UH SB-90 Peregrine Performance and Propulsion Individual Report

Group 11

Role: Performance and Propulsion

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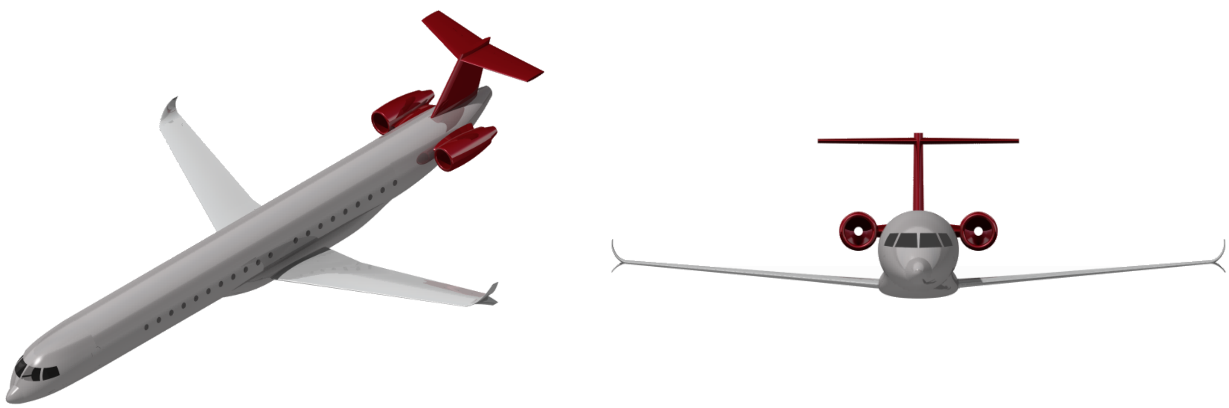

I. Abstract

This report details the development of the UH SB-90 Peregrine aircraft both in terms of performance and propulsion. The engine type and location are selected and justified. Then the calculations for the performance specifications are explained and the results shown and interpreted. These results are compared to the requirement specification to judge the aircraft's suitability to purpose. This aircraft is able to service regional airports with all but the most extreme conditions and is competitive in the market. The performance of the aircraft makes it highly versatile and the increased efficiencies over aircraft currently in operation provides operational savings and increased profit margins.

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IV. Abbreviations and Symbols

$V_{1.}$	Decision speed. Where the takeoff abort and takeoff continue distances are equal.
$V_{LOF.}$	Liftoff speed. Where lift equals weight.
$V_{2.}$	Takeoff speed. A safety speed from which the aircraft can safely climb.
$V_{CR.}$	Cruise speed. The speed that produces the greatest efficiency at that altitude.
IAS. (KIAS)	Indicated airspeed. The airspeed that is displayed by the cockpit instruments. Related to true airspeed by: $TAS = IAS * \sqrt{\frac{\rho}{\rho_{SL}}}$. KIAS is simply the indicated airspeed in knots.
TAS.	True airspeed. The absolute speed of the aircraft relative to the air.
NM.	Nautical Mile. A unit used by convention in the aviation industry equal to 1.852 km or 1.151 miles.
AEO.	All engines operational. The aircraft is operating normally with both engines running.
OEI.	One engine inoperable. One of the two engines is no longer producing thrust.
FOD.	Foreign object debris. An object from the surroundings that is in some way interfering with the aircraft. Usually denoted as a hazard.
APR thrust.	Automatic power reserve thrust. This thrust level is used in emergencies when more thrust is needed than is normally available from the engines.
ISA.	International standard atmosphere. This is an internationally agreed standard for the properties of air for certain altitudes and temperatures. ISA SL conditions typically refer to air densities of 1.225 kg/m^3 at 15°C.
BFL	Balanced field length. This is a critical safety distance defined as the shortest runway length which a safe takeoff can be performed.
ATC	Air traffic control. They are responsible for the directing of aircraft on the ground and in the air.
MTOW	Maximum takeoff weight. The absolute heaviest the aircraft can be to get airborne.
MZFW	Maximum zero fuel weight. The heaviest the aircraft can be without any fuel loaded.
MOEW	Maximum operational empty weight. The maximum weight of the aircraft without any passengers or payload. And with the maximum amount of fuel.
TSFC / SFC	Thrust specific fuel consumption, otherwise known as specific fuel consumption is the mass flow rate of fuel supplied to the engines divided by the thrust they are producing. It is also known as the propulsive efficiency.

1. Introduction

This report details the conceptual design of a regional jet. The timespan given prohibits an in depth design of the aircraft; however the results and findings of this report coupled with the other reports should give any potential investors sufficient information to decide whether to continue development of the aircraft.

1.1. Design Philosophy

The chosen philosophy to which the design decisions are being made will be given in this section. The philosophy was chosen by the group as the best tactic to tackle the requirement specification and make the aircraft suitable for purpose.

“To innovate a new short-range aircraft model with a maximum operational range of 1250 nautical miles. With a focus on performance and lightweight design through use of composite materials and operational optimisation for rapid turn-around time to ensure the highest levels of short-haul competitive operational dynamics.”

The chosen design philosophy shows the approach the team have taken to ensure the requirement specification is met. In general terms the approach is to favour large passenger flow rather than higher efficiency to result in increased profits. Efforts to increase the efficiency of the aircraft are to be made only if they don’t result in a lower passenger throughput.

1.2. Requirement Specification

Below is listed the given requirement specification around which the whole aircraft has been designed:

1. Seat capacity between **70** and **100 passengers**.
2. Minimum range of **750 nautical miles** with **70 passengers**.
3. Be able to carry freight in **standard sized containers**.
4. Be able to **take off and land** at **regional airport runways** at world locations associated with target airline customers.
5. Be able to **operate alongside other commercial aircraft** at flight speeds and altitudes acceptable to Air Traffic Control.
6. Be able to operate to an **airport turnaround time** of no more than **30 minutes.**
7. Have a fully accounted **fuel burn per mile** substantially better than for existing aircraft serving these markets.
8. Demonstrate operating costs (**per revenue passenger mile**) that are significantly better than those of existing aircraft serving these markets.
9. Have provision for later changes to the aircraft specification to allow ‘stretched’ and ‘shrunk’ versions to **suit evolving market needs**.
10. Be designed to comply with appropriate European standards for commercial passenger carrying aircraft, **EASA document CS-25**.

To achieve this requirement specification a few factors must be met from a performance standpoint. A design range must be calculated such that it is able to service as many city pairs as possible. A design range that is too large forces the aircraft to compete with larger aircraft more suited to international flights. Regional runways present further problems in that the aircraft must have a high thrust-to-weight ratio in order to be able to take off from short runways. These runways may not have the airport services of the larger airports.

Having increased capabilities necessitates the use of new technologies to increase the performance of the aircraft against current technology in service. The aviation industry is notorious for the slow acceptance and implementation of new technologies. So the suggestion of future technologies such as electric aircraft or boundary layer ingestion technology is outside of the scope of development inside the timeframe.

1.3. Capabilities

From the requirement specification some of the capabilities of the aircraft can be surmised. To be able to service city pairs effectively, the aircraft must be efficient propulsively; aerodynamically; and most of all financially. Propulsive efficiency means either using turboprop engines for their increased efficiency or taking advantage of the fact that turbojets become more efficient with increasing size due to an increased bypass ratio. Financially both turbojets and turboprops have their merits and this will be discussed later in the report.

Being able to service regional airports means the aircraft needs to be able to cope with subpar conditions on takeoff and landing; shorter runways, increased runway debris and a more extreme range of conditions - such as airfield altitude, temperature and crosswinds.
The airfield is also unlikely to have the same degree of services as large international airports such as passenger boarding bridges, which means that boarding would take longer and thus reduce the turnaround time.

1.4. Resources

There are several pieces of computer software that can enhance and simplify the calculations to determine the performance metrics. The resources used in the calculation of the performance of the aircraft are as follows.

The calculations and graphs were done using Mathworks' Matlab R2018b version. The program allows the creation of mathematical algorithms that can automatically calculate performance values consistently and reliably. It can also generate graphs and figures. It allows for a greater level of precision than could be achieved by hand calculations or even using spreadsheets. Examples of Matlab M-Code can be found in Appendix A.

The storage and communication of key specification data was handled by Google Sheets via shared Google Drive. This allowed all members of the group to have access to and modify any of the aircraft metrics as well as perform calculations using constantly updating values. Thus making sure that each member of the group as using the most up-to-date values. Two change control processes are in place to prevent unauthorised changes to values.

2. Decisions

This section will detail the key performance and propulsion decisions for the aircraft in order for it to meet the requirements; as well as the justifications for each of those decisions.

2.1. Engine Type

The choice of engine is a critical decision for the aircraft. It dictates pretty much all of the performance metrics as well as other factors ranging from passenger comfort to undercarriage height. The first key decision in choosing the engines is the type of engine being used.
The main engine variants are *turbofan, turboprop and propfan,* with a near future technology known as *boundary layer ingestion turbofans.* But as these are largely theoretical currently they have been discounted as a valid option.

Turbofans are a good option as they have reasonable efficiencies and large thrusts. They also allow the aircraft to travel at much higher speeds, meaning journey times are shorter and the range of the aircraft is also larger. They are very well developed with new technologies being developed such as geared turbofans which promise to increase the efficiency further.

Turboprops are another very valid option owing to their increased efficiencies over turbofans. Meaning they have a lower fuel cost and therefore cheaper operating costs. However they are limited in speed due to shockwave effects occurring on the blades of the turboprop when it attempts to travel too quickly.

Propfans are another emerging technology, albeit a more conventional one. They have a greater efficiency than even turboprops. There are inherent problems with them however, they are louder than is allowed by airport regulation and they have problems with blade containment in the event of a failure. Both propfans and turbofans have another problem which is public perception. Turboprops are seen as outdated technology despite their efficiency savings.

