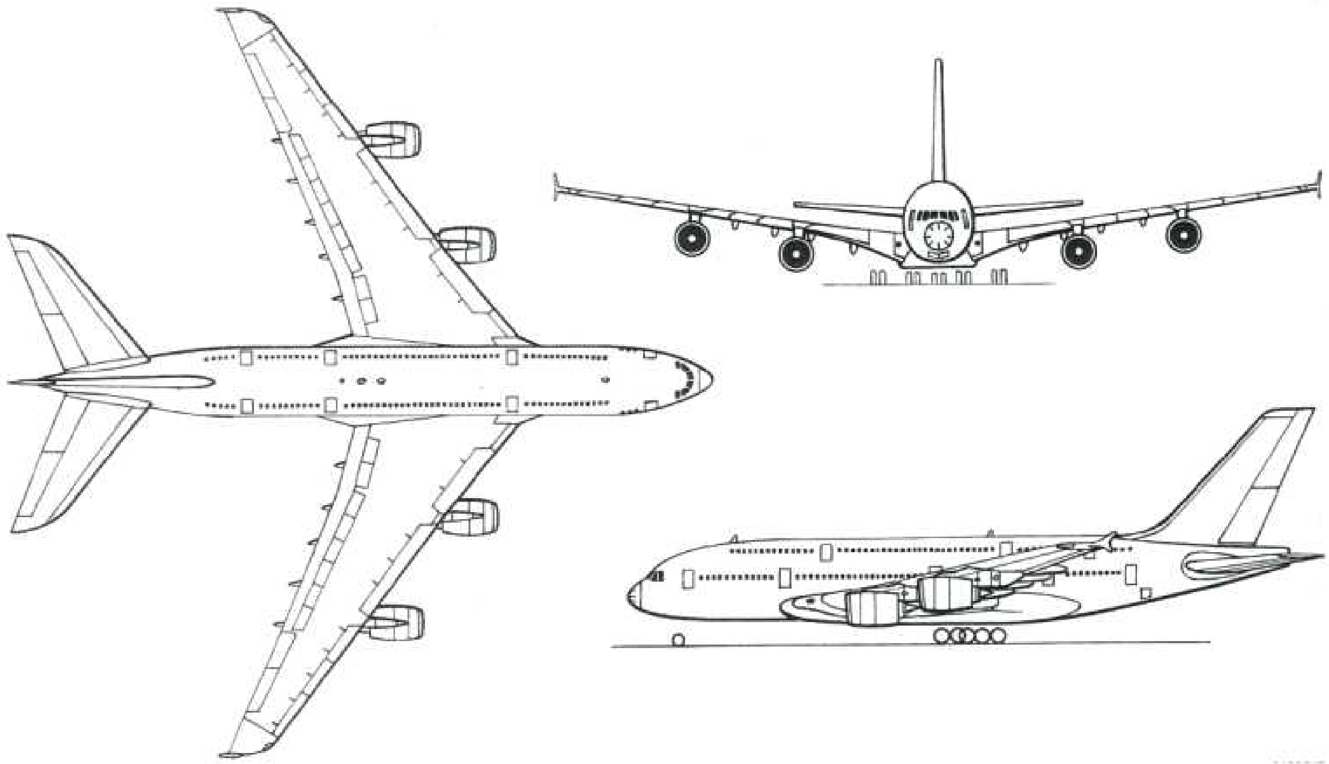

Airbus A380-800M, Image Source - SkyBrary Aviation

Flight Mechanics Project 2022-2023

Aircraft #8 Airbus A380-800M

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Roll Number - 31
Registration Number - 210933058

Batch of 2021-2025
Manipal Institute of Technology
Bachelor of Technology in Aeronautical Engineering

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Contents

1 Introduction

The following report outlines the methodology and the results of the performance analysis conducted on the Airbus A380- 800M as a part of the Flight Mechanics coursework for the academic year 2022-2023 at the Manipal Institute of Technology, Karnataka, India.

The performance analysis was conducted, and the results were plotted using MATLAB. LaTeXwas used to formulate the report. Once the results were plotted, they were analysed, and suitable conclusions were drawn from the respective polars.

While conducting the performance analysis of the aircraft, six aspects of the aircraft's performance were focused on. Namely, the drag polar, the flight envelope (V-h Plot), the aircraft's climb, turn, take-off and landing performance. All these analyses culminated into the Payload v/s Range trade-off study.

1.1 Preliminary Aircraft Data (A380-800M)

The following table elucidates the preliminary data used to conduct the performance analyses of the aircraft.

