-out speed requirements specified by FAR Part 25 and the sizing of the vertical tail were important considerations in determining the engine placement. After several iterations, the engine was positioned 8 feet away from the aircraft centerline and 1.3 foot above the wing chord line. Following figure illustrates the engine layout and the propeller diameter.

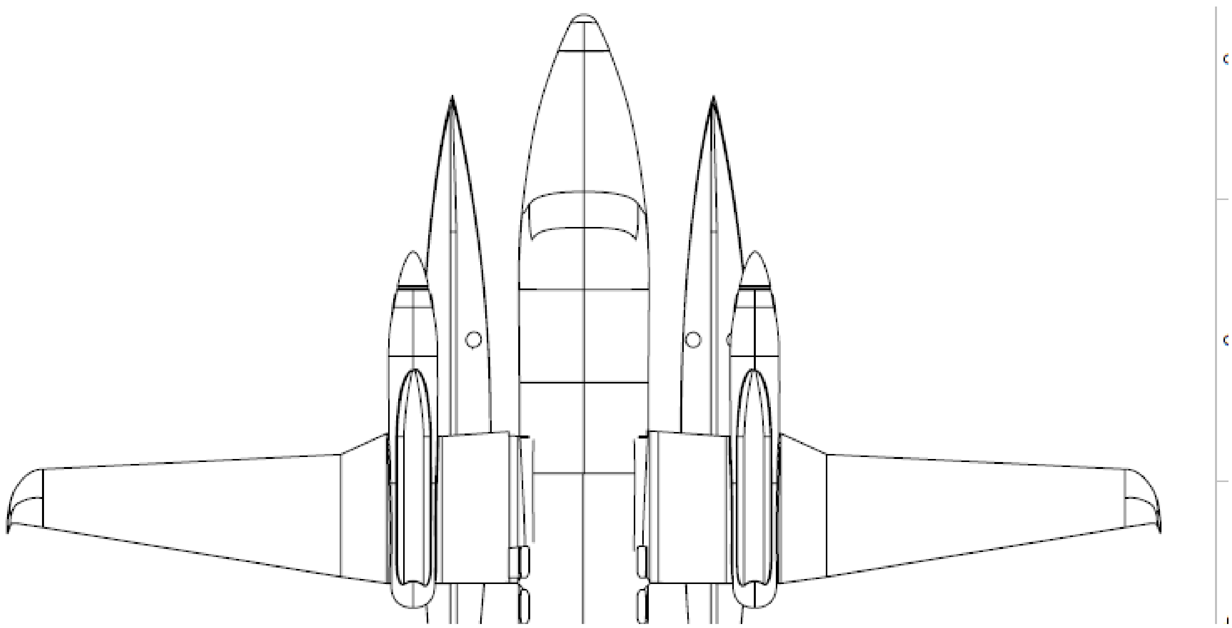


Figure 6 Engine Location

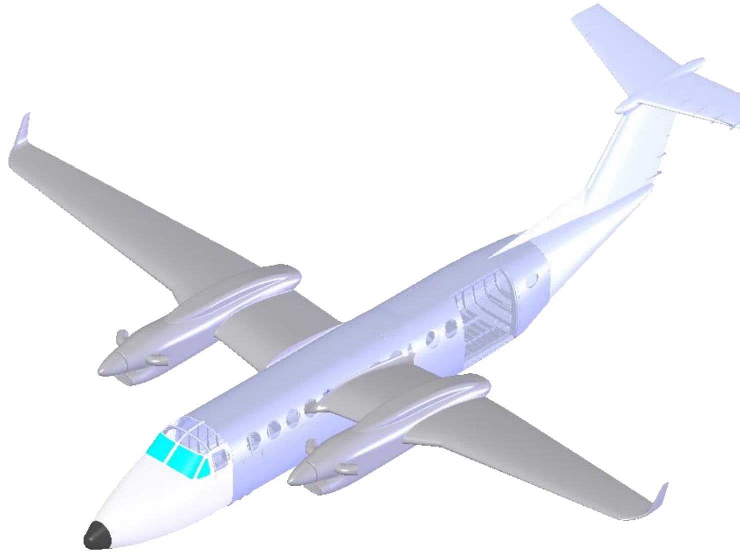


Figure 7 Engines Placed

14 Wing configuration

Wing design is a critical aspect of aircraft engineering that determines the performance and efficiency of an aircraft. A well-designed wing is essential for generating lift and controlling the direction and stability of the aircraft. The shape, size, and angle of attack of the wings are calculated to achieve optimal lift and drag characteristics. Engineers also consider factors such as the weight of the aircraft, the altitude and speed of flight, and the intended use of the aircraft when designing the wings. With advances in technology, new materials and techniques are being used to design more efficient and effective wings for modern aircraft.

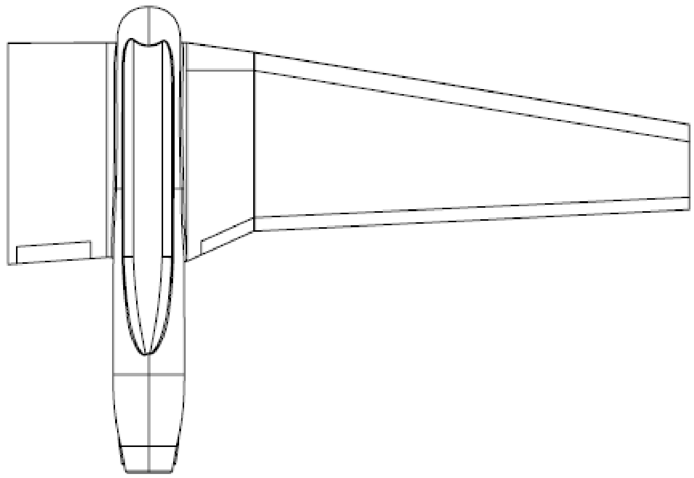


Figure 14-1 Top View of the Wing

Table 15 Wing Dimensions

AR		9
Span		60 ft
Root Chord		6ft 5in
Taper Ratio		0.5

15 Empennage Design

The Empennage structure was evaluated based on a set of simplifying assumptions. The weights of each aircraft component were approximated as point masses, and the analysis was focused on the section with the highest internal forces and moments. To determine the locations of the ribs and skin thickness, shear and buckling analyses must also be performed. Additionally, it is recommended to conduct a more precise analysis using advanced methods such as Finite Element Analysis.