Overall the turbofan is the engine that has been selected going forward. This choice is based off of several factors. Increased efficiency of turbofans using gearing technology allows for less fuel requirement than previously. Faster airspeeds mean more flights can be flown in the same duration; thus increasing the revenue in the duration. The increased thrust from a turbofan also means that takeoff distances can be reduced to a level where regional runways become feasible. Another benefit of the increased thrust of a turbofan is that in the event of one engine inoperable (OEI) operation the aircraft can still maintain an altitude that is sufficient to operate at the higher ground altitudes of Asia and the mountain ranges of the Himalayas and the Alps.

2.2. Engine Placement

Likewise the placement of the engines on the airframe is also a key decision for the performance of the aircraft. There is the underwing design favoured by the majority of recent mid-to-large aircraft and the fuselage mounted design favoured by business jets and small-to-medium aircraft. Older aircraft such as the McDonnell Douglas DC10 have two fuselage mounted engines and a single engine inset into the vertical stabiliser.

Figure 1 McDonnell Douglass DC10

Underwing mounting would seem like a good option for any modern aircraft. It provides a weight to the wing to counter the stresses from the lift generated and places the typically heavy engines along the centre of mass. They also place the engines father away from the cabin which reduces the noise in the cabin and the vibration through the structure -as the wings act to damp this vibration. Underwing mounting naturally necessitates a taller aircraft, which for an aircraft frequenting larger airports this isn't an issue. However regional runways are unlikely to have the scale of services of a larger airport and so unloading a taller aircraft would likely take longer; rendering it unable to fulfil the 30 minute turnaround time. Regional runways are also unlikely to have the same level of upkeep as bigger airports and as such foreign object debris (FOD) becomes an issue. Underwing engines are much closer to the ground and the suction generated by the intake can cause FOD to be ingested causing damage and necessitating increased maintenance. On the topic of maintenance, underwing engines are easier to access and maintain. Possibly reducing the maintenance time for engine repairs. It is unlikely though that this outweighs the increased need for maintenance.

Fuselage mounted engines do provide attractive benefits for a regional jet. They have better characteristics for smaller airfields. The problems attributed to rear mounted engines are ones that can be surmounted with careful design. The wing bending can be solved by careful fuel management and structural considerations. Having heavy engines at the rear of the aircraft causes the centre of mass to be shifted aft; a solution to this is to move the wings further back to move the centre of lift closer to the centre of mass. One further unaddressed problem is that having fuselage mounted engines necessitates the use of either a T-tail or a cruciform tail layout; this is because the tailplane needs to be out of the jet exhaust to prevent unwanted aerodynamic effects and damage. This in-and-of itself is not an issue, but T-tails tend to have undesirable stall characteristics such as entering into a deep stall. Deep stalls can be prevented by use of flight control systems that prevent the pilots from triggering a maneuver that would result in a deep stall condition. Fuselage mounted engines also perform better under OEI conditions, owing to their closer proximity to the centre line of the aircraft meaning the moment on the aircraft is smaller; requiring less rudder deflection to counter and thus lesser drag.

The decision was made going forward that fuselage mounted engines would be used for the aircraft due to their superior features when dealing with shorter regional runways and the possible decrease of turnaround time. The idea being that the combination of short turnaround times from fuselage mounting and the additional speed of using turbojets will ultimately garner more profit than the losses associated with using less efficient engines.

2.3. Engine Selection

The next choice available was the choice of engines currently in production. The main companies producing turbojets are Rolls Royce (RR), Pratt & Whitney (P&W) and General Electric (GE).

Both P&W and RR are currently designing geared turbofans which promise to improve the efficiency by around 15%. For RR these plans are being rolled out for only the larger turbofans while P&W are designing smaller turbofans for regional jets. The P&W 1200g is currently being designed for the Mitsubishi regional jet. The issue with P&W engines is that they provide precious little data as can be seen in figure 2**.**

Name	Maximum Take-Off Thrust	Specific fuel consumption 35K/0.8 Mn max cruise	Bypass Ratio	Maximum overall pressure ratio	Thrust/Weight Ratio	Fan Diameter	Maximum Diameter	Length	Weight	TSFC
GE CF34-10E	90.57 kN	0.64	5.4:1	29:1	5.4:1	1.35 m	1.45 m	3.68 m	1,678.29 kg	17.6E-06
GE CF34-10A	78.47 kN	0.65	5:1	29:1	5.1:1	1.35 m	1.45 m	2.29 m	1,678.29 kg	17.6E-06
GE CF34-8E	64.50 kN	0.68	5:1	28.5:1	5.6:1	1.17 m	1.35 m	3.07 m	1,179.34 kg	Unk.
P&W PW6000	105.87 kN	Unk.	4.8:1	28.2:1	Unk.	1.44 m	Unk.	2.74 m	2,288.83 kg	Unk.
P&W PW1200G	71.17 kN	Unk.	9:1	Unk.	Unk.	1.42 m	Unk.	Unk.	Unk.	Unk.
P&W PW1700G	68.95 kN	Unk.	9:1	Unk.	Unk.	1.42 m	Unk.	Unk.	Unk.	Unk.
P&W PW1900	93.41 kN	Unk.	12:1	Unk.	Unk.	1.85 m	Unk.	Unk.	Unk.	Unk.
P&W PW1500G	97.86 kN	Unk.	12:1	Unk.	Unk.	1.85 m	Unk.	Unk.	Unk.	Unk.
P&W PW1100G-JM	126.77 kN	Unk.	12:1	Unk.	Unk.	2.06 m	Unk.	Unk.	Unk.	Unk.
P&W PW1400G-JM	131.22 kN	Unk.	12:1	Unk.	Unk.	2.06 m	Unk.	Unk.	Unk.	Unk.
RR AE3007	35.85 kN	Unk.	5:1	23:1	Unk.	0.98 m	Unk.	Unk.	Unk.	18.1E-06
RR BR725	75.20 kN	Unk.	4.1:1	Unk.	4.69:1	1.27 m	Unk.	3.30 m	1,635.20 kg	18.1E-06
RR BR715	95.33 kN	Unk.	Unk.	Unk.	4.66:1	1.47 m	Unk.	3.74 m	2,085.00 kg	18.1E-06
RR Tay 620-15	62.82 kN	Unk.	3.04:1	Unk.	4.2:1	1.12 m	Unk.	2.41 m	1,501.40 kg	19.5E-06

Figure 2 Table of in service turbofan engines.

The choices for the engines therefore are limited to GE and RR, with the GE engines looking more favourable both performance wise and due to the availability of technical specifications. A larger engine would provide favourable takeoff performance and provide more versatility in a OEI scenario. The GE CF34-10E and 10A are excellent candidates providing high thrust and low fuel consumption. The CF34-10E has higher thrust and a better fuel consumption than the 10A and therefore is a better candidate and will be taken forward. However because the 10A and 10E have identical masses and dimensions they could easily be exchanged if so desired.

Now the engine model has been selected the subvariant can be chosen. The figure below details the specification of the individual variants of the engine.

Name	Maximum Takeoff	Normal Takeoff	Maximum Continuous	Maximum Takeoff Temperature	Maximum Continuous Temperature
GE CF34-10E2A1	75.44 kN	75.44 kN	67.21 kN	30.00 C	25.00 C
GE CF34-10E5	83.72 kN	77.35 kN	75.80 kN	30.00 C	25.00 C
GE CF34-10EA1	83.72 kN	83.72 kN	75.80 kN	30.00 C	25.00 C
GE CF34-10E6	83.72 kN	77.35 kN	75.80 kN	35.00 C	25.00 C
GE CF34-10E6A1	83.72 kN	83.72 kN	75.80 kN	35.00 C	25.00 C
GE CF34-10E7	90.57 kN	83.72 kN	75.80 kN	30.00 C	25.00 C
GE CF34-10E7-B	90.57 kN	83.72 kN	75.80 kN	30.00 C	25.00 C

Figure 3 GE CF34-10E Subvariants Table

Each variant has different thrust characteristics and operational temperatures; the temperatures being the key factor here for deciding the variant to go forward. The 10E6 and 10E6A1 both have a higher maximum takeoff temperature which would allow the aircraft to continue operation in hotter climates such as southern Europe and Asia. The subvariant selected was therefore the GE CF34-10E6 because of its temperature tolerance and range of takeoff thrusts which would prove useful over the range of conditions the aircraft will encounter.

3. Calculations

In this section, the major calculations of aircraft performance will be described and explained here. As well as giving the results of the calculations in the form of tables and graphs which again will be explained to show their relevance to the aircraft and how they should be interpreted.

3.1. Thrust

In this section the thrust will be reviewed throughout the flight envelope to ensure it is sufficient. The thrust lapse will also be calculated; thrust lapse being how thrust reduces with increasing altitude and mach number.

3.1.1 Thrust Provision

Flight Envelope	Thrust	Throttle Position	Thrust to Weight
Takeoff (Normal)	34,778 lbf / 154.7 kN	92%	0.526
Takeoff (Engine failure after V1)	18,821 lbf / 83.72 kN	100% (APR)	0.284
Climb	17041 lbf / 75.8 kN	45%	0.258
Typical Cruise (12 km)	5845 lbf / 26.0 kN	60%	0.088
Descent & Approach	1.12 lbf / 5 kN	3% (Idle)	0.017

Figure 4 Table of thrust values throughout flight envelope

APR thrust is the emergency maximum thrust the engines can provide. During normal takeoff with both engines running this thrust level would not be used; however in the event of an engine

failing after the aircraft has reached V1, this thrust level would be used. The value for climb thrust will be discussed in section 3.6. The cruise thrust throttle position takes into account thrust lapse at that cruise altitude and speed resulting in a larger throttle position than would be expected.
The thrust-to-weight ratios being so high is a natural consequence of choosing larger engines in order to shorten the takeoff field length. While these may seem very high compared to aircraft such as the airbus a320 with a value of 0.3084 (Source 8) it is important to remember that the aircraft need only operate under this high thrust regime on takeoff. The climb and cruise values show that once airborne the aircraft can throttle back to decrease the fuel burn. Larger turbofan engines typically yield higher efficiencies and so operating larger turbofans at lower relative thrust would result in a more efficient aircraft than one with smaller turbofans running at high relative thrust. The benefits of larger engines can be outweighed however if the engines produce more drag or increase the weight of the aircraft sufficiently.