Parameter	**Value**
Take-off Weight (W_{TO})	6695 kN
Empty Weight (W_{Empty})	2725 kN
Payload Weight ($W_{Payload}$)	1480 kN
Fuel Weight (W_{Fuel})	2490 kN
Thrust per Engine (T)	350σ kN
Number of Engines	4
Thrust Specific Fuel Consumption (TSFC)	$47.5\sqrt{\theta}\ {}^{kg}/_{hrkN}$
Wing Planform Area (S)	845 m^2
Wing Aspect Ratio (AR)	7.53
Oswald's Efficiency Factor (e)	0.965
Critical Mach Number (M_{crit})	0.895
Maximum permissible dynamic head (Aeroelastic limit or q_{max})	55 ${}^{kN}/_{m^2}$
Parasitic drag coefficient C_{D_0}	0.011
$C_{L_{max}}$ for climb segment of take-off	0.9 $C_{L_{max_{TO}}}$
C_L (ground effect)	0.12
$C_{L_{max}}$ (For Plain wing)	1.15
$\Delta C_{L_{max}}$ from partial HLD for take-off	1.15
$\Delta C_{L_{max}}$ from Full HLD for landing	1.85
$\Delta C_{D_0\ Landing\,Gear}$	0.0042
$\Delta C_{D_0\ Flap}$	0.0034
Rolling Coefficient μ	0.02
Extra Fuel tank Capacity	30% of W_{Fuel}
Cruise Altitude	12 km

Table 1: Preliminary Data

2 Drag Polar

2.1 Preliminary Calculations

The drag polar and, by extension, the analysis of the aircraft's drag was carried out for three take-off weights and six altitudes. The weights considered for the analysis were 0.9 W_{TO}, 0.8 W_{TO} and 0.6 W_{TO}.

The altitudes at which the drag was estimated were 0.5 km, 3 km, 5.5 km, 8.5 km, 10.5 km and 11.5 km. The V_{stall} and the V_{crit} boundaries were marked to signify the flight envelope limits on each polar. Further, the minimum drag D_{min} and their respective velocities $V_{D_{min}}$ were also calculated.

The total drag coefficient is written as,

$$C_D = C_{D_0} + C_{D_i} + C_{D_{wave}} \tag{1}$$

where C_{D_0} is the parasitic drag coefficient, C_{D_i} is the induced drag coefficient and $C_{D_{wave}}$ is the wave drag coefficient. The term $C_{D_{wave}}$ is zero for subsonic and transonic flight. Hence it is neglected, leading to the equation,

$$C_D = C_{D_0} + C_{D_i} \tag{2}$$

Substituting the value for C_{D_i} we get,

$$C_D = C_{D_0} + kC_L^2 \tag{3}$$

From this relation, we can obtain drag for level flight,

$$D = \left(C_{D_0} + kC_L^2\right)\left[{}^1\!/\!{}_2\rho V^2 S\right] \tag{4}$$

However, for level flight,

$$C_L = \frac{W}{{}^1\!/\!{}_2\rho V^2 S} \tag{5}$$

Substituting for C_{D_0} in equation 4 we get,

$$D = AV^2 + {}^B\!/\!{}_{V^2} \tag{6}$$

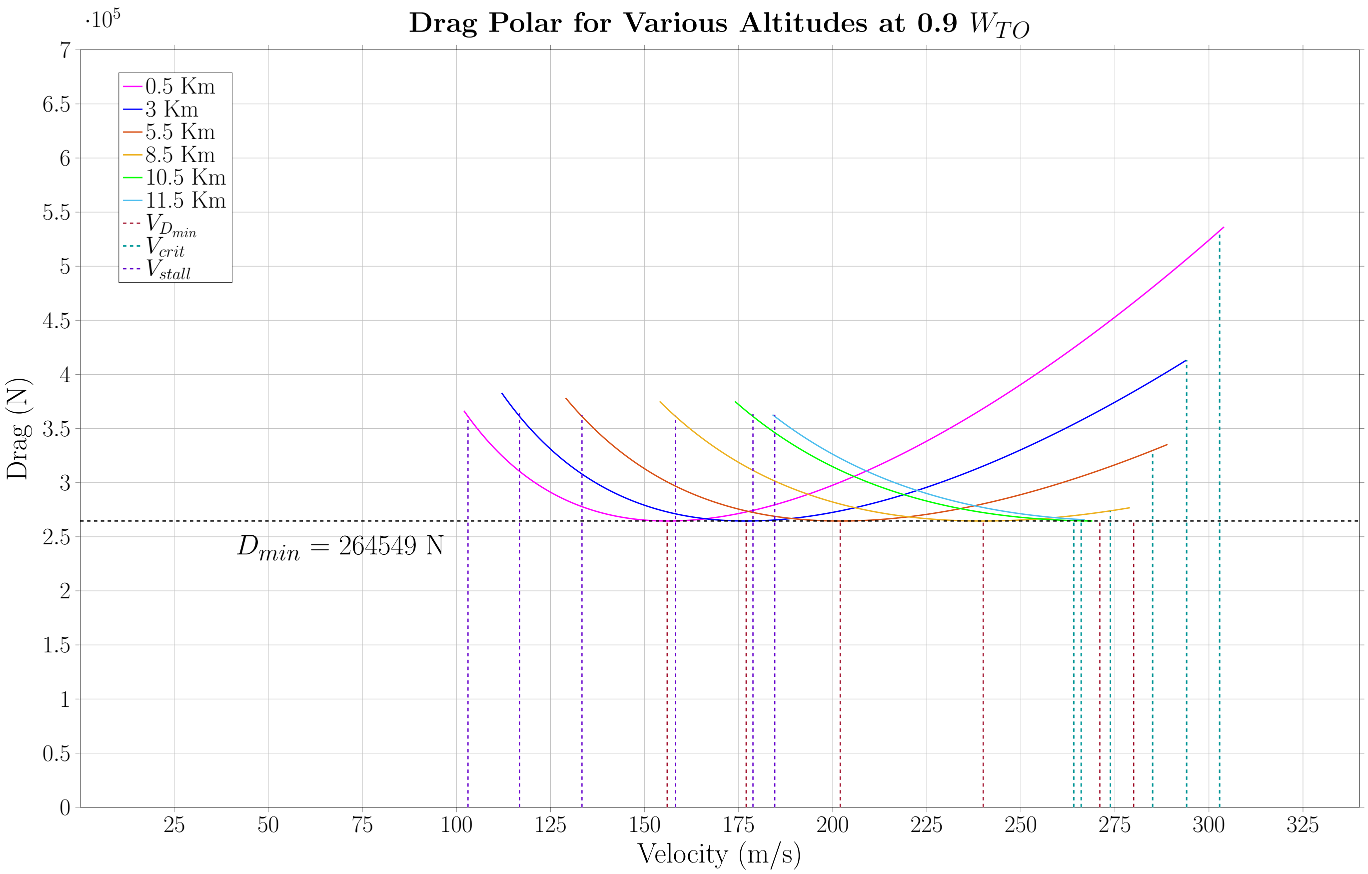
where A = ${}^{C_{D_0}\rho S}\!/\!{}_2$ and B = ${}^{2kW^2}\!/\!{}_{\rho S}$. The flight speed for minimum drag $V_{D_{min}}$ was obtained from the plot. The corresponding minimum drag D_{min} was identified from the respective drag polars. The flight envelope was defined by the region of the plot between the V_{stall} and the V_{crit} values for each corresponding curve.