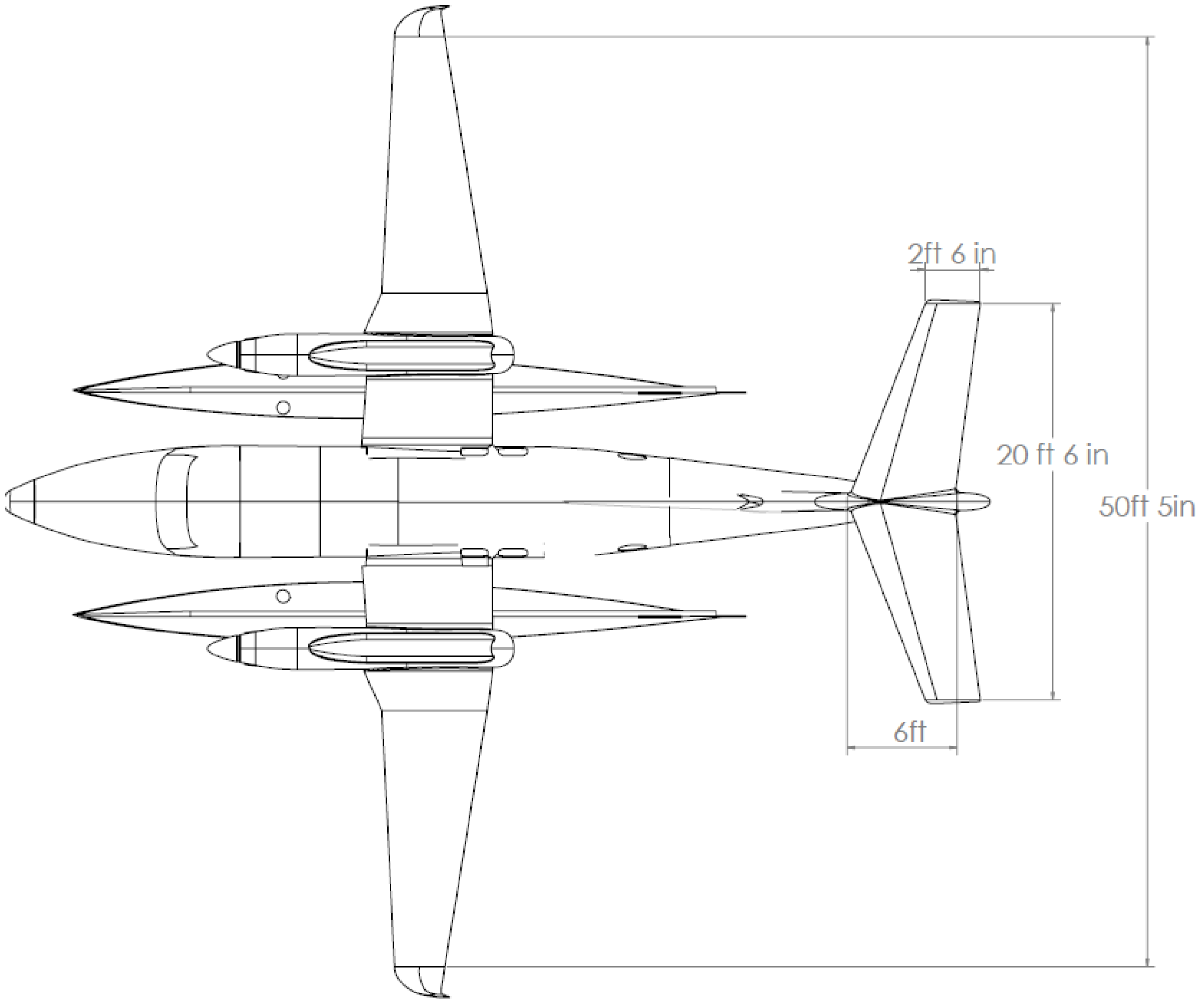


Figure 15-1 Top View of Airplane with Dimensions

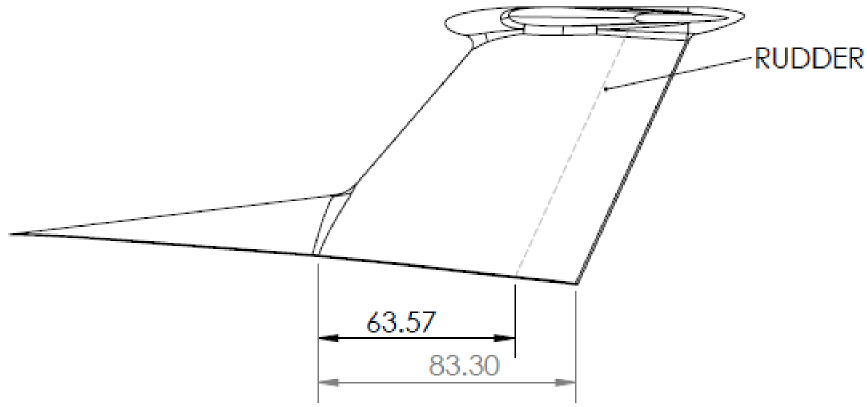


Figure 2 Vertical and Horizontal Tail

the positioning of the vertical tail in relation to the horizontal tail is a crucial factor to consider during spin recovery. For optimal vertical tail control characteristics, it is recommended that at least 30% of the rudder be located away from the wake of the horizontal tail. Unfortunately, the initial placement of the horizontal and vertical tails only allows for 11% of the rudder to meet this requirement. To enhance flow characteristics at the vertical tail during high angles of attack and increase the effectiveness of the rudder, a dorsal fin was incorporated. However, the use of a dorsal fin does not necessarily guarantee improved flow behavior during high angles of attack.

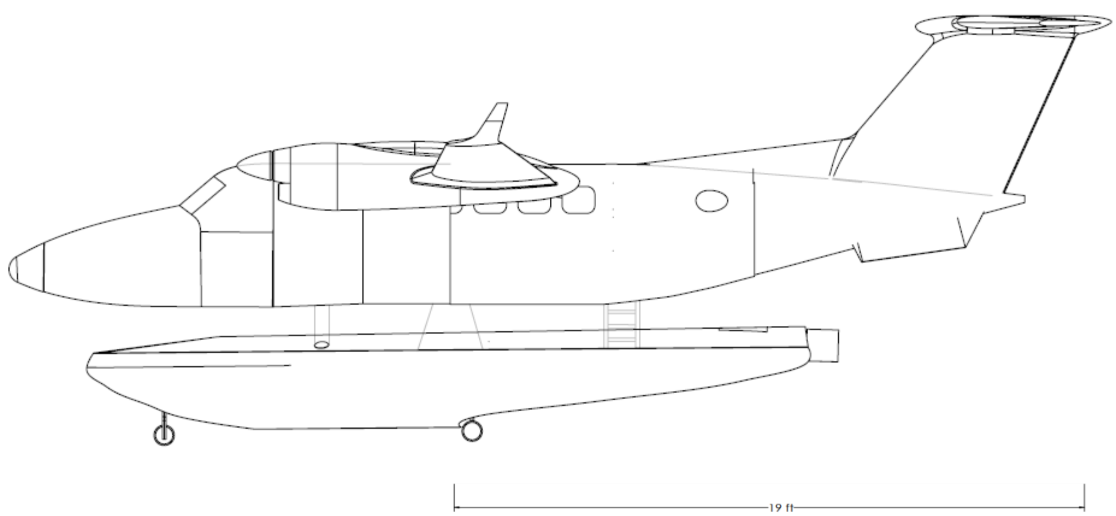


Figure 30 SideView of the Little Goose

In order to meet the turning performance standards outlined in FAR Part 25, it is crucial to ensure that the ailerons are appropriately sized. However, the size of the ailerons is limited by the flaps that are required to meet takeoff requirements. To estimate the roll rate, Sadraey's method [8] was utilized and then compared to the MIL-STD Category B Class 2 criteria. A maximum aileron deflection of 200 was assumed during the analysis.

Aspect Ratio	1.5
Volume Ratio	0.04
Span	6ft 5in
Root Chord	6ft
Taper Ratio	0.5

16 Landing gear design

Landing gear design is an integral aspect of aircraft engineering that involves the design and construction of landing gear systems to support the aircraft during landing and takeoff. The design process involves considering factors such as the weight of the aircraft, the intended use of the aircraft, and the type of terrain that the aircraft will be operating in. Engineers must also ensure that the landing gear can withstand the impact of landing, provide stability during takeoff and landing, and be retractable to reduce drag during flight. The landing gear system typically includes shock absorbers, wheels, brakes, and struts to distribute the weight of the aircraft evenly and reduce the impact of landing. With advances in technology, new materials and techniques are being used to design more efficient and durable landing gear systems for modern aircraft.
The nose landing gear should bear no more than 20% of the MTOW when the center of gravity is at the forward limit and no less than 10% when at the aft limit. This information summarizes the percentage of the MTOW that the aircraft experiences at its most forward and aft positions.

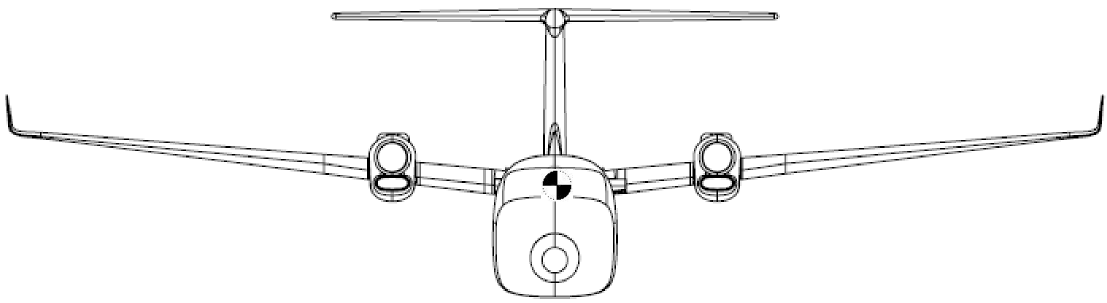


Figure 16-1 Engine and CG

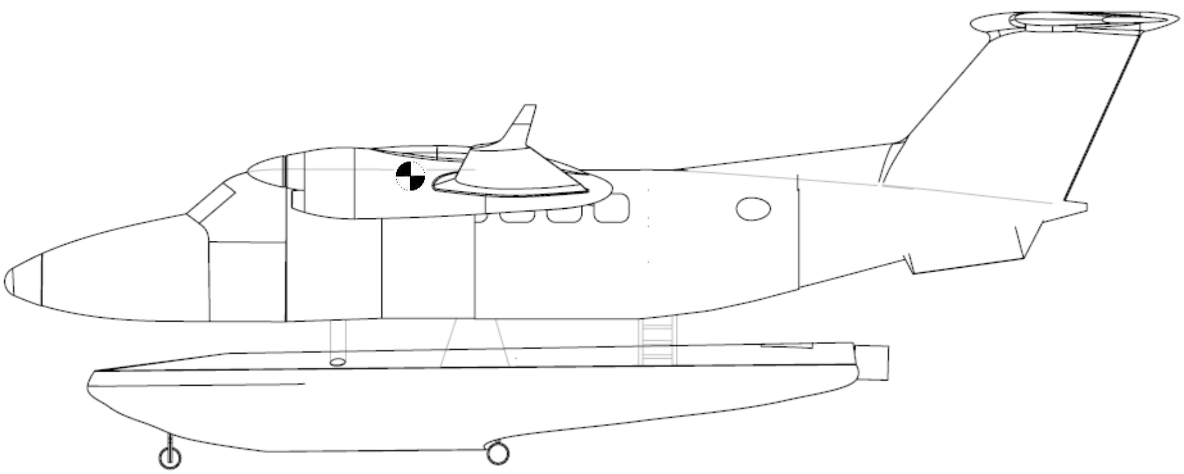


Figure 16-2 sideview of liitle goose

The position of the main landing gear is critical to prevent tail strikes during maximum angle of attack rotations. It is recommended that the main gear be located behind the most aft cg and offset in such a way that the angle between the vertical line through the gear and the line crossing the gear and the cg is equal to the maximum possible rotation angle. Figure 10.1.1 provides a diagram illustrating the longitudinal location of the landing gear.

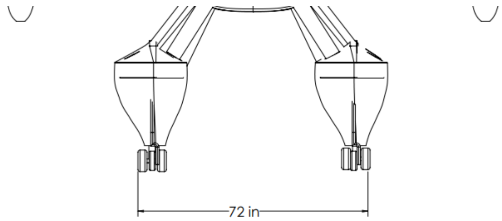


Figure 16-3 Landing Gears dimensions.

The tires of an aircraft are essential for its takeoff capabilities on various surfaces. For soft and wet profiles, low-pressure tires are preferred, and thus, for the current design, 60 psi tires were taken into consideration. The weight experienced by the tires is based on the most aft cg for the main gear and the most forward cg for the forward cg, along with a 25% weight increase to account for the historical tendency of aircraft weight to increase over time.

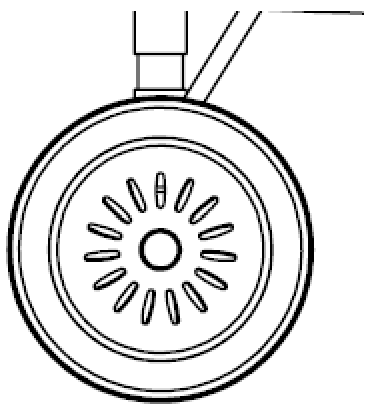


Figure 16-4 Landing Gear Layout

17 Floats

The main advantage of airplane floats is their versatility. Floats allow aircraft to take off and land on bodies of water, opening up new routes and destinations for aviation. Additionally, floats can be easily removed or replaced, allowing the aircraft to operate on both land and water as needed. Floats also provide better shock absorption during water landings, reducing stress on the airframe and making landings smoother. Finally, floatplanes have a shorter takeoff and landing distance than traditional land-based aircraft, making them ideal for use in remote locations with limited runway space.