3.1.2 Thrust Lapse Rate

As altitude and mach number increase, the available thrust reduces. With increased altitude comes reduced air density, this affects the air mass flow through the engine; which is directly proportional to thrust. Additionally the larger the change of velocity across the engine, the larger the thrust. One equation found in literature (source 2) estimates this relationship and the equation is detailed here: $T = T_{SL}(\frac{\rho_{ALT}}{\rho_{SL}})(1 + kM)$

where T_{SL} = Takeoff thrust (sea level), ρ = air density, M = mach number, k = constant between -0.1 and -0.9.

All this culminates in a thrust lapse rate which for the chosen engines are displayed below in figure 5. As can be seen, the thrust variation at sea level is much greater than at 12,000 m meaning that at higher altitudes, the difference between the thrust at a range of speeds is not as significant. This also indicates that thrust lapse rate is more significant at takeoff and must be factored into the calculations. The lapse rate is also important when calculating the ceiling heights, as without it the ceiling would be much higher than actually possible.

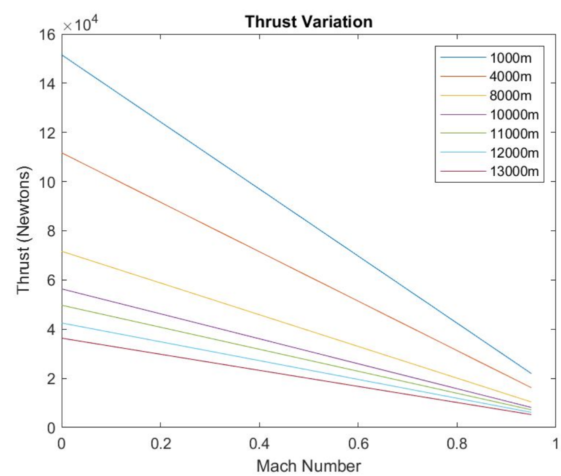

Figure 5 Thrust Lapse Rate for altitudes and mach numbers

3.2. Design Range

Before any calculations of can be made for the aircraft it would be prudent to have design goals in mind beforehand. The requirement specification gives a minimum range of 750 nautical miles but no maximum range. Obviously for a regional jet the range needn't be too high as the idea is that the aircraft only ferries passengers between transportation hubs. To get the design range several of Europe's largest regional airlines were picked and their main hubs located. Then using the website.asroutemap.info the number of airports within a set range of those hubs was found.

Airline	Main City Hub	Flight Range Brackets (Nautical Mile)							
		750	900	1050	1200	1350	1500	1650	1800
Aegean Air	Athens	154	210	279	346	419	476	540	578
	Birmingham	215	256	308	355	387	418	442	463
Flybe	Manchester	200	250	295	343	380	409	438	459
Air Dolomiti	Verona	264	329	363	398	436	482	514	543
Air Malta	Malta	140	191	265	335	389	447	494	533
Air Nostrum	Valencia	167	221	265	313	356	380	409	460
LuxAir	Luxembourg	258	309	352	391	421	446	485	518
S7 Airlines	Moscow	89	145	224	315	390	463	528	564
Atlas Global	Istanbul	164	217	280	366	425	495	556	597
Air Serbia	Belgrade	218	291	372	440	491	522	547	566
CSA Czech	Prague	261	335	384	424	467	498	521	541
	European Average:	193.6	250.4	307.9	366.0	414.6	457.8	497.6	529.3

Figure 6 Airline range study table

An average was found for each range bracket and the graph plotted. The graph was used to find the gradient; as a decrease in gradient denotes a drop off in the number of airports within the range. For the European market this drop off occurs between 1200 and 1350 nautical miles.

This manner of range study was repeated for each continent, with specific emphasis on Europe and Asia as these are the target markets. The general outcome of this range study was that Europe and Asia drop off around 1250 nautical miles while the Americas, Africa and Oceania drop off between 1350 and 1500 nautical miles. Therefore it would be ideal to design two variants of the aircraft: the principle design having a range of 1250 nautical miles and an extended range version that has a range of over 1400 nautical miles at least.

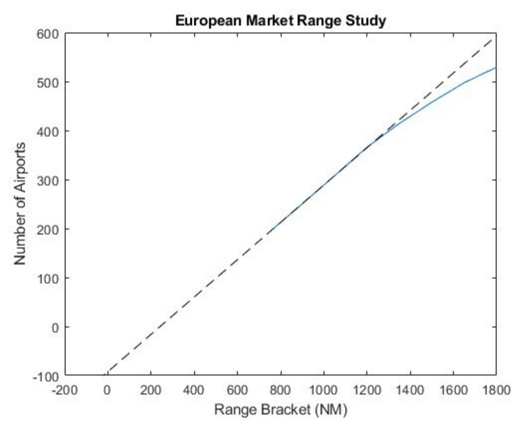

Figure 7 Airline range study graph

Further to the extended range variant is the United States scope clause that states that a regional aircraft should have at most 76 passengers. Therefore in order for the extended range variant to include operation in the US it must conform to this certification. The decreasing passenger mass does allow for the possibility of adding more fuel to extend the range. It may be possible to create an extended range variant without significant external modification; rather just changing the cabin layout by adding two classes rather than the standard single class system on the principal variant. This provides versatility to airlines allowing them to change the internal layout to suit their needs and also increasing their range to open up new routes.

3.3. Takeoff

The takeoff distance is arguably one of the most important metrics for the entire aircraft, considering that it determines whether or not it can fulfill criterion 4 and operate out of regional runways. It is highly affected by a multitude of factors among which are the runway altitude, aircraft takeoff mass and runway temperature. The aim is to have a sufficiently small takeoff field length that regardless of those factors, the aircraft can still take off safely. This opens up a multitude of regional runways which tend to be approximately 2400 m on average. The graph below shows the research gathered on regional runway lengths across Europe and Asia.

From the graph the mean runway length is 2401 m (7877.3 ft) and has a standard deviation of 554 m (1817.6 ft). Therefore to service regional runways the aircraft should have a takeoff and landing distance within 1 standard deviation of the mean value to access as many runways as possible. The goal value then is 1847 m (6059.7 ft).

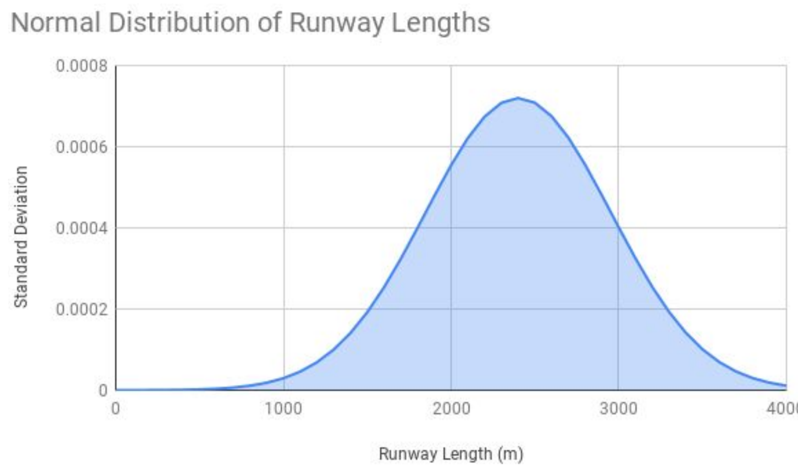

Figure 8 Runway Length distribution

Performing the calculation using value of takeoff lift coefficient given by the aerodynamics specialist of 2.6 the takeoff distances at across several airfield altitudes are given in figure 9.

Airfield Altitude	Takeoff Field Length
SL (0m)	1250.8 m / 4103.7 ft
1000 m	1350.5 m / 4430.8 ft
2000 m	1465.1 m / 4806.4 ft
3000 m	1594.9 m / 5232.6 ft
4000 m	1746.6 m / 5730.3 ft

Figure 9 Table of Takeoff Field Lengths

Note that all of these values were calculated at maximum takeoff weight, however runway temperature was considered to be 15°C. Meaning that while figure 8 infers that the aircraft should be able to take off within the requirements set by the runway study, a combination of takeoff mass, runway altitude and temperature may collate to push the takeoff field length above 1847 m. In this case two steps can be implemented to overcome this: the airline could leave empty seats on the aircraft or not completely fill the aircraft full of fuel to reduce the takeoff mass; or the pilot could decide to sacrifice efficiency and use APR thrust.

3.4. Landing

The next set of calculations to be performed in order to confirm criterion 4 is secure, is to calculate the landing field lengths of the aircraft. Certification states that the aircraft must be able to stop on the runway without the use of thrust reversers or lift spoiling devices.

3.4.1. Thrust Reversers

These devices are fitted to the engines of aircraft in order to generate thrust counter to the motion of the aircraft rather than with the motion as usual. There are two main methods of thrust reversal for turbojets. The first method is somewhat antiquated on modern turbofans and was more popular on older turbojets and low bypass turbofans. This method is the bucket thrust reverser and involves placing a scoop in the exhaust stream of the jet to redirect the thrust forwards.

The second method is called cold stream thrust reversal and is more commonplace on modern turbofans because it uses the bypass air (the air from the fan that bypasses the core and is not burned). Modern turbofans typically have high bypass ratios and therefore this method takes the relatively larger mass of cold air and redirects that instead. Doors in the bypass duct open to expose thrust reverse vanes which redirect the air backwards. Figure 10 shows this process. These are the thrust reversers that are equipped to the aircraft.

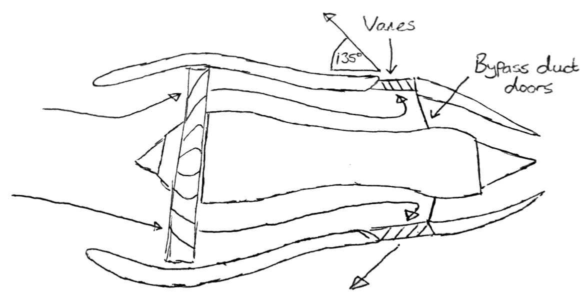

Figure 10 Diagram of the operation of thrust reversers.