The stall velocity V_{stall} was calculated using the relation,

$$V_{stall} = \sqrt{\frac{2W_{TO}}{\rho S C_{L_{max}}}} \tag{7}$$

The critical velocity (V_{crit}) was calculated from the initial value at sea level by varying the speed of sound according to the altitude.

2.2 Drag Polar for 0.9 W_{TO}

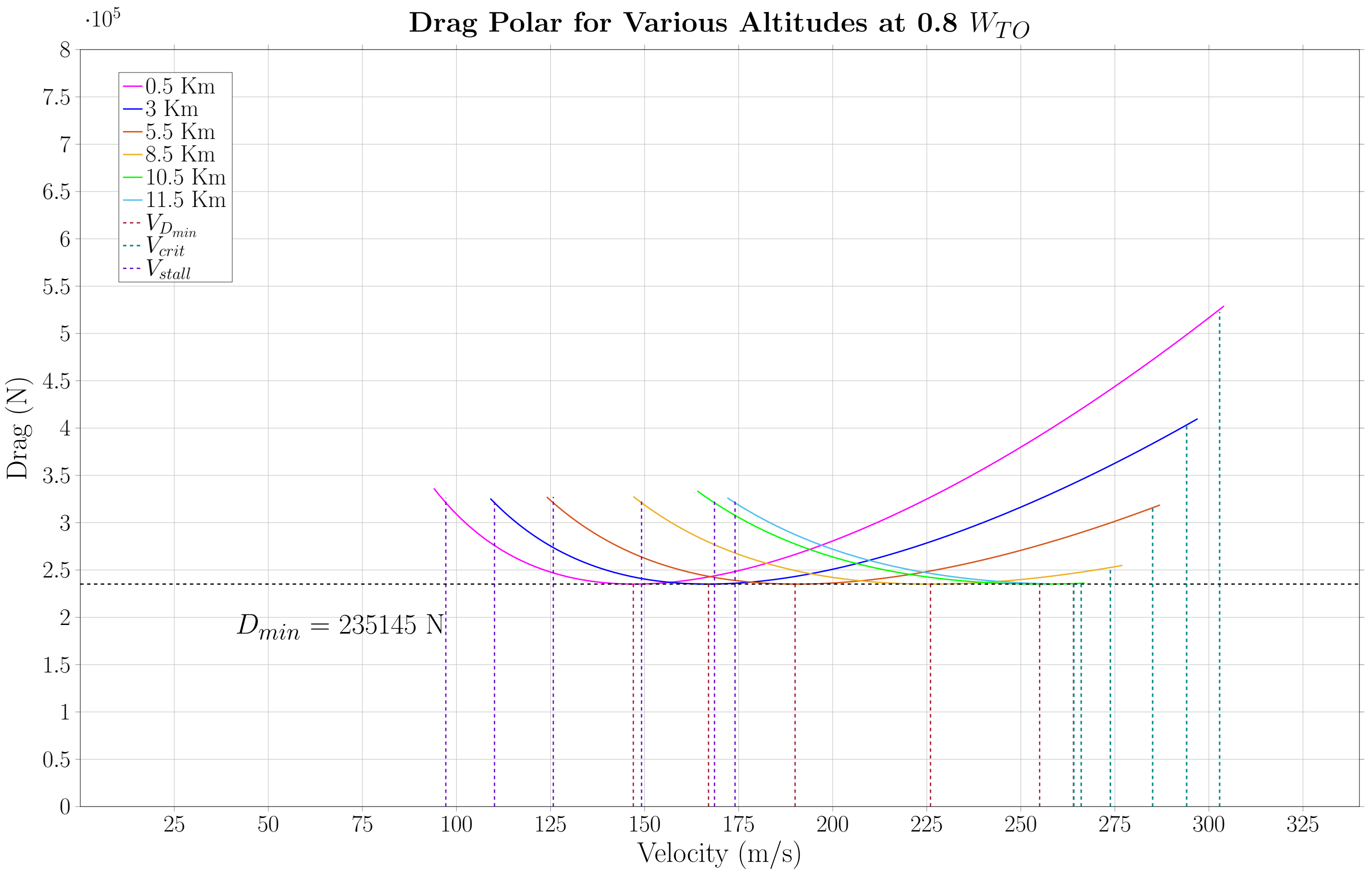


Parameter	Value
Take-off Weight (W_{TO})	6025.5 kN
V_{stall} at 0.5 km	103.06 m/s
V_{stall} at 3 km	116.78 m/s
V_{stall} at 5.5 km	133.36 m/s
V_{stall} at 8.5 km	158.24 m/s
V_{stall} at 10.5 km	178.81 m/s
V_{stall} at 11.5 km	184.60 m/s
$V_{D_{min}}$ at 0.5 km	156 m/s
$V_{D_{min}}$ at 3 km	177 m/s
$V_{D_{min}}$ at 5.5 km	202 m/s

Parameter	Value
Take-off Weight (W_{TO})	6025.5 kN
$V_{D_{min}}$ at 8.5 km	240 m/s
$V_{D_{min}}$ at 10.5 km	271 m/s
$V_{D_{min}}$ at 11.5 km	280 m/s
V_{crit} at 0.5 km	302.84 m/s
V_{crit} at 3 km	294.07 m/s
V_{crit} at 5.5 km	285.04 m/s
V_{crit} at 8.5 km	273.80 m/s
V_{crit} at 10.5 km	266.05 m/s
V_{crit} at 11.5 km	264.07 m/s