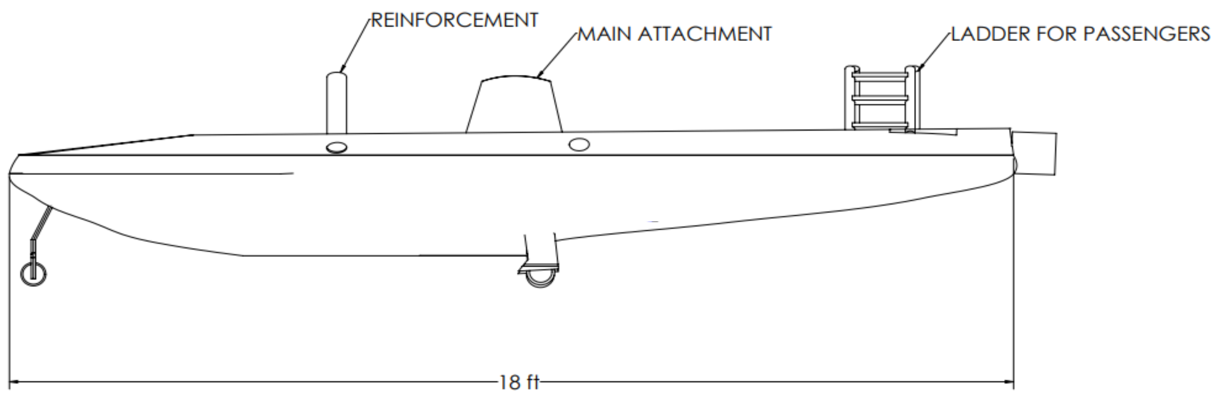


Figure 17-1 Little Goose Floats

18 Weight and Balance

The weight and balance calculations for the aircraft's final configuration were performed using techniques described in Roskam's Airplane Design Part V: Component Weight Estimation. These methods involve estimating the weight of each major component of the aircraft, including the wings, fuselage, empennage, landing gear, and propulsion system, and combining them to obtain the total weight of the aircraft. This information is then used to determine the aircraft's center of gravity, which must be within acceptable limits to ensure safe and stable flight.

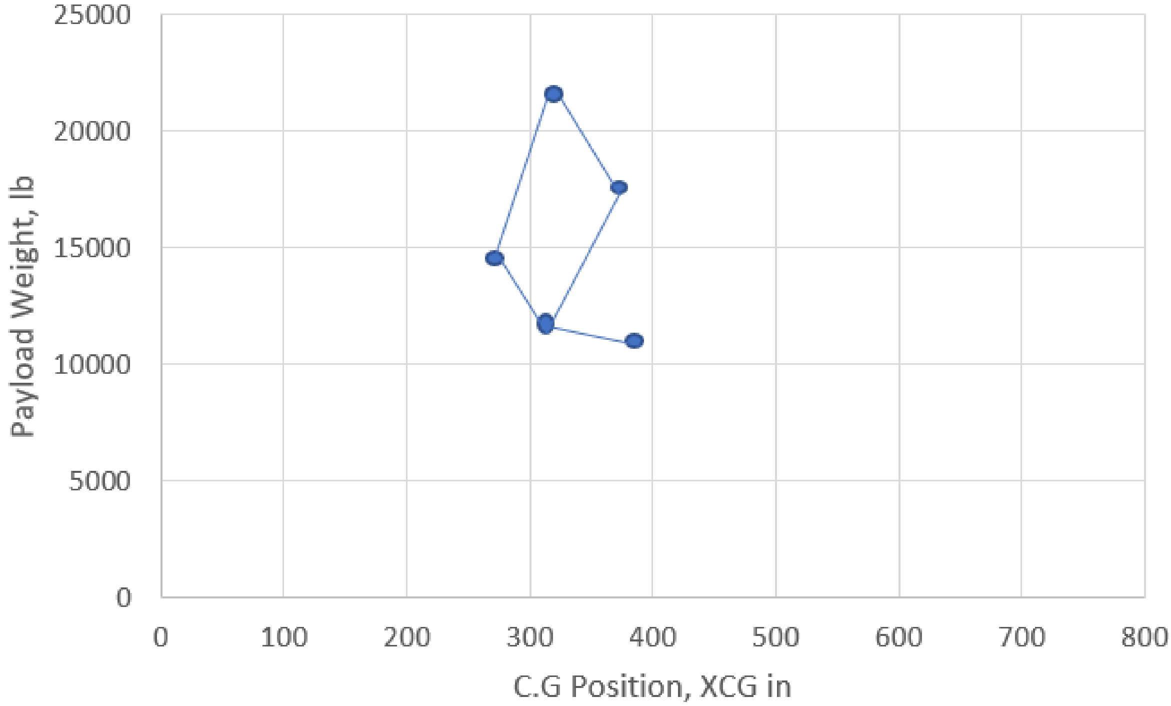


Figure 18-1 Excursion Diagram

18.1 CG Excursion and Effects on Static Margin

The center of gravity for the little goose calculations are shown below.

18.1.1 Items to Account for Static Margin and CG Excursion

Table 7 displays the location of items respect to CG.

Table 16 Weight and Balance Sizing

	Xcg (in)	W*Xcg (lb-in)	Zcg (in)	W*Zcg(lb-in)
Wing	352.44	2312991.78	99	649716.54
H. Tail	700.92	499348.74	170.28	121310.64
V. Tail	643.5	465429.36	138.6	100246.08
Fuselage	305.58	2363842.14	53.46	413544.78
avionics	248.16	403260	106.92	173745

Floats	349.8	349800	27.06	27060
Fuel system	330	351935.1	27.06	28858.5
Fuel	405.24	1569899.76	99	383526
Engine	297	3451734	27.06	314491.32
Pasenger	231	1108800	106.92	513216
Baggage	350.46	5323109.88	49.5	752400
Cargo	350.46	438455.82	69.3	86763.6
Baggage	350.46	657684.06	31.68	59495.04
bagand crew	92.4	60984	49.5	32684.52
hydraulic	231	2299164.12	39.6	394142.1