3.4.2. Lift Spoilers

On touchdown the aircraft is still travelling fast enough to be able to lift off again, this is partially so that if the landing goes wrong the aircraft can take off again and perform a go around maneuver. If the landing does go well however the lift from the wings reduces the contact of the wheels with the ground and therefore the braking efficiency. To counter this, lift dumping spoilers can be deployed to greatly reduce the lift generated by the wing and also increase the drag. The aircraft is equipped with a set of multi-role spoilers that function as both lift dumpers when landing and as a method of increasing the descent rate without increasing airspeed. The flight electronics can also use the spoilers asymmetrically to roll the aircraft if necessary.

The landing distance therefore is more a function of the braking power and is independent of thrust where the certification landing distance is concerned. Runway conditions also affect the stopping distance, headwings would allow the aircraft to have a lower ground speed and provide greater drag, reducing the distance. Likewise a tailwind would increase the landing field length. Snow and rain can also affect the stopping distance by causing hydroplaning. Hydroplaning is

where the fluid creates a thin film between the tyres and the runway which has lesser friction and therefore the braking force is smaller and the aircraft takes longer to stop.
These conditions are outside of the scope of the certified landing distance and constitute a scenario where thrust reversers would be used.

For regular conditions, the landing field length is given in figure 11 across a range of altitudes as with takeoff distance. These distances do not include the use of thrust reversers and spoilers as per certification requirements.

Airfield Altitude	Landing Field Length
Sea Level	2736 ft / 834 m
3281 ft / 1000 m	3015 ft / 919 m
6562 ft / 2000 m	3330 ft / 1015 m
9843 ft / 3000 m	3681 ft / 1122 m
13,123 ft / 4000 m	4088 ft / 1246 m

Figure 11 Table of landing field lengths with altitude.

Source 3 gives the factors that can be applied to the landing field length to estimate the effect of different runway conditions and allowances for pilot error. These factors are tabled in figure 12 below. These factors are being applied to the actual runway distance at ISA sea level conditions.

Factor	Landing Field Length
Actual Runway Length (1.00)	2736 ft / 834 m
Regulatory Runway Length (Dry) (1.67)	4570 ft / 1393 m
Regulatory Runway Length (Wet) (1.92)	5253 ft / 1601 m
Wet Runway (1.4)	3832 ft / 1168 m
Slush / Standing Water (2.3)	6293 ft / 1918 m
Icy Runway (4.5)	12314 ft / 3753 m
Overspeed of 10% (1.2)	3284 ft / 1001 m
Crossing threshold at +50% Altitude (+1000 m)	6017 ft / 1834 m

Figure 12 Table of the effect of runway conditions on landing field length

As can be seen from the table, the runway conditions have to either be extreme (ice or standing water) or a combination of multiple factors in order for the landing distance to be above the goal landing field length of 1847 m stated in section 3.2.

3.5. Balanced Field Length

In order for aircraft to be certified, the takeoff distance is not important. What is important is the ability of the aircraft to accelerate down the runway, then if an engine were to fail the aircraft must be able to either continue its takeoff or abort and slow down. All without running off the end of the runway. This is known as the balanced field length (BFL) and is defined as the distance for an aircraft to accelerate to the decision speed V1 then either slow down or continue takeoff. The decision speed is clearly important here and is defined as the speed where the distance to continue the takeoff and come to a stop are the same if one engine fails during takeoff. In order to calculate the balanced field length V1 is required. The difficulty is that V1 and the BFL are difficult values to separate, usually requiring estimations or trial and error. It is possible to use symbolic rearrangement to analytically find V1 and hence the BFL without having to estimate. This is the method used in this report for its enhanced accuracy.

There are several factors that affect the BFL, the main ones being takeoff mass, runway altitude and runway temperature. As the aircraft has been designed with the Asian market in mind the runway altitude is a large consideration. Because the aircraft must be able to operate from short regional runways that are potentially at high altitude at a range of temperatures; the high levels of thrust can be justified.

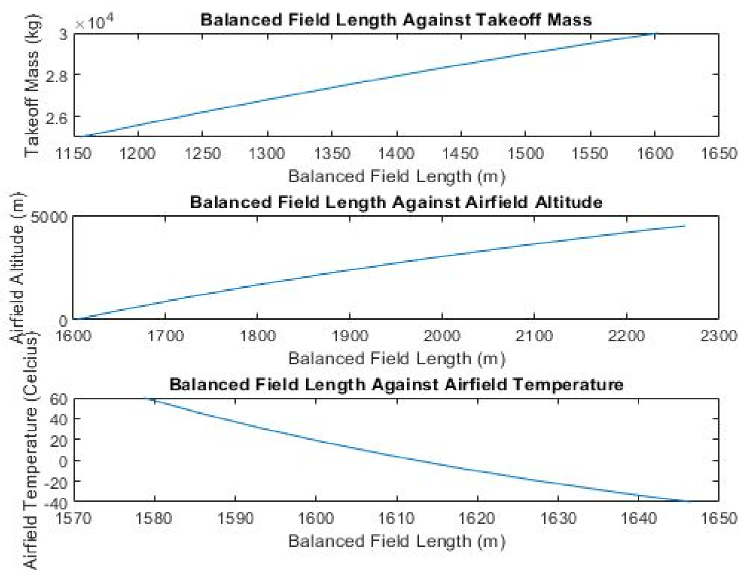

Figure 13 Balanced field length variation.

As can be seen from figure 13 the aircraft is entirely able to operate on essentially any airport with a runway of over 3000m (, regardless of conditions. This gives the aircraft great versatility on high altitude airfields and also means that on longer runways the aircraft can be throttled back to conserve fuel even on takeoff. The runway performance of the aircraft is detailed in figure 14 below.

Altitude	Balanced Field Length	V1
Sea Level	4836 ft / 1,474.00 m	117.2 kts / 217.1 km/h
6562 ft / 2000 m	6077 ft / 1852.3 m	128.5 kts / 237.96 km/h
13,123 ft / 4000 m	7305 ft / 2,226.53 m	143.65 kts / 266.04 km/h

Figure 14 Table of balanced field lengths and decision speeds.

Higher altitude airports tend to have longer runways to accommodate the longer takeoff and landing field lengths of the aircraft that service them; which tend to include larger medium to long haul aircraft. In the event of an airfield which has an elevation and runway length that result in the aircraft being unable to take off, the passenger load can simply be reduced. In conjunction with the increased APR thrust available to pilots, this aircraft is suitably designed to service any airport that the equivalent turboprop aircraft could handle.

3.6. Climb

There are two key modes of climbing flight that both need to be considered. These are best angle of climb and best rate of climb. Best angle allows the aircraft to gain the most altitude in the least horizontal distance in order to avoid obstacles and reduce noise. Once at sufficient altitude to avoid hazards (~1500 ft) the aircraft switches to best rate of climb. This climb profile allows the aircraft to climb to cruise altitude in the least time; thus reducing the fuel burn.

Ideally the aircraft would climb at the speed that created the largest climb rate for this mode; however in practice this would require the pilot to constantly make throttle adjustments. For practicality the aircraft instead climbs at a constant indicated airspeed to ease the workload of the pilot. The calculations done in this section takes a range of indicated airspeeds and finds the one that results in the quickest climb time; corresponding to a close approximation of the best rate of climb speed. Figure 15 below shows how the time to height varies with indicated airspeed and how the optimum airspeed was selected.

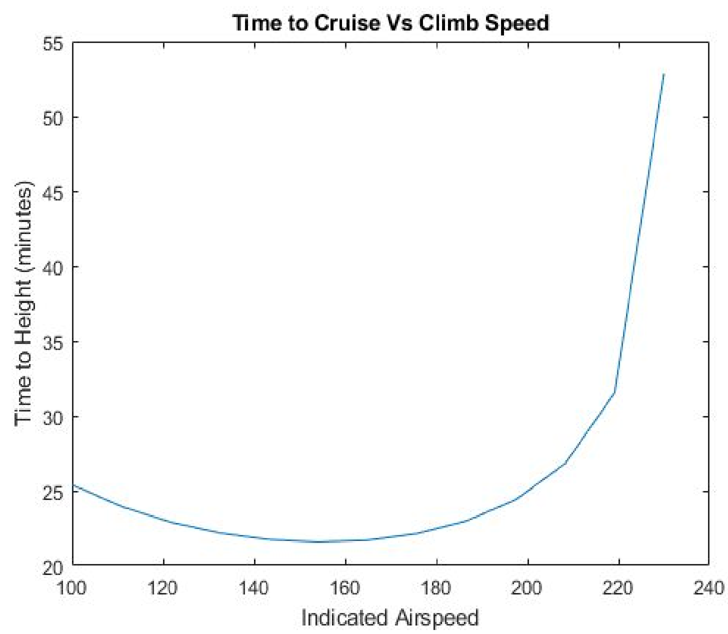

Figure 15 Graph to show optimum climb airspeed.

From the graph it is clear that there is an optimum speed that results in the lowest time to height. This turns out to be around 165 KIAS. Note this graph is using climb thrust stated in section 3.1.1 rather than full thrust to both reduce fuel burn and increase operational life. The time to height at maximum continuous thrust is 10 minutes while at climb thrust this time is increased to 20 minutes. This allows the cabin to pressurise slower and therefore reduce the ring stress on it, extending its operational life. Also reducing the thrust has a marked effect on fuel burn. Figure 16 shows the performance of the aircraft during normal climb.

Optimum Climb Speed	Time to Height	Horizontal Distance	Thrust
172 KIAS	21.11 min	65.47 NM / 121 km	17041 lbf / 75.8 kN

Figure 16 Table of typical climb data.

3.7. Descent and Approach

The descent of aircraft is usually dictated by air traffic control (ATC) meaning continuous descent from cruise altitude to landing is exceedingly rare. As such a stepped descent has been modeled for the aircraft to more accurately represent the conditions it would encounter in operation. There are several restrictions imposed upon aircraft during their descent that aircraft must comply with. Namely airspeed may not exceed 250 KIAS under 10,000 ft (3048 m). The aircraft must also follow a descent profile of 3 degrees to match the glide slope angle of the runways.