Table 2: Data for 0.9 W_{TO}

2.3 Drag Polar for 0.8 W_{TO}

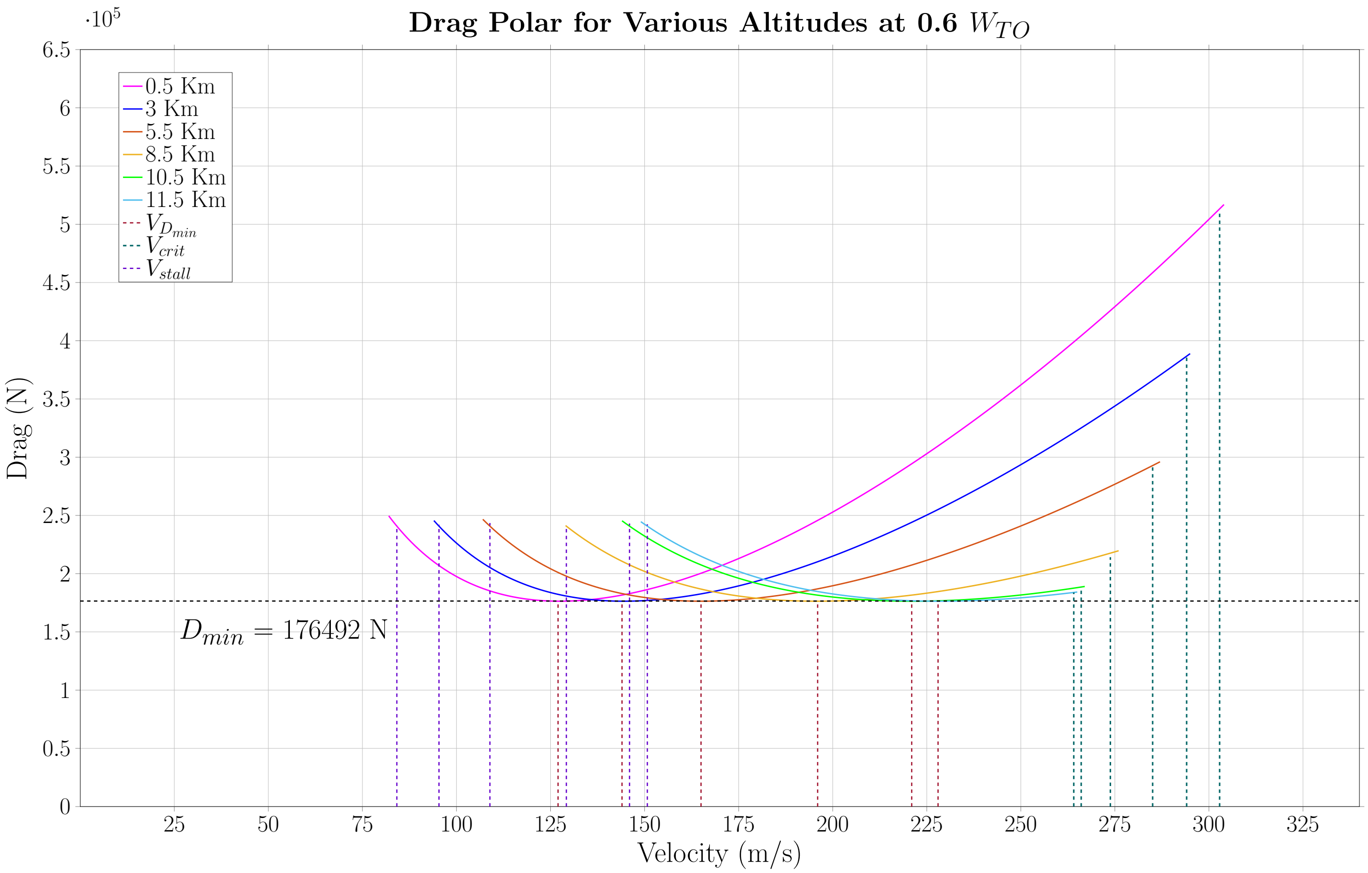


Parameter	Value
Take-off Weight (W_{TO})	5356 kN
V_{stall} at 0.5 km	97.17 m/s
V_{stall} at 3 km	110.10 m/s
V_{stall} at 5.5 km	125.73 m/s
V_{stall} at 8.5 km	149.19 m/s
V_{stall} at 10.5 km	168.58 m/s
V_{stall} at 11.5 km	174.04 m/s
$V_{D_{min}}$ at 0.5 km	147 m/s
$V_{D_{min}}$ at 3 km	167 m/s
$V_{D_{min}}$ at 5.5 km	190 m/s

Parameter	Value
Take-off Weight (W_{TO})	5356 kN
$V_{D_{min}}$ at 8.5 km	226 m/s
$V_{D_{min}}$ at 10.5 km	255 m/s
$V_{D_{min}}$ at 11.5 km	264 m/s
V_{crit} at 0.5 km	302.84 m/s
V_{crit} at 3 km	294.07 m/s
V_{crit} at 5.5 km	285.04 m/s
V_{crit} at 8.5 km	273.80 m/s
V_{crit} at 10.5 km	266.05 m/s
V_{crit} at 11.5 km	264.07 m/s