19 Advanced CAD

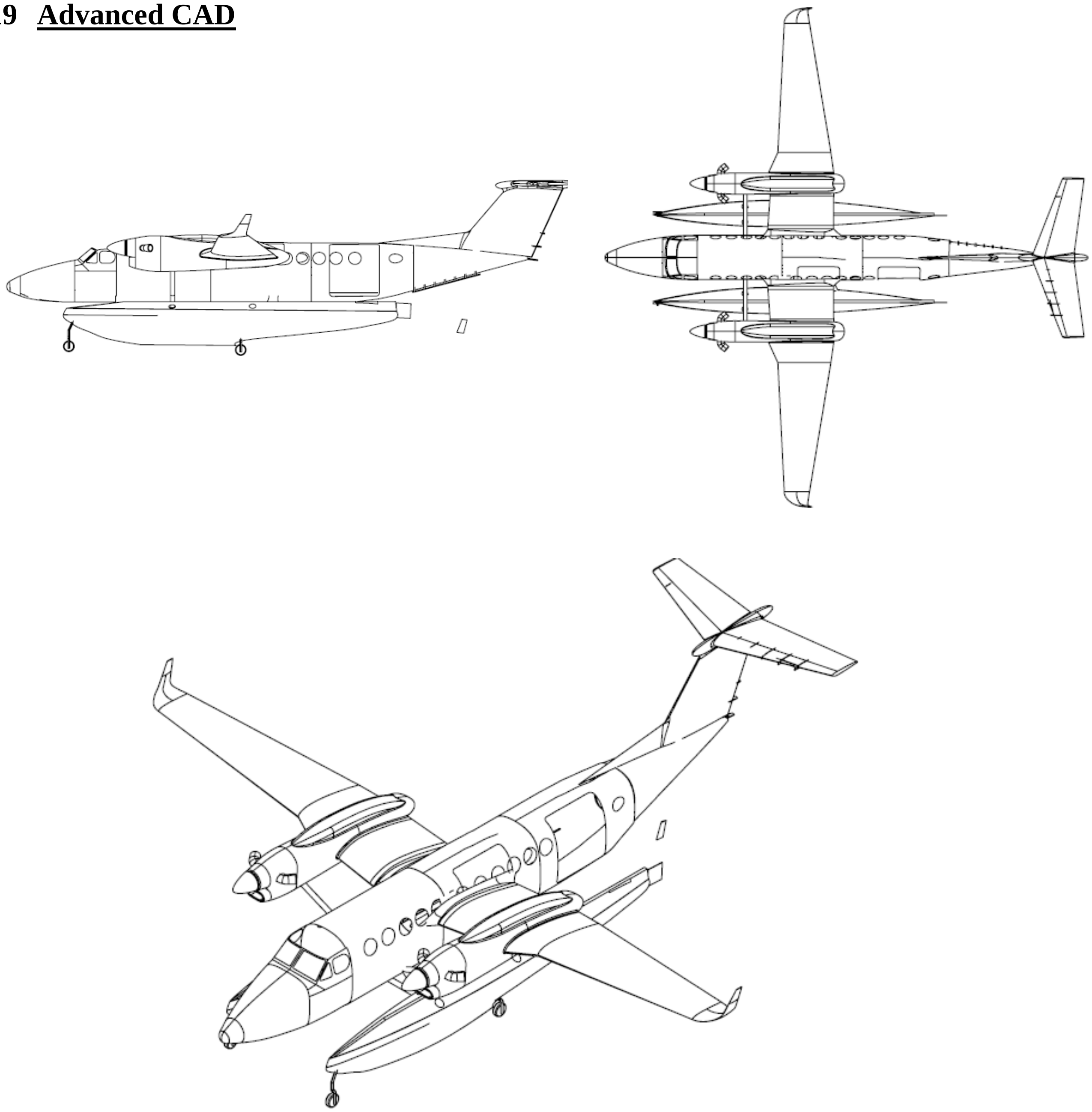


Figure 37 Three view of The Little Goose

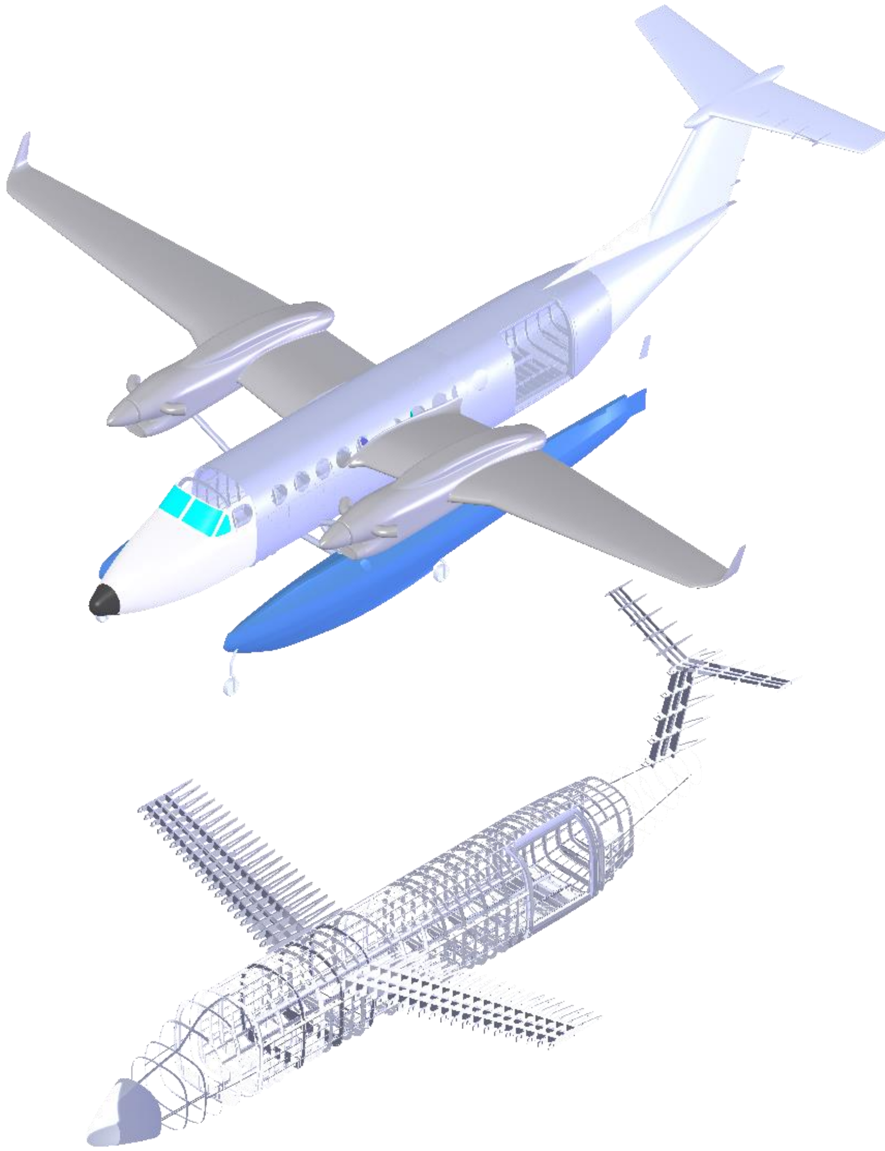


Figure 38 Exploded View

20 Material Selection

Material selection plays an important role in structural behavior of the aircraft, its weight, and cost related to both manufacturing and maintenance. For the given RFP, aluminum was used as the main material due to its low cost, predictable strength capabilities, and ease of certification. For major parts of the structural analysis, Aluminum 2024-T4 was used because of its high strength and weight combination. Table 8.2.1 shows material properties of Aluminum 2024-T4.

Table 17 Aluminum 2024 T3 Material Properties

Density (lb/in^3)	0.1
Ultimate Tensile Strength (ksi)	62.0
Yield Strength (ksi)	40.0
Young's Modulus (10^6 psi)	10.5
Shear Modulus (10^6 psi)	4.1

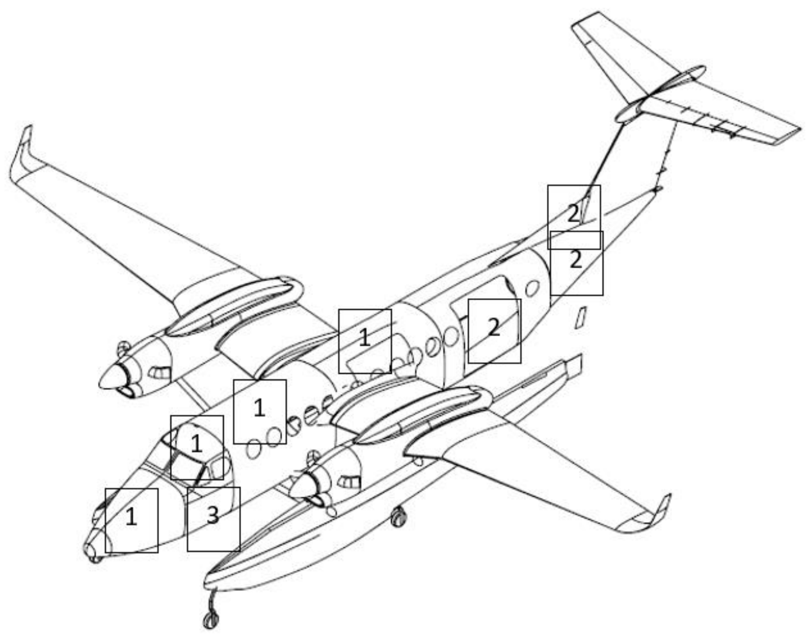


Figure 4 Fuselage Skin thickness

Table 18 Fuselage Skin Thickness

Item	Material	Thickness in Inches
1	2024T3	0.025
2	2024T3	0.040
3	2024T3	0.050

For the floats which are in direct and constant contact with water, Toray FGF7781-071 was used, This material has excellent mechanical properties, including high strength and stiffness, good impact resistance, and low thermal expansion. It also has good resistance to chemicals and moisture, making it suitable for use in harsh environments.

The most common layup for similar projects is shown in the following table:

Table 19 Ply Table E-Glass

PLY TABLE (E-GLASS)		
GROUP	ORIENTATION	MATERIAL
A	0°	TORAY FGF7781-071
	45°	TORAY FGF7781-071
	90°	TORAY FGF7781-071
	0°	TORAY FGF7781-071
	45°	TORAY FGF7781-071
	90°	TORAY FGF7781-071
CORE	N/A	F40
B	0°	TORAY FGF7781-071
	45°	TORAY FGF7781-071
	90°	TORAY FGF7781-071
	0°	TORAY FGF7781-071
	45°	TORAY FGF7781-071
	90°	TORAY FGF7781-071

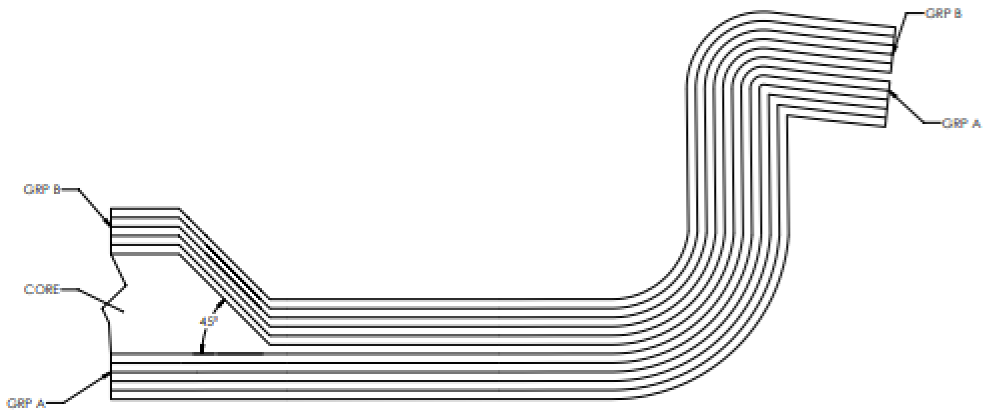


Figure 20-5 Section View of the composite material

21 Substructures

The Little Gosse substructure is presented below.

21.1 Fuselage

The fuselage structure was evaluated using a series of simplified assumptions. The weight of the aircraft's various components was treated as concentrated masses, and the analysis focused on the section that experienced the greatest internal forces and moments. The fuselage structure is designed to withstand loads and is composed of two primary components: the skin and 24 stringers. The skin is the outermost layer of the fuselage, and it is responsible for bearing the majority of the load. The 24 stringers are thin, longitudinal beams that run parallel to the fuselage's length and are attached to the skin. They provide additional support and stiffness to the structure, helping it to resist bending and torsional forces. Together, the skin and stringers work in tandem to create a strong, lightweight structure capable of withstanding the various loads and stresses that the aircraft will experience during flight.