Before the descent begins, the horizontal descent distance must be considered. As this informs the pilot when they must begin their descent in order to not overshoot the runway. This distance is dependant on the altitude of the aircraft before the descent; as the higher the altitude the longer it takes to descend. Descending too quickly can reduce the operational life of the aircraft due to rapid pressurisation cycles of the cabin. Figure 17 shows the descent brackets and their respective descent rates, distances and times.

Descent Bracket	Descent Rate	Horizontal DIstance	Time
> 10,000 ft	2500 fpm / 12.7 m/s	154.4 NM / 286 km	11.75 min
10,000 ft to approach	1500 fpm / 7.6 m/s	28.5 NM / 52.8 km	6.27 min
Approach to ground	750 fpm / 3.81 m/s	3 NM / 5.6 km	1.23 min
Total		185.9 NM / 344.4 km	19.25 min

Figure 17 Table of descent data.

These are the descent rates from a cruise altitude of 12 km. From the total horizontal distance it becomes clear that in order to not overshoot the runway, the aircraft must begin its descent 186 NM before the destination.

3.8. Cruise

The cruise performance is critical to the design of the aircraft, as ideally this is where most of the aircraft's time should be spent. Therefore it is important to design the aircraft to be most efficient during cruise. Two important parameters to determine are the optimum cruise speed and altitude. Cruise speed is usually defined as the minimum drag speed. Plots of drag versus airspeed can be employed to find these minimum drag points and are comprised of three main types of drag. Parasitic drag (blue line) which is the drag caused by the form of the aircraft and increases with airspeed. Induced drag (red line) is a byproduct of lift generation and decays with increasing airspeed. The third type of drag considered is wave drag, this is caused by shockwaves forming around the aircraft as it enters a transonic regime (Mach > 0.8). Wave drag rises sharply to a peak around mach 1 and settles back down to a slightly higher baseline afterwards. Combining these variables gives a graph such as figure 18. Yellow line is the combination of parasitic, induced and wave drag.

3.8.1 Drag Curves

The two black lines on the graph show the stall speed and optimum cruise speed (from left to right respectively). This particular graph shows the drag curve at 12km (39,370 ft) with a stall speed of 161 knots and a cruise speed of 238 knots.

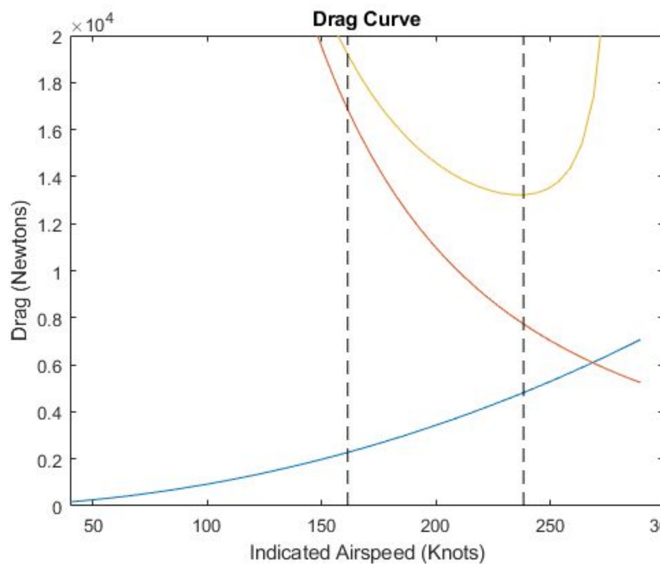

Figure 18 Drag Curve (12km)

There is one key airspeed that is missing here; this value being the maximum speed. This speed is not only dependant on the drag but also the thrust. Maximum speed has been achieved at the speed where thrust is equal to drag.

Therefore if the curve of thrust (red line) versus airspeed is overlaid onto the graph of drag (blue line) versus airspeed, the intersection point of the two lines will be the maximum airspeed. This can be seen in figure 19.

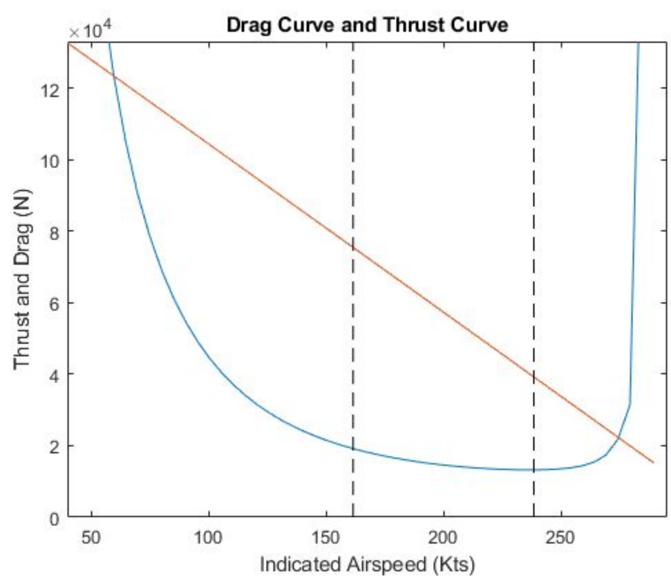

Figure 19 Thrust and drag curves. (12km)

Notice that there are two intersect points on the graph, one at around 60 knots and one at 273 knots. At first this may look confusing but notice that the first intersect is left of the stall speed. Any speed left of the stall speed is unsustainable for the aircraft in its current configuration and therefore need not be considered. The second intersect point is the one that results in the maximum speed of the aircraft at that altitude. The important speeds of the aircraft at the graphed altitude (12km) are then as follows:

Description	Indicated Airspeed	True Airspeed
Stall speed	161.5 knots	319 knots
Optimum cruise speed	238 knots	472 knots
Maximum cruise speed	273 knots	542 knots

Figure 20 Table of key airspeeds at 12km

Note that these are the speeds for just one cruise altitude and depending on air traffic control and destination distance the cruise height may be less than this. This is discussed in the next section.

3.8.2 Flight Profile

The flight profile shows what the average flight would look like including all phases of flight. Figure 21 shows an exemplary short-haul flight and figure 22 an exemplary medium-haul flight.

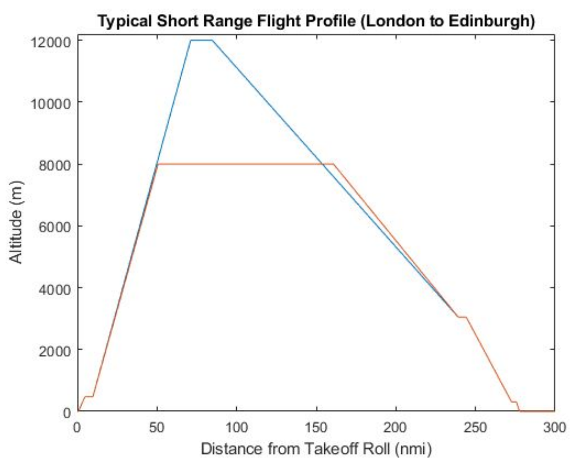

Figure 21 Typical short-haul flight profile.

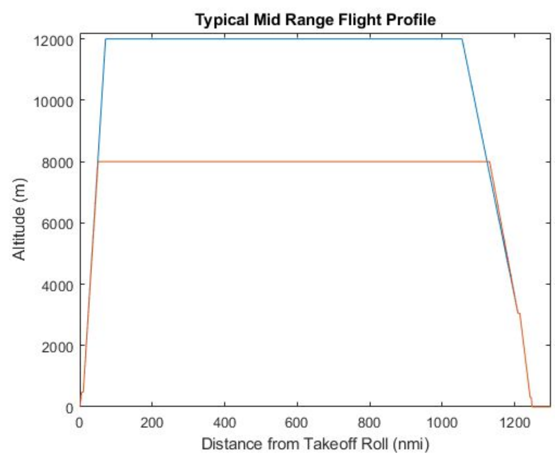

Figure 22 Typical medium-haul flight profile.

These profiles also show how cruise altitude affects the cruise duration. For shorter haul flights the lower altitude leads to an extended period for cruise. As cruise is the most efficient mode of flight this decreases the fuel burn for the flight. However this doesn't necessarily make lower altitudes more efficient; it is a balancing act between higher altitudes having lower drag and higher cruise speeds; and lower altitudes meaning more time spent at cruise. From figure 21 it can be seen that the difference between cruise durations that for short haul flights, lower altitudes will be more efficient. Figure 22 on the other hand has very little relative difference between cruise duration for the two flight levels and as such the savings would be negated by the increased drag at lower altitudes.

3.9. Ceiling

The ceiling height of an aircraft is the maximum altitude the aircraft can *theoretically* reach before it can climb no longer. There are two ceiling heights, one being the absolute ceiling where the aircraft has no thrust left to overcome drag and continue climbing. The other is an imposed service ceiling defined as the point where the aircraft can no longer climb at a rate of 500 ft/min *(2.54 m/s), (Source 7).* As discussed previously in this report the climb rate of an aircraft is directly proportional to the excess thrust (thrust minus drag) at that particular altitude. As both thrust and drag are also functions of altitude they both tend to decrease, with thrust decreasing at a faster rate with increasing altitude; where drag begins to level off after around 12km. The figure below shows the altitude vs excess thrust.

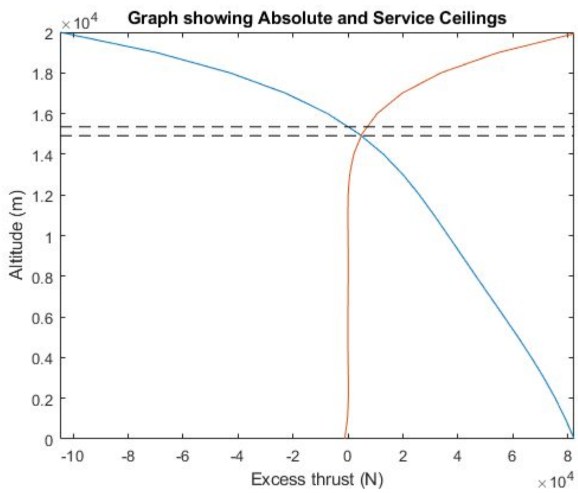

Figure 23 Ceiling heights graph (AEO).