Table 3: Data for 0.8 W_{TO}

2.4 Drag Polar for 0.6 W_{TO}

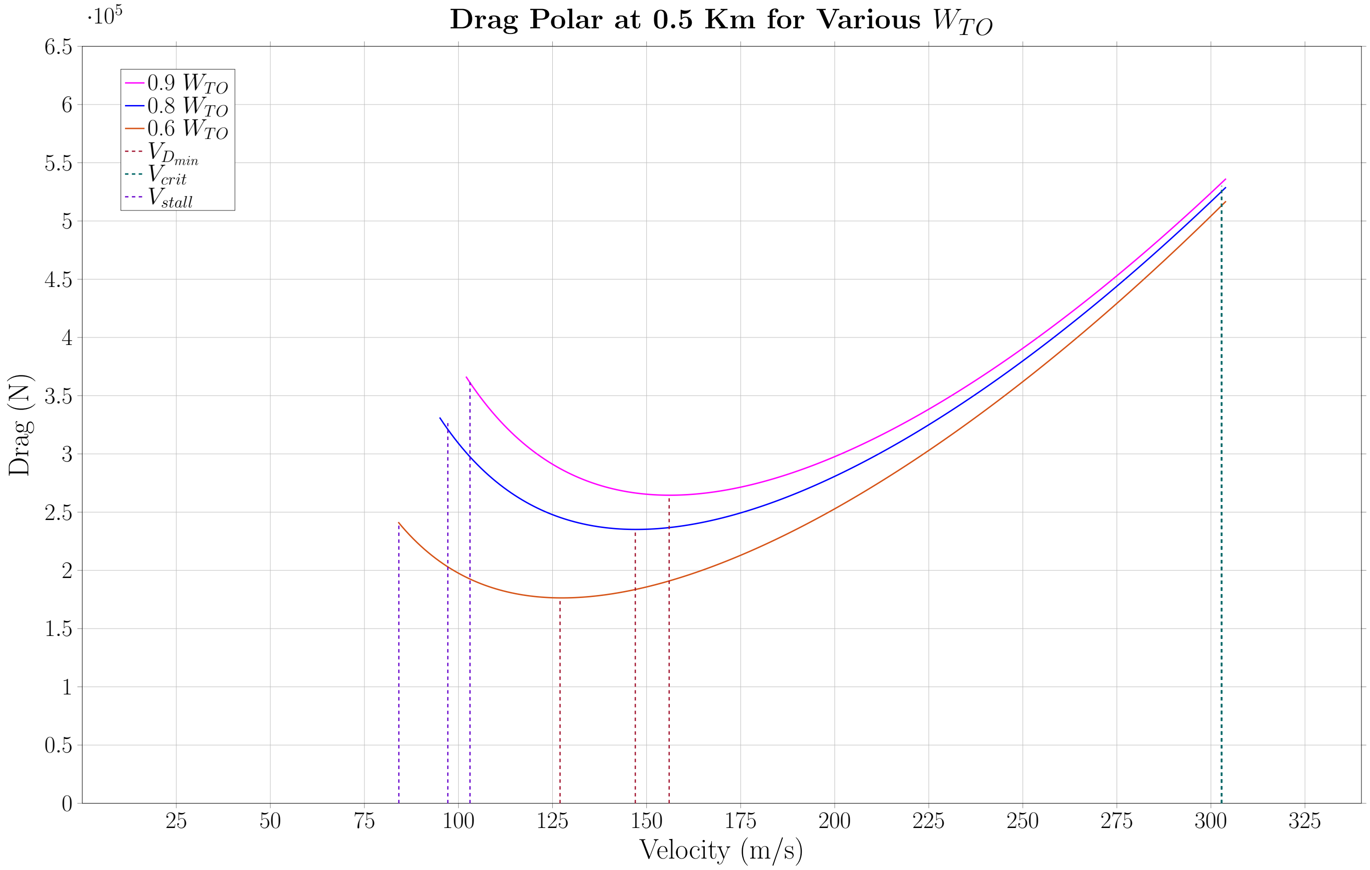


Parameter	Value
Take-off Weight (W_{TO})	4017 kN
V_{stall} at 0.5 km	84.15 m/s
V_{stall} at 3 km	95.35 m/s
V_{stall} at 5.5 km	108.88 m/s
V_{stall} at 8.5 km	129.20 m/s
V_{stall} at 10.5 km	145.99 m/s
V_{stall} at 11.5 km	150.72 m/s
$V_{D_{min}}$ at 0.5 km	127 m/s
$V_{D_{min}}$ at 3 km	144 m/s
$V_{D_{min}}$ at 5.5 km	165 m/s

Parameter	Value
Take-off Weight (W_{TO})	4017 kN
$V_{D_{min}}$ at 8.5 km	196 m/s
$V_{D_{min}}$ at 10.5 km	221 m/s
$V_{D_{min}}$ at 11.5 km	228 m/s
V_{crit} at 0.5 km	302.84 m/s
V_{crit} at 3 km	294.07 m/s
V_{crit} at 5.5 km	285.04 m/s
V_{crit} at 8.5 km	273.80 m/s
V_{crit} at 10.5 km	266.05 m/s
V_{crit} at 11.5 km	264.07 m/s