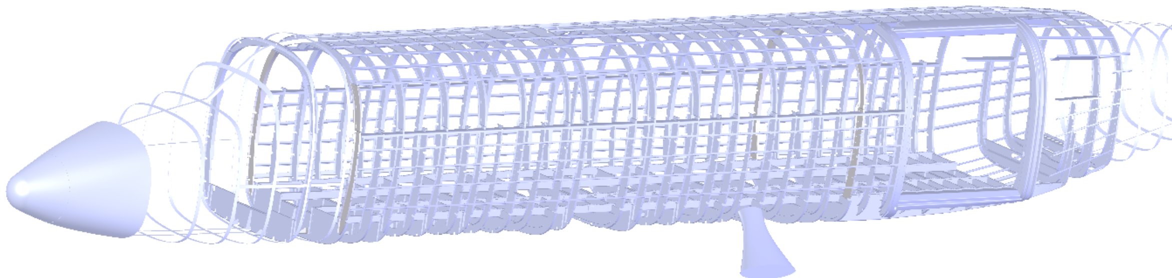


Figure 6 Fuselage Substructure

21.1.1 Windows

They are designed to withstand the immense forces and stresses of flight, including changes in air pressure and temperature. The window structure is reinforced by a frame made of aluminum 2024-t3, same material used for the fuselage, those windows have a diameter of 10 in.

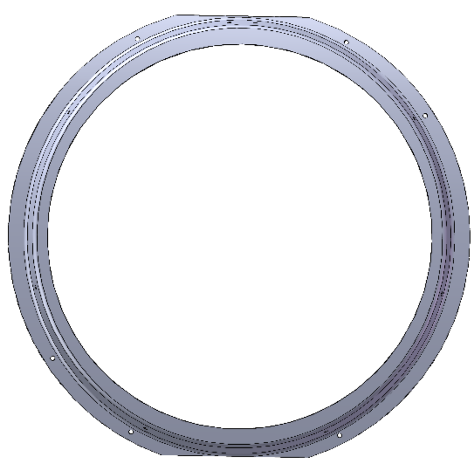


Figure 42 Window Substructure

21.1.2 Door

The design and engineering of the airplane door substructure is critical for maintaining the integrity of the aircraft's structure and ensuring the safety and comfort of passengers during flight. The door substructure must be strong, lightweight, and highly effective, while also providing easy access to the aircraft's interior for passengers and crew. The frames have a thickness of 0.175 in. which is designed to withstand the various stresses and forces experienced during flight, including changes in air pressure and temperature.

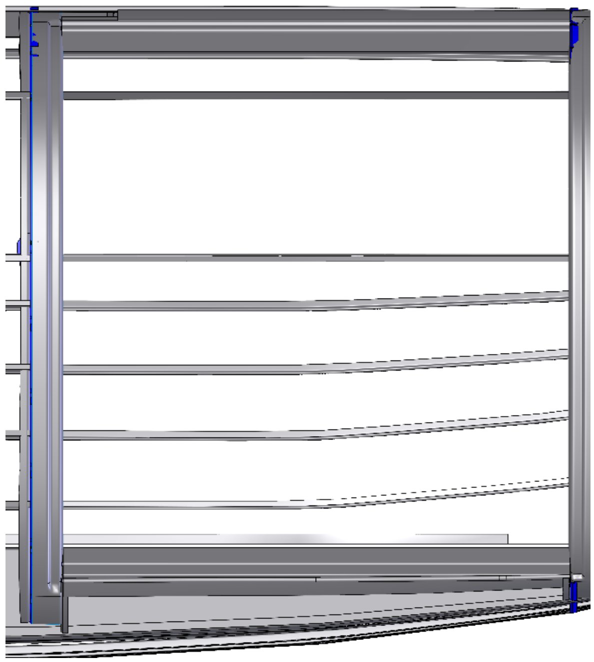


Figure 8 Door Substructure

21.2 **Tail**

The horizontal and vertical tail substructures of an aircraft are also critical components that provide stability and control during flight. The horizontal tail substructure typically features a two-spar design (as shown in the figure below), similar to the wing substructure. The two spars run the length of the horizontal tail and provide the necessary support for the tail surfaces. The elevator is the only control surface on the horizontal tail and is used to control the aircraft's pitch.

The vertical tail substructure, on the other hand, typically features a three-spar design. The three spars provide additional support and stability to the vertical tail surfaces, which are responsible for controlling the aircraft's yaw. The rudder is the only control surface on the vertical tail and is used to control the aircraft's yaw by deflecting the air flow over the surface of the rudder.

Overall, the design of the tail substructures is critical for maintaining the stability and control of the aircraft. The use of spars and other structural components is carefully engineered to provide the necessary strength and support while minimizing weight. The control surfaces are also designed to be highly effective while maintaining the aerodynamic efficiency of the tail surfaces.

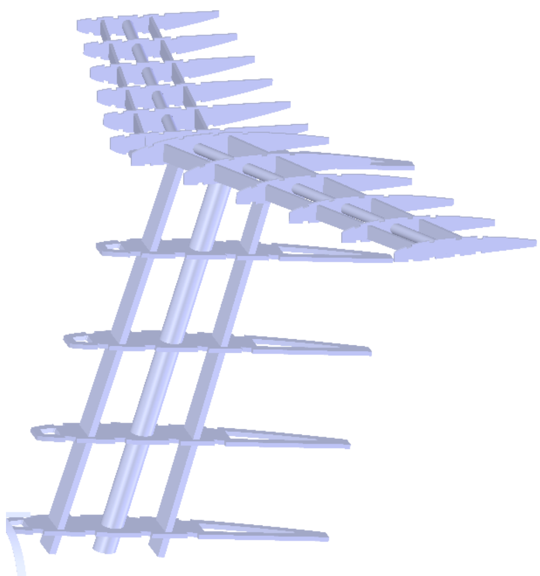


Figure 9 Tail Substructure

21.3 <u>Wing</u>

The wing substructure of an aircraft typically consists of a series of internal components that provide support and stability to the wing. In the case of the wing substructure with a two-spar design (as shown in next figure) there are two main spars that run the length of the wing. These spars are typically made of lightweight but strong materials, such as aluminum alloys or composites, and are designed to bear most of the wing's weight and lift forces.

The wing also features several control surfaces that enable the pilot to control the aircraft's motion and attitude. These include inboard and outboard flaps, which can be extended or retracted to adjust the wing's lift and drag, and ailerons, which are located on the outer rear edges of the wing and are used to control the aircraft's roll.

Overall, the wing substructure is carefully designed to provide strength and stability while minimizing weight. The control surfaces are also engineered to be highly effective while maintaining the aerodynamic efficiency of the wing.

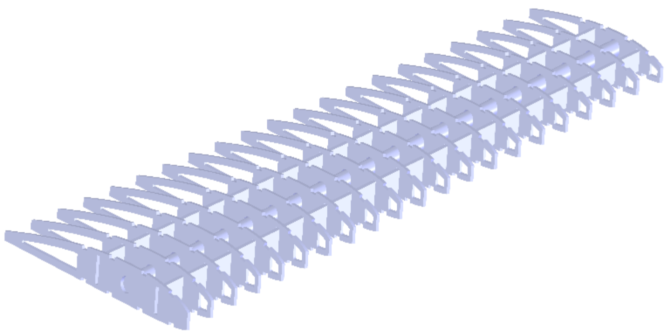


Figure 10 Wing Substructure

22 Fuel system

2 fuel tanks are located in this aircraft, one located in each wing, between main an rear spars, each tank has a capacity of 350 gallons, giving the aircraft a total of 700 gallons.

The little Goose is powered as mentioned above by two Pratt & Whitney Canada PT6A-67D turboprop engines, which can use Jet-A or Jet-A1 Fuel. These types of fuel are kerosene-based and are commonly used in aviation. The specific type of fuel used can depend on factors such as location and availability.

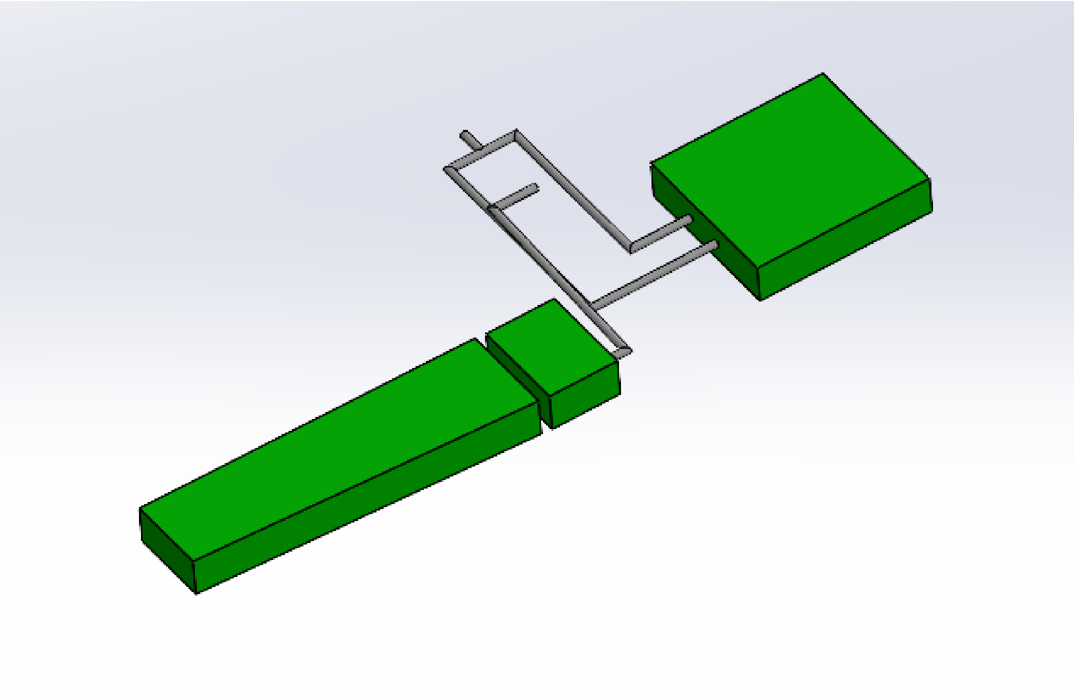


Figure 22-1 Fuel tank layout

22.1 Hydraulic System

A hydraulic system in an airplane is an essential component that uses pressurized fluids to operate various mechanical systems. These systems include the landing gear, brakes, flaps, and control surfaces, among others. The hydraulic system ensures that these components operate smoothly and efficiently, providing safe and reliable flight operations. Pressurized fluid is typically a type of oil that is stored in a reservoir and pumped by hydraulic pumps throughout the aircraft. In the event of a failure in the hydraulic system, pilots have backup systems and controls to maintain safe flight operations. Overall, the hydraulic system is a crucial aspect of an airplane's design, ensuring the safety and reliability of the aircraft during flight.