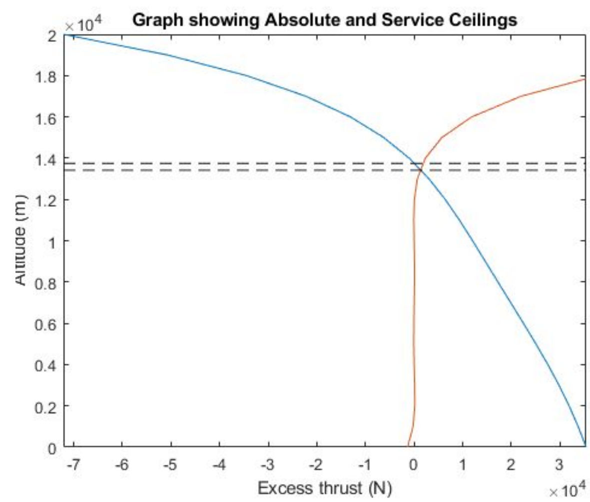

Figure 24 Ceiling height graph (OEI).

Figure 23 showing the aircraft with all engines operating (AEO) while figure 24 shows one engine operation. The blue line denotes the excess thrust of the aircraft at different altitudes. The orange line shows the certification climb rate of 500 ft/min projected onto the graph and is calculated using the maximum aircraft speed at each altitude. Therefore the intersection of these two lines denotes the point where the aircraft is both at its maximum airspeed and also has only 500 ft/min of climb rate left; the service ceiling. The absolute ceiling can be found as the point where the blue line crosses 0 Newtons of excess thrust. The black lines on the diagrams illustrate the service and absolute ceilings. Notice how the OEI graph has lower ceilings than AEO; thus in the event of an engine malfunction the aircraft should decrease its altitude to well below the new ceiling.

Ceiling	Height	
Service (AEO)	44,068.24 ft	13,432.00 m
Absolute (AEO)	44,625.98 ft	13,602.00 m
Service (OEI)	37,047.24 ft	11,292.00 m
Absolute (OEI)	37,306.43 ft	11,371.00 m

Figure 25 Table of ceiling heights.

A consequence of the high thrust engines fitted to the aircraft to improve its takeoff performance is that the excess thrust is significant. This meant previously that the climb rate is faster than would be expected but it also causes the aircraft ceiling to be large as well. This is by no means detrimental for the aircraft and does not impact the suitability of the aircraft to the requirement specification. It must however be noted that for shorter trips that the aircraft will likely be operating the cruise altitude would be much lower than the ceiling heights. Aircraft are most efficient at cruise and therefore it is more fuel efficient to reach cruise as soon as possible and stay there for the majority of the flight. When the aircraft has to climb to a higher cruise altitude it spends more of the flight in climb and descent and therefore has a higher fuel consumption. As a result of this it would likely be commonplace for the aircraft to be operated at a cruise altitude of closer to 30,000 ft so that it can maintain cruise for a greater percentage of the flight. Figures 21 and 22 (section 3.8.2) exemplify this; with figure 21 showing that a decreased cruise altitude results in a larger amount of time spent at cruise and therefore a higher efficiency.

3.10. Payload Range

This section contains the payload range graph for this aircraft, including the calculation of fuel requirements and the other ranges other than the design range. Figure 26 shows the payload range graph of the aircraft.

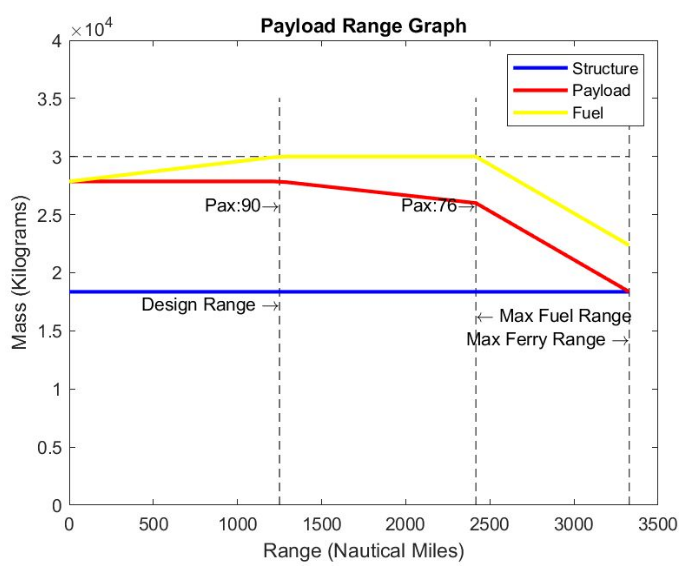

Figure 26 Payload range graph.

The payload range graph shows that for the maximum passenger number the fuel mass needed to reach the design range (found in section 3.2) is around 2 tonnes. If a further increase in range is to be had, there needs to be a decrease in payload mass. The payload decreases while the fuel mass increases up until the fuel mass is the maximum allowable; either the maximum fuel volume in the tanks has been reached; or the structure of the wings cannot safely support any more fuel. At any rate this point is known as the max fuel range, and the payload mass at this point corresponds to 76 passengers. To garner more range from the aircraft, the payload mass can be reduced down to zero while maintaining the maximum fuel mass in order to give the max ferry range; the range of the aircraft when there are no passengers.

The fuel amounts and ranges are tabled below in figure 27 while the corresponding aircraft masses are tabled in figure 28.

Range	Fuel Mass
Design Range (1250 NM)	4189 lb / 1900 kg
Maximum Fuel Range (NM)	8378 lb / 3800 kg
Maximum Ferry Range (NM)	8378 lb / 3800 kg

Figure 27 Table of ranges.

Structural Mass is simply the mass of every permanent component of the aircraft, for the sake of simplicity this also includes the reserve fuel mass, as this does not change flight to flight.
MTOW is the maximum aircraft mass that can physically take off and is largely dependant on the wing geometry.
MZFW is the structural mass plus payload mass.
MOEW is the structural mass plus maximum fuel mass.
Finally payload mass is the average mass of passengers plus baggage.

Aircraft Mass	
Structural Mass	38,623 lb / 17,556 kg
Maximum Takeoff Mass (MTOW)	66,000 lb / 30,000 kg
Maximum Zero Fuel Mass (MZFW)	59,413 lb / 27,006 kg
Operational Empty Mass (MOEW)	45,210 lb / 20,550 kg
Maximum Payload Mass	20,790 lb / 9450 kg

Figure 28 Table of key aircraft masses.

There is also the matter of various auxiliary fuels that need to be included. These fuels are again tabled below in figure 29.

Fuel	Mass
Takeoff	118.62 lb / 53.92 kg
Climb	934.23 lb / 424.65 kg
Descent	140.05 lb / 63.66 kg
Reserve	752.49 lb / 342.04 kg
Deviation	418.00 lb / 190.00 kg
Miscellaneous	182.78 lb / 83.08 kg

Figure 29 Table of auxiliary fuel masses.

3.11. Efficiency

The various efficiencies of the aircraft are the major yardsticks for which to compare aircraft from a business perspective. There are several efficiency factors to consider to judge the performance of the aircraft. One example of this is the Breguet equation for estimating aircraft range. This equation makes use of two seperate efficiencies of the aircraft; the propulsive efficiency and the aerodynamic efficiency.

3.11.1 Aerodynamics Efficiency

The aerodynamic efficiency of an aircraft is the ratio of lift generated to the drag generated. The ratio has ramifications for not only the general aerodynamic efficiency of the aircraft but it is also directly proportional to the glide ratio. The glide ratio being how far forwards the aircraft travels forward to how far it descends when unpowered.

Figure 30 shows both the lift to drag ratio variation with altitude and the glide range from different altitudes. Note that these values assume the aircraft to be flying at minimum drag speed (Vcr) and with a clean wing (no high lift devices).

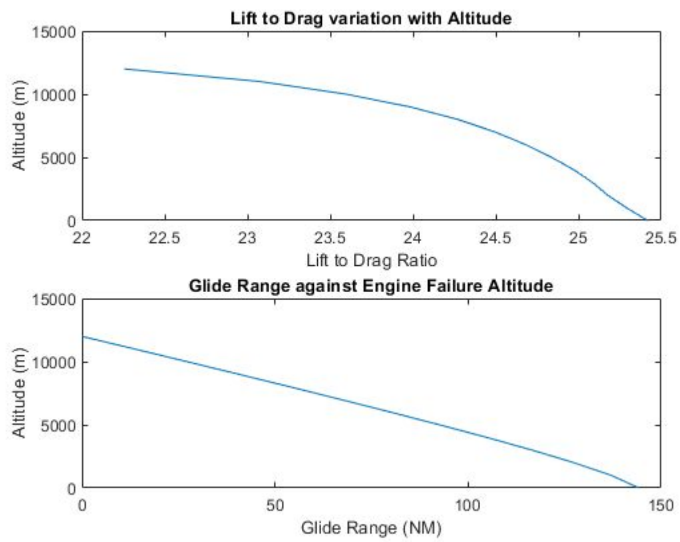

Figure 30 Graphs of aerodynamic efficiency and glide range.

These lift to drag ratios while preliminary, show promise for the aerodynamic efficiency of the aircraft. With these values showing incremental improvements over older civil aircraft currently in operation. Real world testing would be required to determine the true drag on the aircraft and therefore a more accurate efficiency. For comparison, the Boeing 878 ‘Dreamliner’ has an estimated lift to drag ratio of 20.84 at cruise (6). Since the dreamliner is also composite based and a fairly recent aircraft it is safe to assume that the calculated ratio of this aircraft is not a bad estimate.

3.11.2 Propulsive Efficiency

The propulsive efficiency of an aircraft is also known as the thrust specific fuel consumption (TSFC or just SFC). As engines are throttled up, more fuel is injected into the engine to produce more thrust. Naturally this uses more fuel and as such propulsive efficiency is commonly given with the thrust component removed so that the efficiency can be compared between engines of different thrust levels and throttle settings.