Table 4: Data for 0.6 W_{TO}

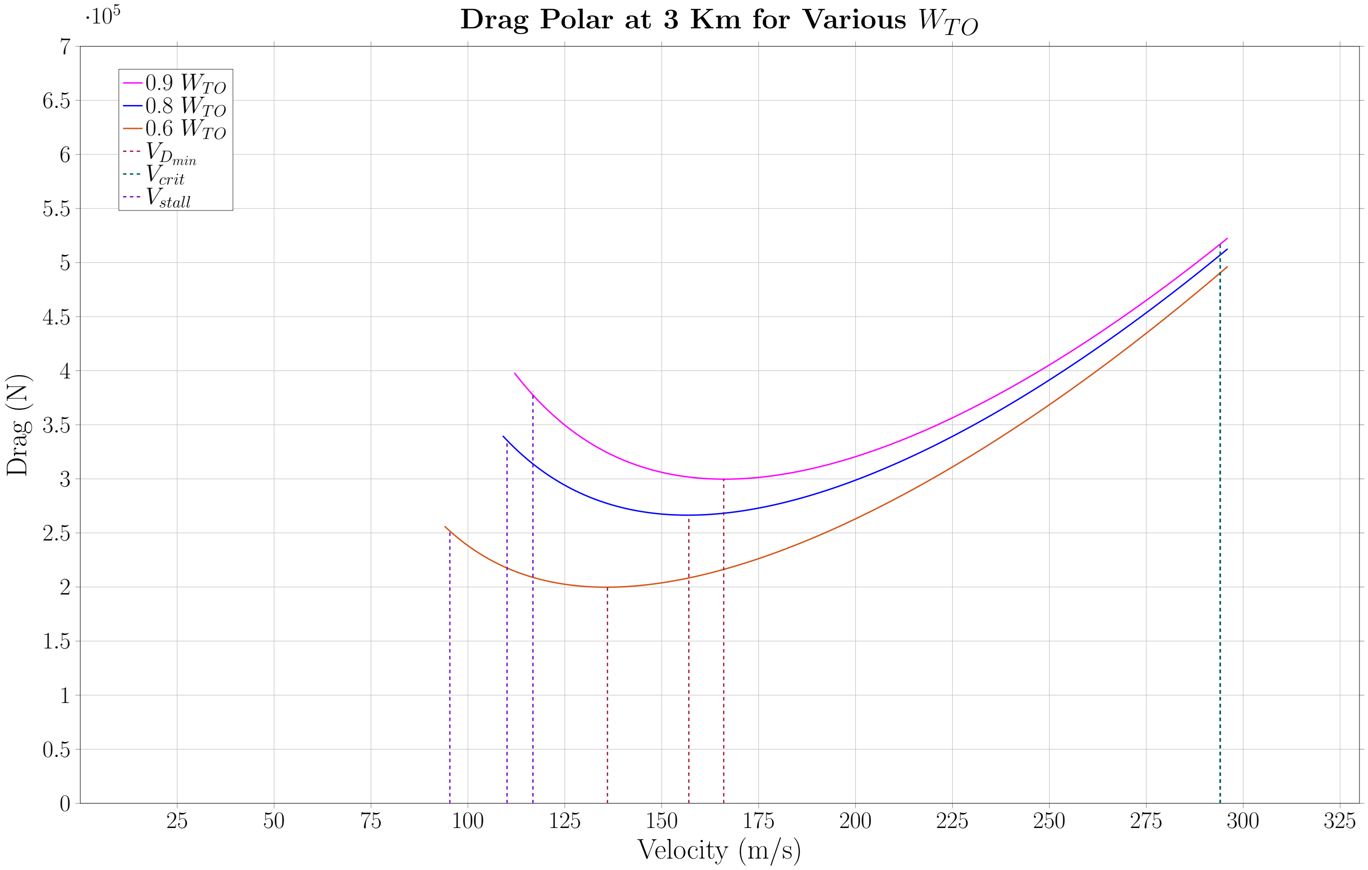
2.5 Drag Polar for 0.5 km



Parameter	Value
Altitude	0.5 km
V_{stall} at 0.9 W_{TO}	103.06 m/s
V_{stall} at 0.8 W_{TO}	97.17 m/s
V_{stall} at 0.6 W_{TO}	84.15 m/s
$V_{D_{min}}$ at 0.9 W_{TO}	156 m/s
$V_{D_{min}}$ at 0.8 W_{TO}	147 m/s
$V_{D_{min}}$ at 0.6 W_{TO}	127 m/s
V_{crit} at 0.9 W_{TO}	302.84 m/s
V_{crit} at 0.8 W_{TO}	302.84 m/s
V_{crit} at 0.6 W_{TO}	302.84 m/s