Below hydraulic system layout and pipeline system

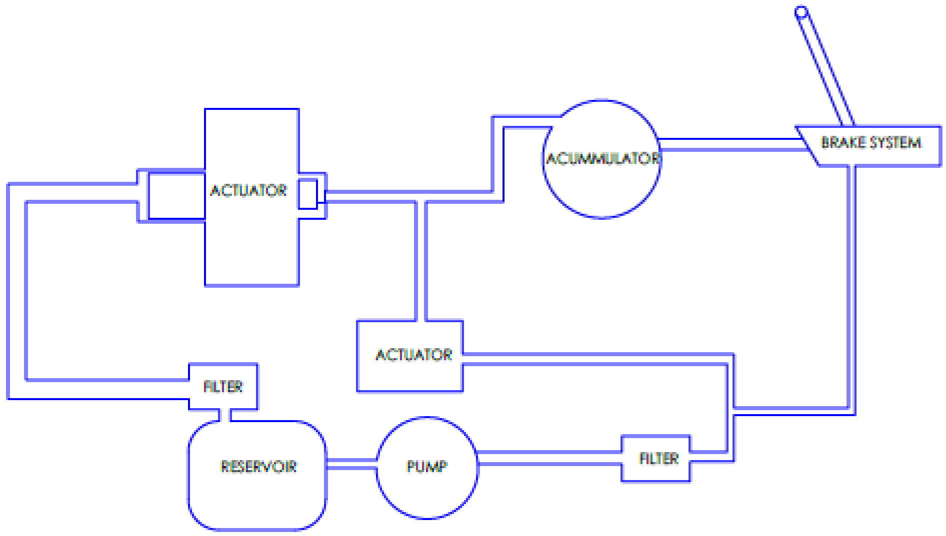


Figure 22-2 Hydraulic System Layout

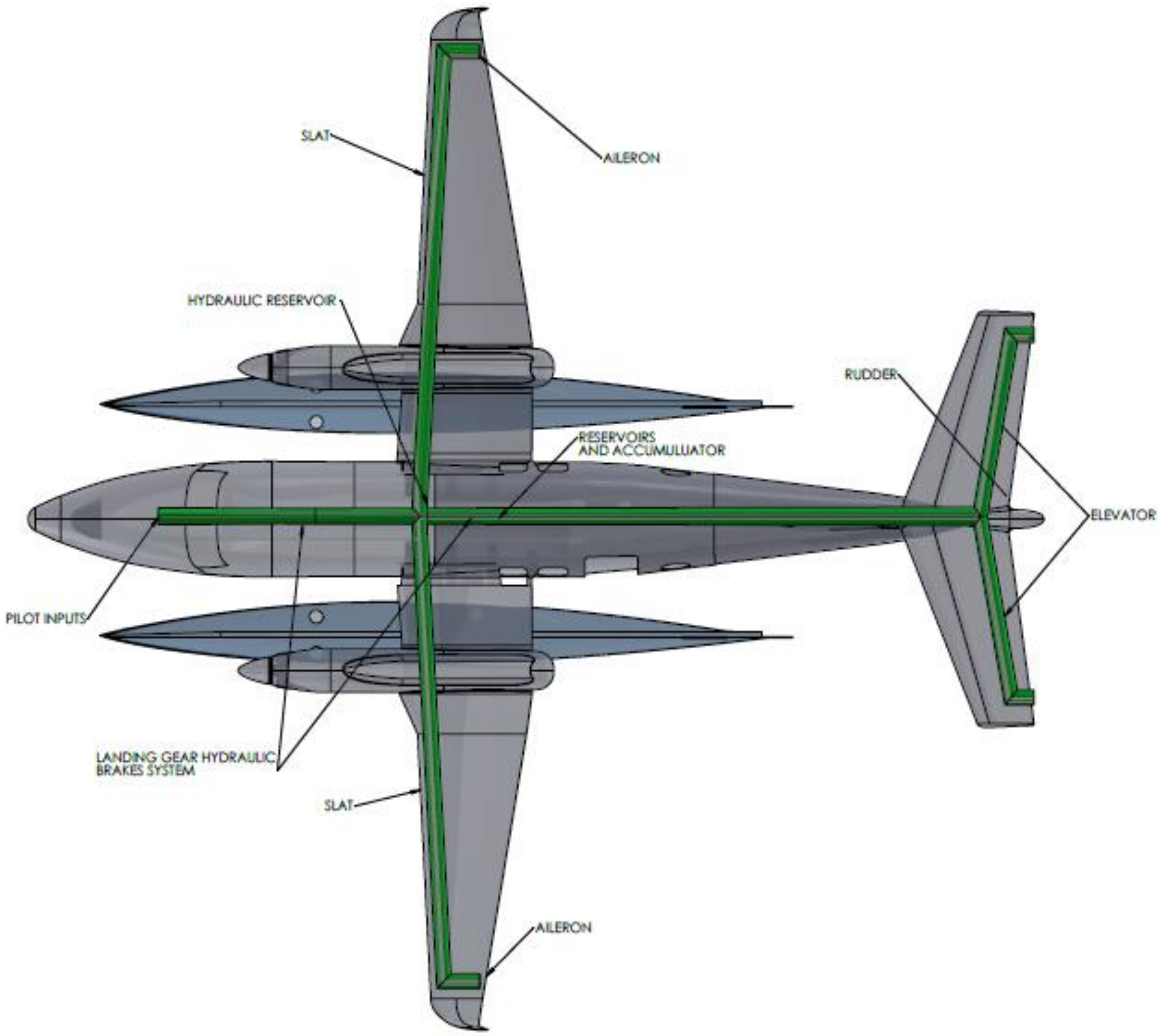


Figure 22-3 Hydraulic pipeline

22.2 Electrical System

The aircraft's electrical system is an essential component that powers various critical systems, including avionics, lighting, and instruments. The system uses a 28-volt direct current (DC) electrical system, powered by two 50-ampere alternators driven by the aircraft's engines. The system also includes a 24-volt lead-acid battery, which provides backup power for critical systems in the event of an alternator failure. The electrical system is controlled and monitored by a central power distribution unit, which ensures that power is distributed efficiently and safely to all the aircraft's electrical systems.

22.1 Cockpit Instrumentation

Cockpit instrumentation design is a critical aspect of aircraft engineering, as it directly impacts the safety and efficiency of flight operations. The design of cockpit instruments is based on a combination of regulatory requirements, human factors considerations, and technological advancements. Modern cockpit instrumentation incorporates advanced digital displays, which offer pilots enhanced situational awareness, improved accuracy, and more efficient decision-making capabilities.

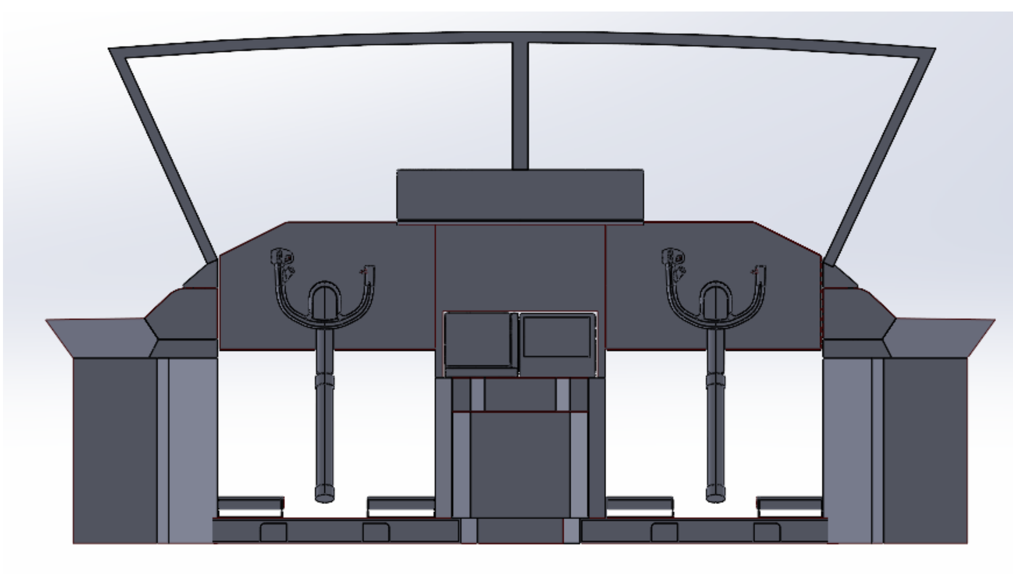


Figure 4 Cockpit Instrumentation

22.2 Anti-Icing System

Anti-icing system is located in the wing leading edge along the whole span for both vertical and horizontal tails to ensure safe operation and prevent fatal flow separation. The anti-icing system is an essential safety feature for operations in cold weather conditions and helps to ensure the aircraft's continued safe operation.