This SFC varies with altitude and mach number similarly to thrust; although while an approximate equation can be found for the thrust lapse rate, SFC lapse rate defies a simple equation to define it. Therefore the method of deduction used in this report is the interpolation of experimental data scaled to fit known data points for the chosen engine. Figure 31 shows the result of this method in finding the lapse rate for a range of altitudes and mach numbers. From the graphs it can be seen that mach number and altitude not only reduce the thrust of the engines, but also increase the fuel consumption (at the same thrust). Therefore a careful balanced must be obtained between the lower drag at high altitude and the higher SFC at these altitudes.

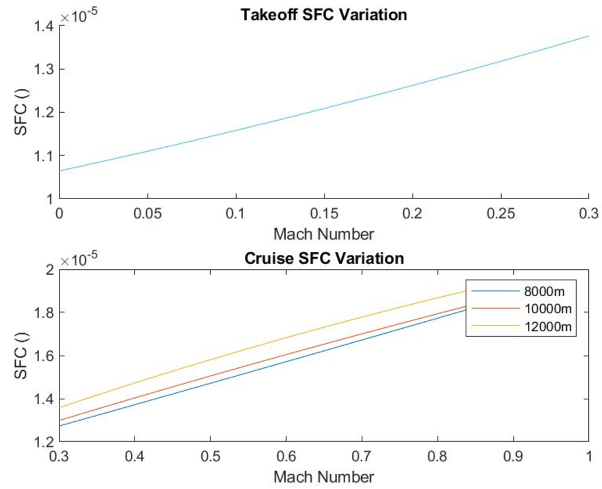

Figure 31 Propulsive efficiency variation graphs.

3.11.3 Fuel Burn

The fuel burn per distance is an important metric in the aviation industry for judging how fuel efficient the aircraft is; and by extension, how much it would cost an airline to operate the aircraft. It is also useful for comparisons between other competitor aircraft.

3.11.4 Seat Efficiency

From an airline standpoint this is likely the most important metric for deciding whether or not to use a certain aircraft over another. It is the amount of fuel burned every 100 km per passenger. This tells the airline how much they would have to charge each passenger to cover their overhead.

3.11.5 Table of Efficiencies

This section gives values to the efficiencies covered in the previous sections. Most of these values are not static and do in fact change with different flight conditions.

Efficiency	UH SB90 (Preliminary)	Dash 8 Q400	CRJ900
Lift to Drag Ratio (Aerodynamic)	20.11		
Thrust Specific Fuel Consumption (Propulsive)	0.56 lb/lbf/hr 15.86 g/kN		
Fuel Burn	6.6 lb/NM 1.62 kg/km	7.43 lb/NM 1.83 kg/km	11.35 lb/NM 2.78 kg/km
Seat Efficiency	106.9 mpg 2.19 L/100km	84.0 mpg 2.79 L/100km	59.7 mpg 3.94 L/100km

Figure 32 Table of efficiencies.

These preliminary value show that the aircraft has the potential to outperform competitor aircraft, including turboprops. These values will likely increase once flight testing can be completed. With fuel burn being one of the recommended ground and flight tests to undertake before production.

4. Conclusions

4.1 Suitability

The suitability of the aircraft against the requirement specification set down in section 1.2 is the most important evaluation of the success of the design and the best indicator of its attractiveness to investors and customers.

1. The aircraft has a design seat capacity of 90 passengers, with an extended range variant with 76 passengers and two classes. This puts the aircraft firmly inside the design bracket.
2. Section 3.10 discusses the range of the aircraft. From figures 26 and 27 it can be shown that for 90 passengers, the range is 1250 nautical miles which increases when the passenger count is dropped to 76. Making it more than fit to meet the range requirement.
3. As this aircraft has been designed with the ferrying of passengers in mind, the carrying of freight has been dismissed over concerns to the efficiency of the aircraft. Therefore requirement 3 does not apply.
4. Requirement 4 mandates that the aircraft should be able to service regional runways of the target customers. Section 3.3 to section 3.5 discusses this and draws the conclusion that for all but the most severe runway conditions; the aircraft is entirely able to service regional airports of the targeted regions.
5. This requirement states that the aircraft must be able to operate alongside other aircraft. The flight profile of this aircraft combined with its airspeeds place it firmly in line with other aircraft currently in operation in terms of speed and altitude requirements. (Sources 4,5 & 8).
6. Every effort has been made to reduce the turnaround time of the aircraft. Reducing the height above the runway for easier loading and unloading without the use of a jetway is one notable example.
7. The fuel burn of the aircraft is as fully formed as possible without flight testing and demonstrates significant savings over other aircraft in operation (section 3.11.5 and sources 4 & 5).
8. The operating costs can only be considered from the perspective of fuel requirements in this report. But as per the previous point they indicate savings over aircraft currently in service.
9. Provisions for a shrunken variant of the aircraft to open up to the American market are already in place and because the engines can easily be substituted for the GE CF34 10A variant the efficiency would be maintained as stated in section 2.3.
10. Every effort has been made to comply with European regulations, as well as other international bodies so long as they do not contradict each other. This is evident in the calculation of reserve fuel, service altitude and descent rate to name examples.

4.2 Reflections.

After having gained knowledge in the performance of aircraft and coming to a deeper understanding of the requirements, I would reconsider my stance on turboprop engines for the aircraft and likely also evaluate the design range. Turboprops are not the slow and cumbersome engines they once were and likely will make a major comeback with increasing fuel prices. It has become clear that our aircraft is on the upper echelon of the requirement specification and straddles the line between regional jet and medium-haul international jet.

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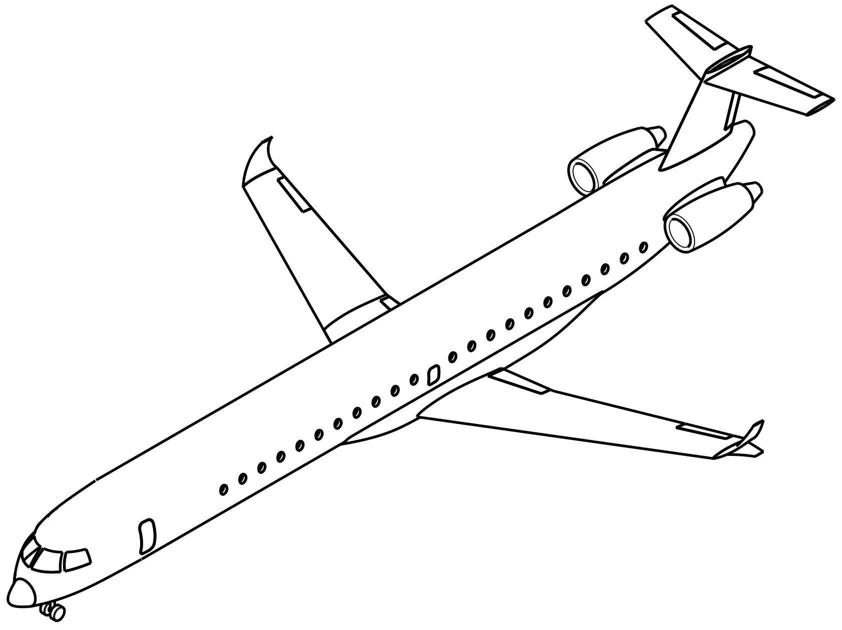
6. Appendix A

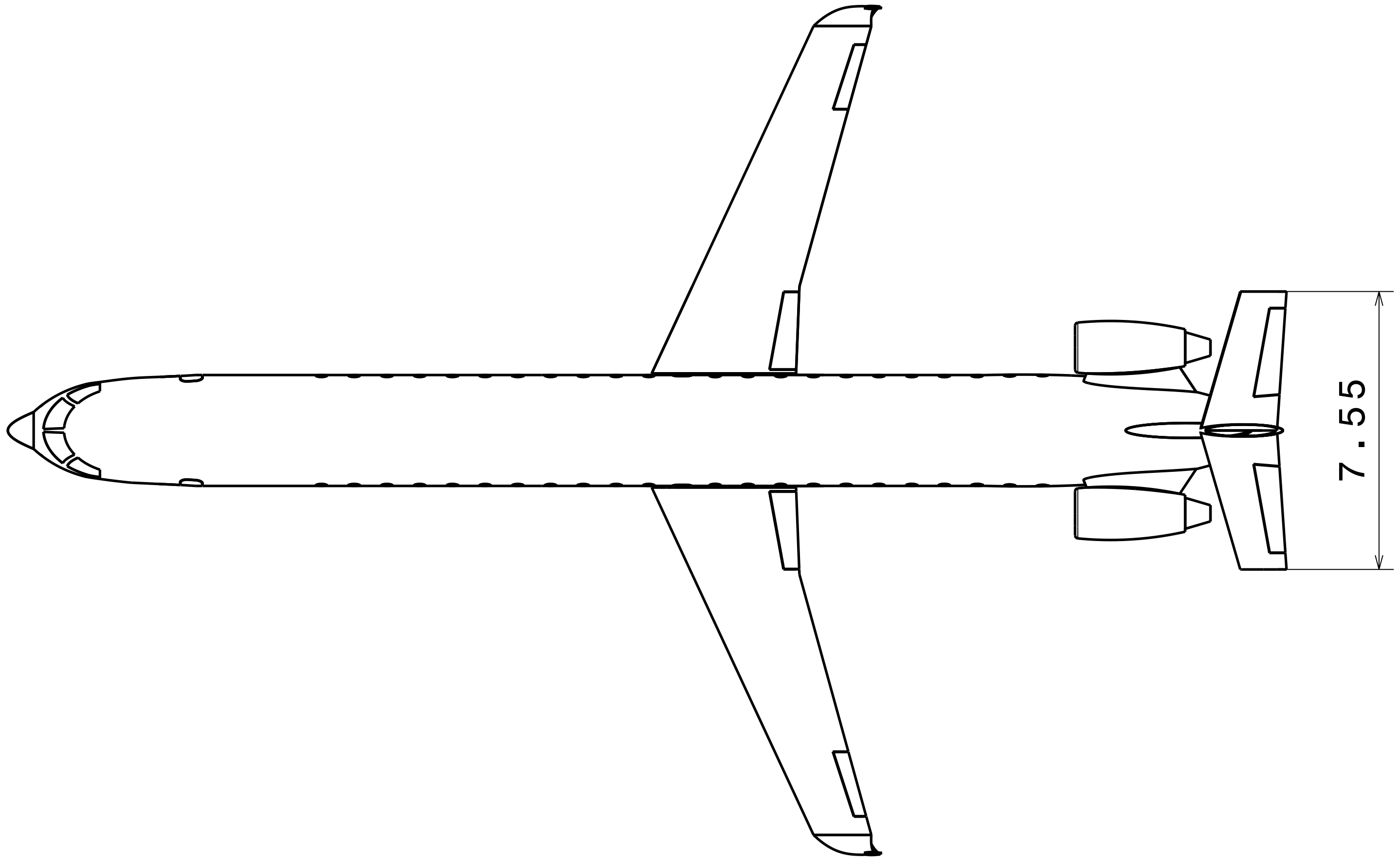
This appendix contains two exemplary matlab scripts used to calculate the performance of the aircraft.

```
function [thrustnew] = thrustvariation(Mach,Alt,Thrust)
%This function return the thrust after the lapse rate has
%been considered at the inputted altitude and Mach
number.

%Call the altitude function to output altitude data at the
%inputted altitude.
altfunc = altitudefunction(Alt);
%Set the density of air at the inputted altitude.
density = altfunc(1,1);
%Call the altitude function to output altitude data at
%sea level.
altfuncsl = altitudefunction(0);
%Set the density of air at sea level.
densitySl = altfuncsl(1,1);
%Set the value of the thrust lapse constant.
K = -0.5;
%Calculate the new thrust using the below equation.
thrustnew = Thrust*(density/densitySl)*(1+K*Mach);
end
```