Table 5: Data for 0.5 km

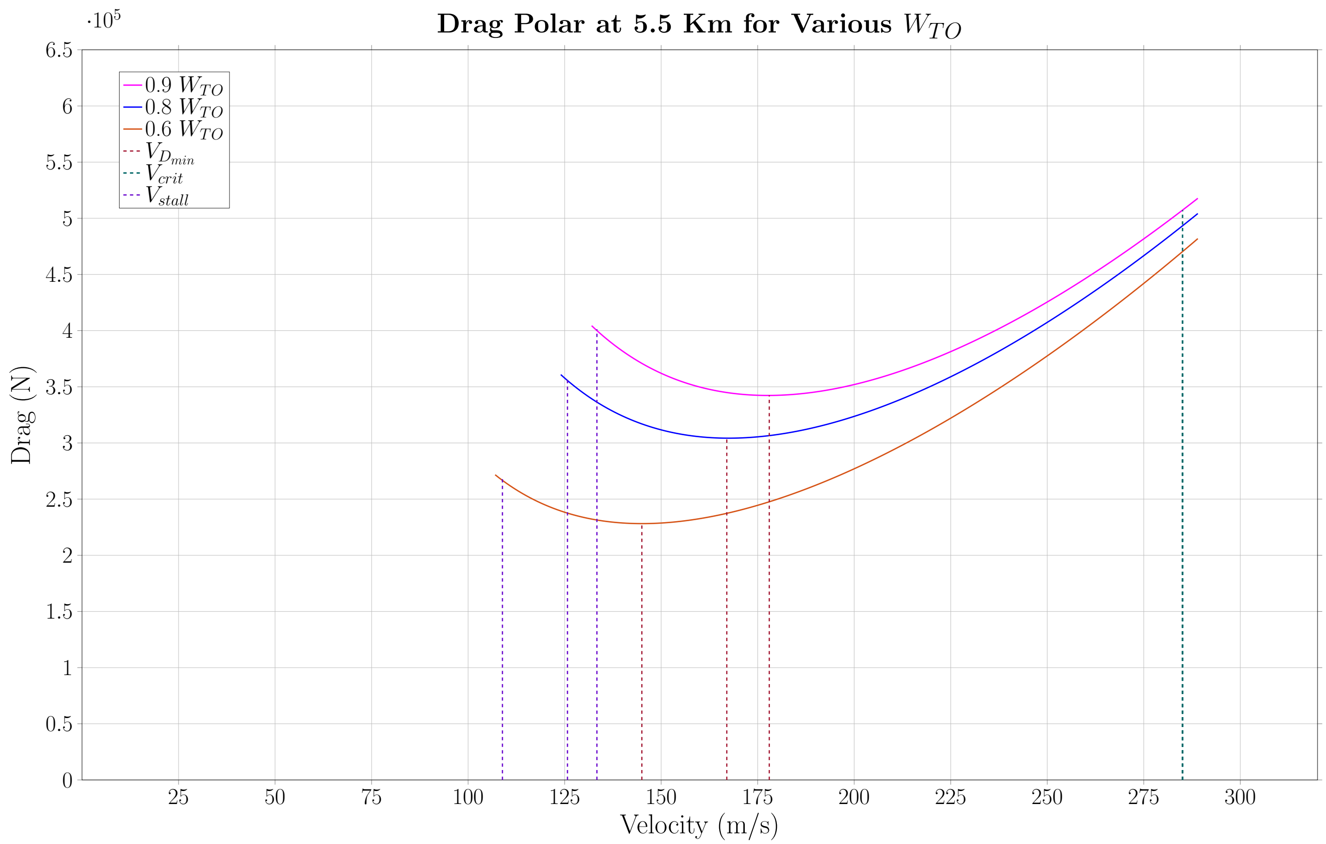
2.6 Drag Polar for 3 km



Parameter	Value
Altitude	3 km
V_{stall} at 0.9 W_{TO}	116.78 m/s
V_{stall} at 0.8 W_{TO}	97.17 m/s
V_{stall} at 0.6 W_{TO}	84.15 m/s
$V_{D_{min}}$ at 0.9 W_{TO}	156 m/s
$V_{D_{min}}$ at 0.8 W_{TO}	147 m/s
$V_{D_{min}}$ at 0.6 W_{TO}	127 m/s
V_{crit} at 0.9 W_{TO}	294.07 m/s
V_{crit} at 0.8 W_{TO}	294.07 m/s
V_{crit} at 0.6 W_{TO}	294.07 m/s