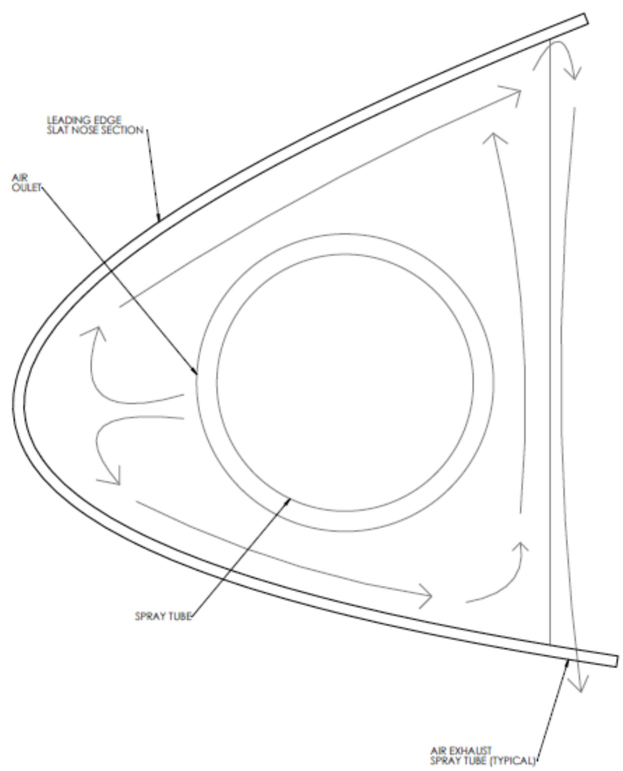


Figure 5 Anti-Icing System

22.3 Antenna Layout

Antenna layout is a crucial aspect of radio frequency (RF) design, as it directly affects the performance of wireless communication systems. Antenna layout involves the positioning and orientation of antennas within a given environment, considering factors such as frequency range, gain, polarization, and interference. The goal of antenna layout is to achieve optimal signal strength and quality, while minimizing the effects of noise and interference. Antenna layout must also take into account practical considerations such as physical size and weight, as well as compatibility with other system components.

22.3.1 Upper Antenna Layout

The choice of upper or lower antenna layout depends on several factors, such as the type of communication system, the frequency range, and the interference profile of the aircraft. Upper antenna layouts are typically used for long-range communication systems, such as satellite communications, where a clear line of sight to the satellite is necessary.

In the figure below shows the location of a TCAS antenna, Two GPS antennas a VHF antenna and a DME Antenna.

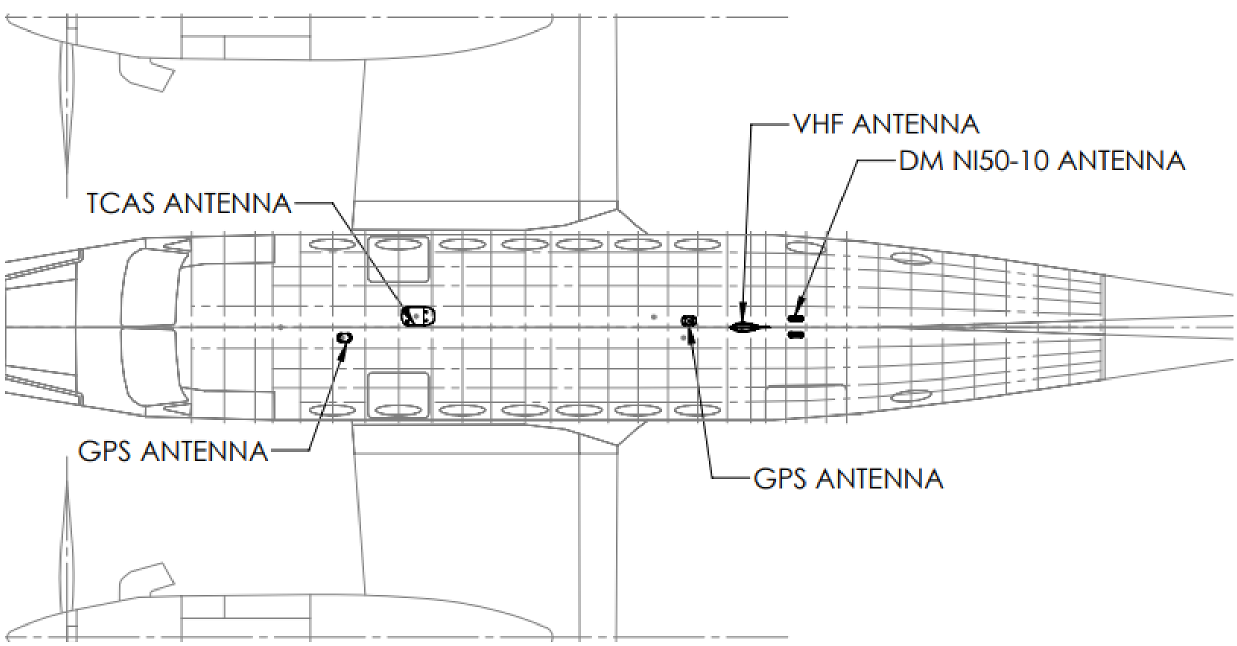


Figure 6 Upper Antenna Layout

22.3.2 <u>Lower Antenna Layout</u>

Lower antenna layouts are commonly used for shorter-range communication systems, such as navigation and surveillance, as they provide a wider coverage area and are less prone to interference from other aircraft components. Here is a list of antennas installed on the lower fuselage.

- ADF antenna
- DME antenna
- Beacon antenna
- Altimeter
- VHF/UHF antenna
- DME antenna

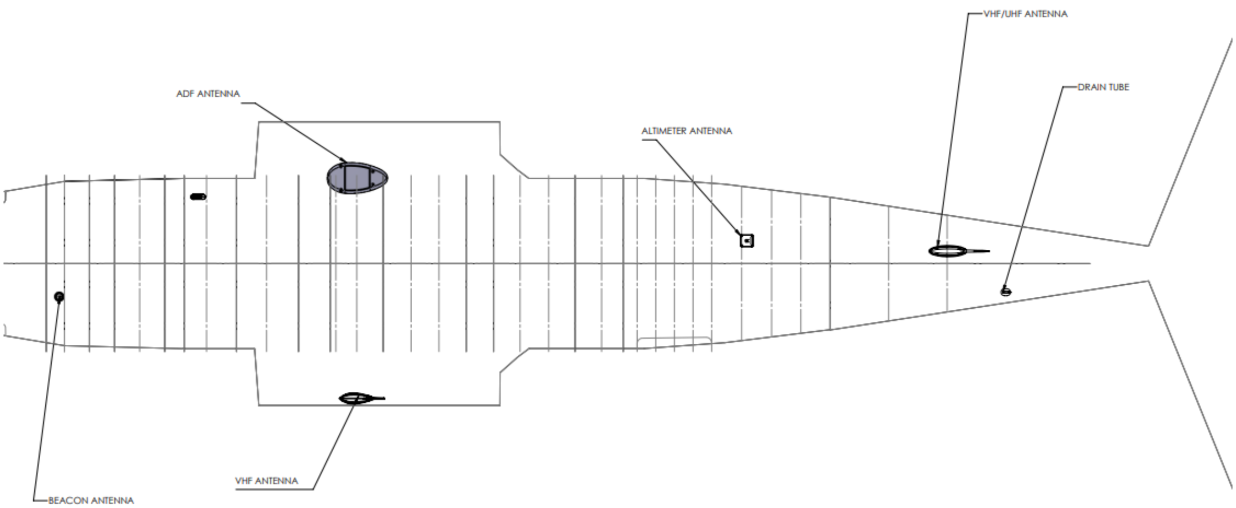


Figure 7 Lower Antenna Layout

23 Class II Stability and Control

The aircraft must exhibit static stability at all operating airspeeds and have a large range of center of gravity (CG) without significant losses in controllability.

AAA was used to perform stability and control analysis, and all the data obtained will be presented below in the following tables.

Table 20 Static Stability

Coefficient	CM_α	CM_q	CY_β	Cn_β	$Cn_{\delta r}$	$Cn_{\delta\alpha}$	Cl_β	Cl_p
Value	-.48	-15.2	3.21	0.112	-.25	-.045	-0.256	0.55

The following table will present the data also obtained from AAA on the analysis of dynamic stability.

Table 21 dynamic Stability

Mode		The Little Goose
Short Period	Damping	.35
	Natural frequency (rad/s)	4.5
Phugoid	Damping	.111
Dutch Roll	Damping	.98
	Natural Frequency (rad/s)	3.2

24 Cost Analysis

Cost analysis determines whether the aircraft will be competitive in the market and how fast is possible to begin getting profit from aircraft manufacturing and selling. The cheapest possible aircraft is desired considering constraints. According to RFP, the little goose shall be available by 2031, so the aircraft cost must be inflated using the following relation.

$$C_i = 1.031^{inflated\ year\ -Current\ year}\ C_c$$

Where:

$$C_i = inflated\ cost$$

$$C_c = Cost\ of\ the\ year\ of\ analysis$$

24.1 Fuel Economy

Results previously showed that little goose demonstrates similar fuel economy comparing to existing aircraft, however it does not outperform them by 21%. Possible solution may be to reduce the aircraft weight by introduction of composite materials and modifications of the wing geometry to increase the glide ratio, so fuel-to-weight ratio may be reduced, and less fuel will be required for the mission to be completed.

Table 22 Fuel per seat

Aircraft Name	Fuel per seat (miles per gal)
Beechcraft 1900D	35.8
Dornier 228	37.8
DHC-6 Twin Otter	34.6
Little Goose	30

24.2 Research, Development, Testing, and Evaluation

The cost of constructing the aircraft was assessed using the Dhc-6 Twin Otter as a reference in terms of 2031 U.S. dollars. A tabulated account of the costs required for all relevant labor associated with aircraft development and production is provided below.

Table 23 Development price per hr

Engineering	60 $/hr
Manufacturing	50 $/hr
Tooling	60 $/hr

It was estimated that 180 aircraft could be produced within a span of five years and be priced at $9.9 million per unit in 2031.