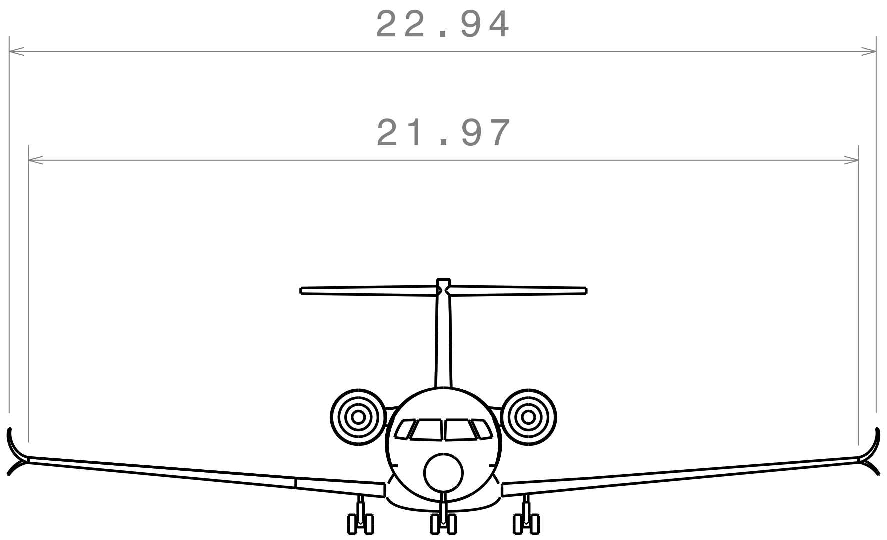
```
function [drag] = dragfunction(alt,area,V,Cl,span,e)
%Function returns the value of drag at a set altitude and velocity.
%V is m/s.

%Interpolates altitude data to get air density.
altfunc = altitudefunction(alt);
density = altfunc(1,1);
%Parasitic drag from altitude and velocity.
Cd0 = pdragvariation(V,alt);
%Wave drag from altitude and velocity.
Cdw = wdragfunction(V,alt);
%Aspect ratio.
AR = (span^2)/area;
%Induced drag.
Cdi = (Cl^2)/(pi*e*AR);
%Total drag coefficient.
Cd = Cd0+Cdi+Cdw;
%Total drag function.
drag = 0.5*density*area*V^2*Cd;
end
```



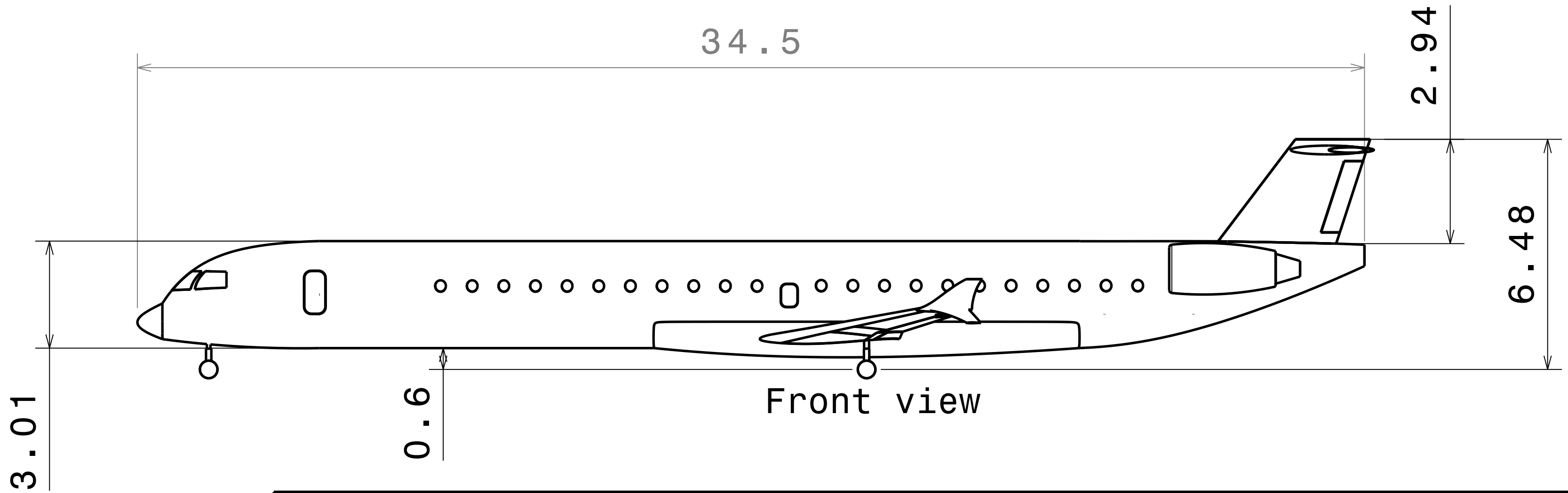
Isometric view
Scale: 1:250



Top view



Left view
Scale: 1:200



Front view

NOTES:

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DRAWN BY DE	DATE 27/02/2019	DRAWING TITLE	GENERAL ARRANGEMENTS DRAWING
CHECKED BY PM	DATE 02/03/2019	SIZE A3	DRAWING NUMBER GD-G11-GAD-001 / REV A
DESIGNED BY GROUP 11	DATE 27/02/2019	SCALE 1:1	WEIGHT(kg) 17556 / SHEET 1/1

UH SB-90 Peregrine

General

Crew

Flight Crew	2
Cabin Crew	3

Passengers

Single Class	90 Passengers (35 in. pitch)
Dual Class	76 Passengers (35 in. pitch)

Avionics Info

Rockwell Collins ADF-2100 Adaptive Flight Display
Rockwell Collins Head-up Guidance System (HGS)
NEXIS Flight-Intelligence System (EFB)

External Dimensions

Length	113.20 ft / 34.50 m
Height	21.39 ft / 6.52 m
Fuselage Max Diameter	9.88 ft / 3.01 m
Wingspan	75.40 ft / 22.98 m
Wing Area	651.90 ft² / 60.56 m²

Internal Dimensions

Cabin Max Width	8.90 ft / 2.71 m
Cabin Height	6.23 ft / 1.90 m
Cabin Length	83.7 ft / 25.50 m

Engines

2x General Electric CF34-10E6 turbofans

Thrust

APR thrust	18,821 lbf / 83.72 kN
Takeoff thrust	17,389 lbf / 77.35 kN
Maximum continuous thrust	17,040 lbf / 75.80 kN

Flat Rating

ISA + 15°C

Thrust Specific Fuel Consumption (0.8 Mach, 11km)

0.544 lb/lbf/hr / 15.395 g/kNs

Performance

Range

90 Passengers	1249 NM / 2313 km
76 Passengers	2736 NM / 5067 km

Speed

Maximum Cruise Speed	0.95 Mach / 542 kts / 1004 km/h
Normal Cruise Speed	0.82 Mach / 472 kts / 874 km/h
Takeoff Speed	157 kts / 291 km/h
Optimum Climb Speed	172 kts (IAS)

Runway length (ISA, SL, MTOW)

Takeoff Field Length	4104 ft / 1251 m
Landing Field Length	2736 ft / 834 m
Balanced Field Length	4836 ft / 1474 m

Ceiling

Absolute Ceiling Altitude	44,626 ft / 13,602 m
Service Ceiling	44,068 ft / 13,432 m

Efficiency

Lift to Drag Ratio	20.49
Fuel Burn	6.6 lb/NM / 1.62 kg/km
Fuel Efficiency per Seat	106.9 mpg / 2.19 L/100km

Weight

Maximum Takeoff Weight	66,139 lb / 30,000 kg
Maximum Landing Weight	61,013 lb / 27,675 kg
Maximum Zero Fuel Weight	59,538 lb / 27,006 kg
Maximum Payload	20,834 lb / 9,450 kg

Doors & Exits

Main Passenger Door

Height	4.00 ft / 1.22 m
Width	2.00 ft / 0.61 m
Height to Sill	5.12 ft / 1.56 m

Overwing Emergency Exit

Height	2.17 ft / 0.66 m
Width	1.57 ft / 0.48 m
Height to Sill	5.12 ft / 1.56 m

Cabin Pressure

Altitude (m)	Cabin Pressure (Pa)
0	74690
2000	74690
4000	74690
6000	57750
8000	57750
10000	57750
12000	57750