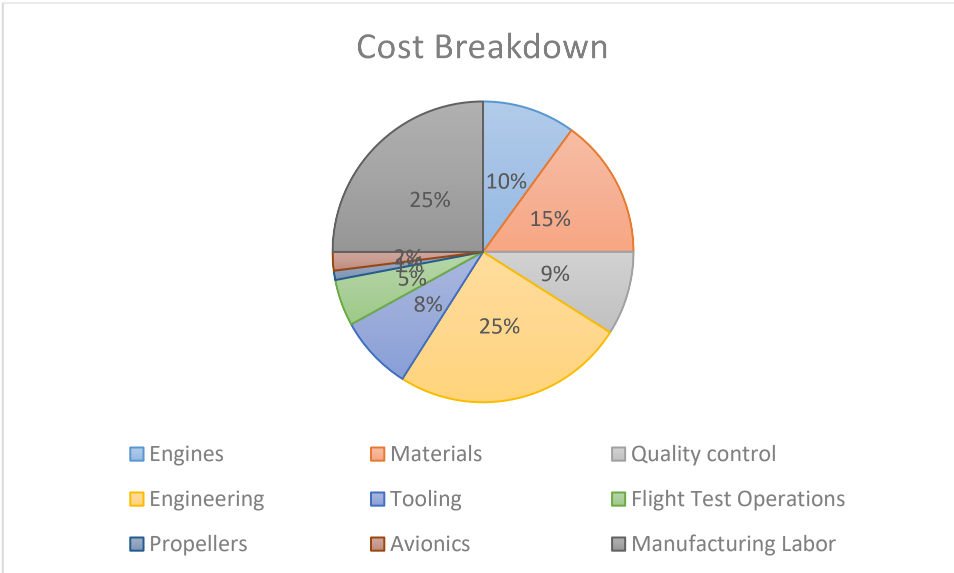


Figure 8 Cost Breakdown

24.3 Operational Costs

The technique outlined by Gudmundsson was utilized to compute the running expenses. The computation took into consideration 500 flight hours every year, 85% power at cruising altitude, an annual storage rate of $1000, JET-A1 fuel cost of $5.2 per gallon, insurance expenses of $8000, and a crew rate of $100 per hour. Consequently, the total yearly operational cost amounts to $900 thousand.

25 Conclusion

The little Goose was the picked configuration with the highest scores of 8 different configurations.

This report presented the final design of the airplane, including its dimensions and internal structure. Also, all the factors considered to arrive at the final design were presented. Although it is true that the number of airplanes that could be provided would be quite small, it is known that there is a highly competitive market for a new airplane like the Little Goose.

In general, the aircraft is expected to be a robust option for medium-range flights with varying airport conditions, offering a viable alternative to existing aircraft models. It is planned to be launched into the market by 2031.

Figure 9 Render Image of the Little Goose

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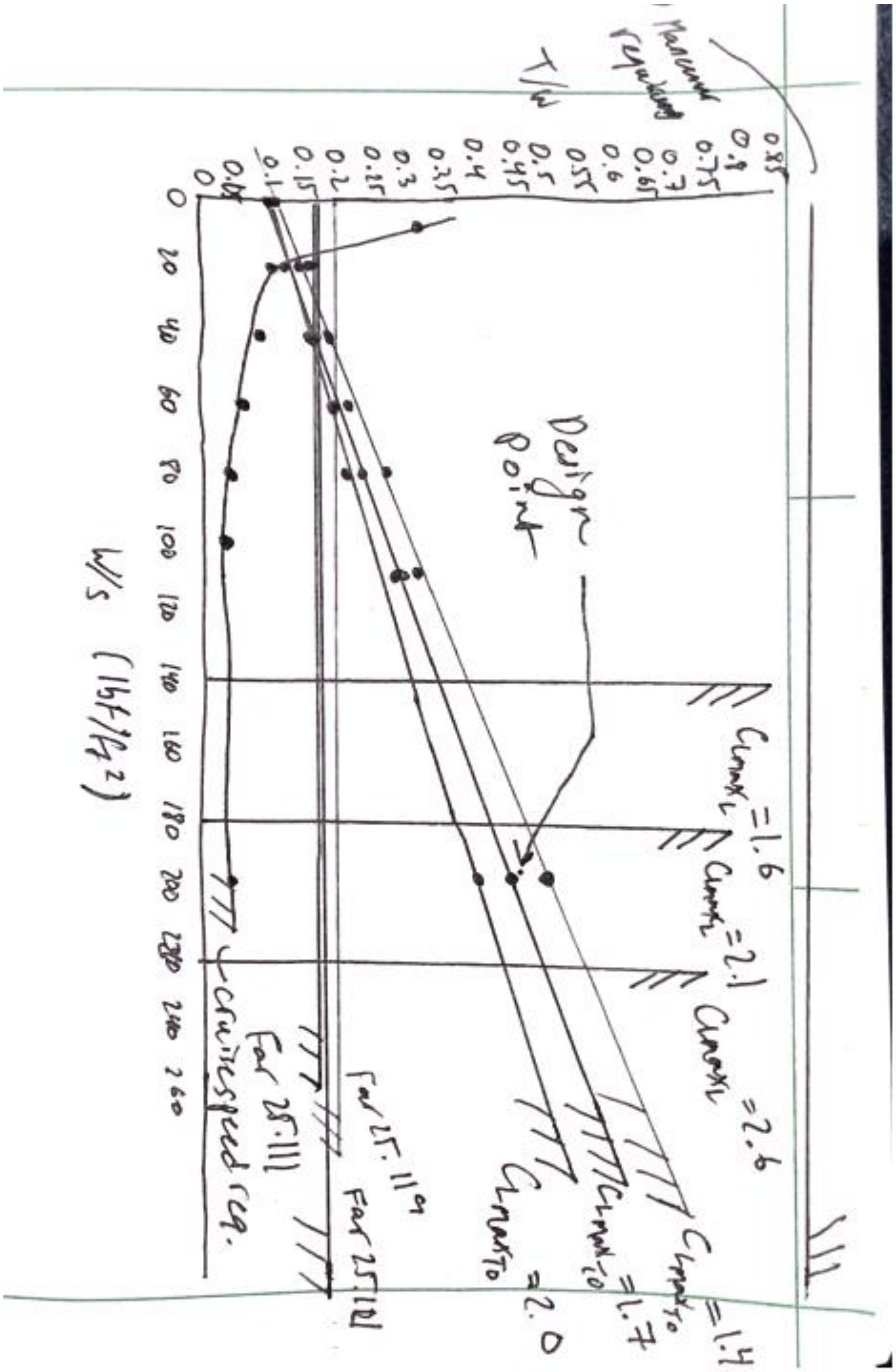
Appendix B

Hand Calculations



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vi.) Speed Constraints

$V_c = 450\text{kts} = 759.514\ \text{ft/s}$

Assuming no compressibility

$$\frac{T}{W} = \frac{q\,C_{D_0}}{(W/S)} + \frac{(W/S)}{q\pi A e}$$

$$q = \frac{1}{2}\rho V^2 = \frac{1}{2}\cdot 0.0023769\ \frac{\text{slug}}{\text{ft}^3}\cdot\left(759.514\ \frac{\text{ft}}{\text{s}}\right)^2$$

$C_{D_0} = 0.00327$ $A = 3.175$ (prior)

$e = 0.825$ ← assume cruise speed is clean value given prior

$$\frac{T}{W} = \frac{3.08412877}{(W/S)} + \frac{(W/S)}{7757.32659}$$

W/S (lbf/ft²)	T/W
10	0.390
20	0.157
40	0.0823
60	0.0591
80	0.0489
100	0.0437
200	0.0412
500	0.0706
700	0.0946
1000	0.132
1500	0.195
2000	0.259

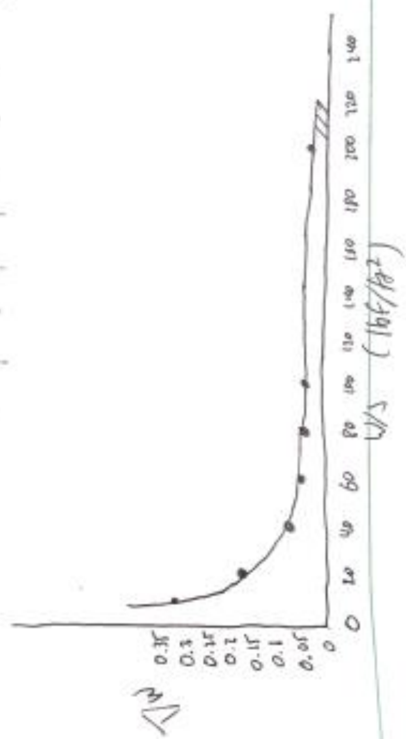

Figure 10 Speed Constraints

iv.) Climb Constraint

assuming two engines all engines operating

$\frac{T}{W} = \frac{1}{L/D} + CGR$ $L/D = 7$ as the results of 8.3 are not likely reliable

FAR 25.111 gives CGR of 1.2%

FAR 25.119 AEO gives CGR of 3.2%

FAR 25.121 gives CGR of 2.1%

$\frac{T}{W} = \frac{1}{7} + 0.012 = 0.155$, FAR 25.111

$\frac{T}{W} = \frac{1}{7} + 0.032 = 0.175$, FAR 25.119 AEO

$\frac{T}{W} = \frac{1}{7} + 0.021 = 0.164$, FAR 25.121

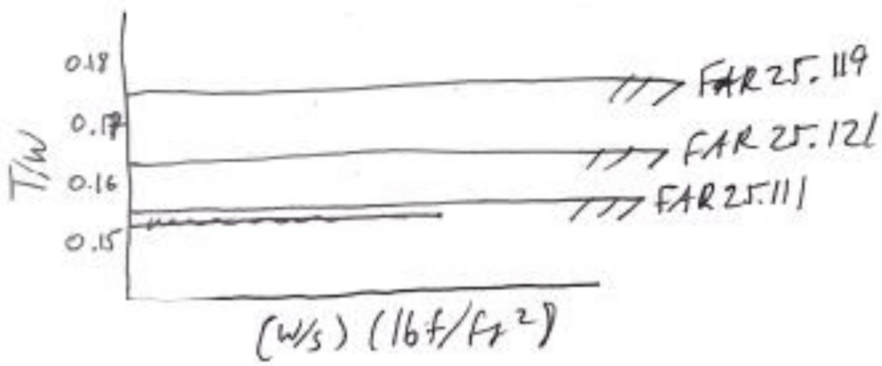

Figure 11 Climb Constraints