Table 6: Data for 3 km

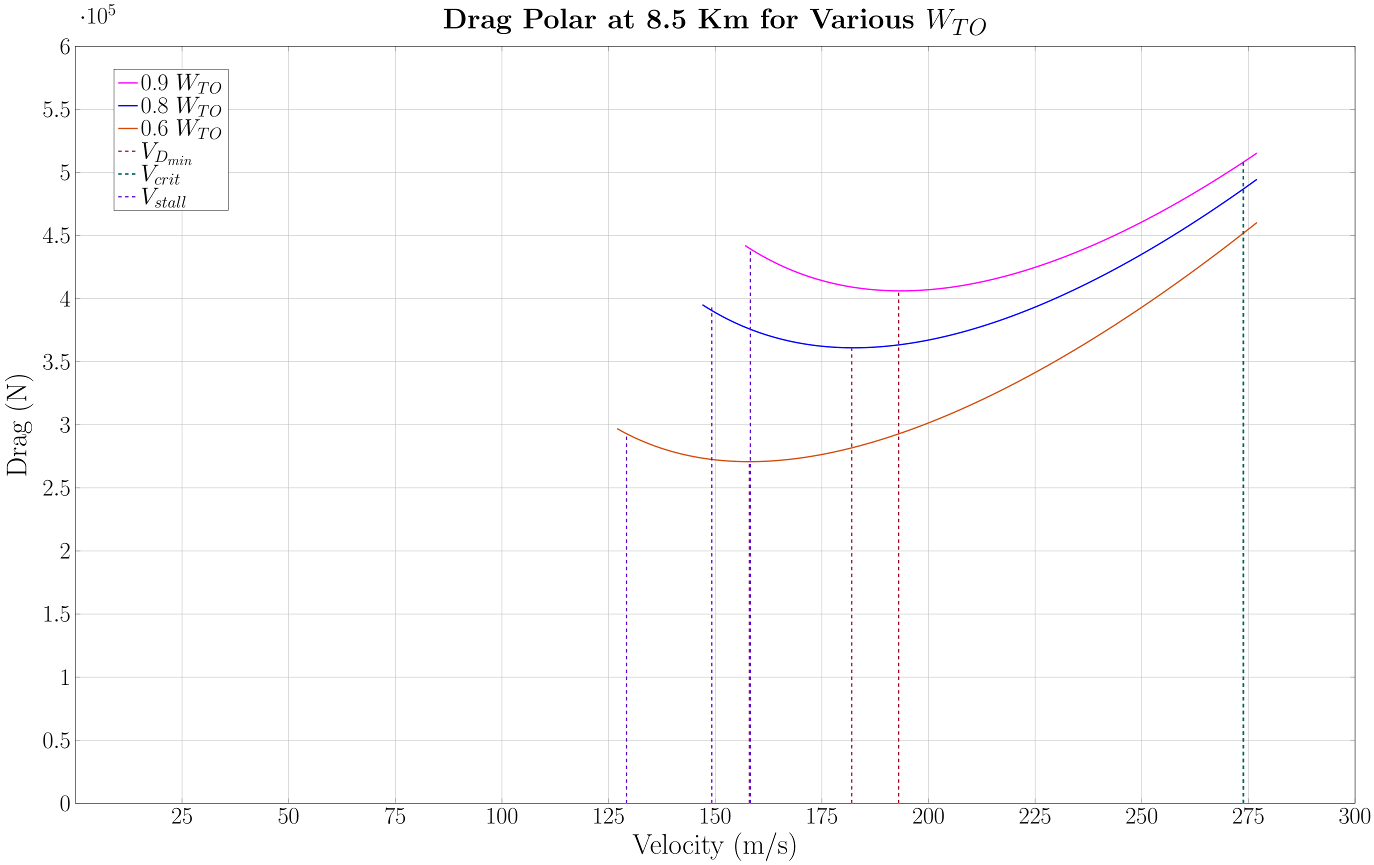
2.7 Drag Polar for 5.5 km



Parameter	Value
Altitude	0.5 km
V_{stall} at 0.9 W_{TO}	103.06 m/s
V_{stall} at 0.8 W_{TO}	97.17 m/s
V_{stall} at 0.6 W_{TO}	84.15 m/s
$V_{D_{min}}$ at 0.9 W_{TO}	156 m/s
$V_{D_{min}}$ at 0.8 W_{TO}	147 m/s
$V_{D_{min}}$ at 0.6 W_{TO}	127 m/s
V_{crit} at 0.9 W_{TO}	285.04 m/s
V_{crit} at 0.8 W_{TO}	285.04 m/s
V_{crit} at 0.6 W_{TO}	285.04 m/s

Table 7: Data for 5.5 km

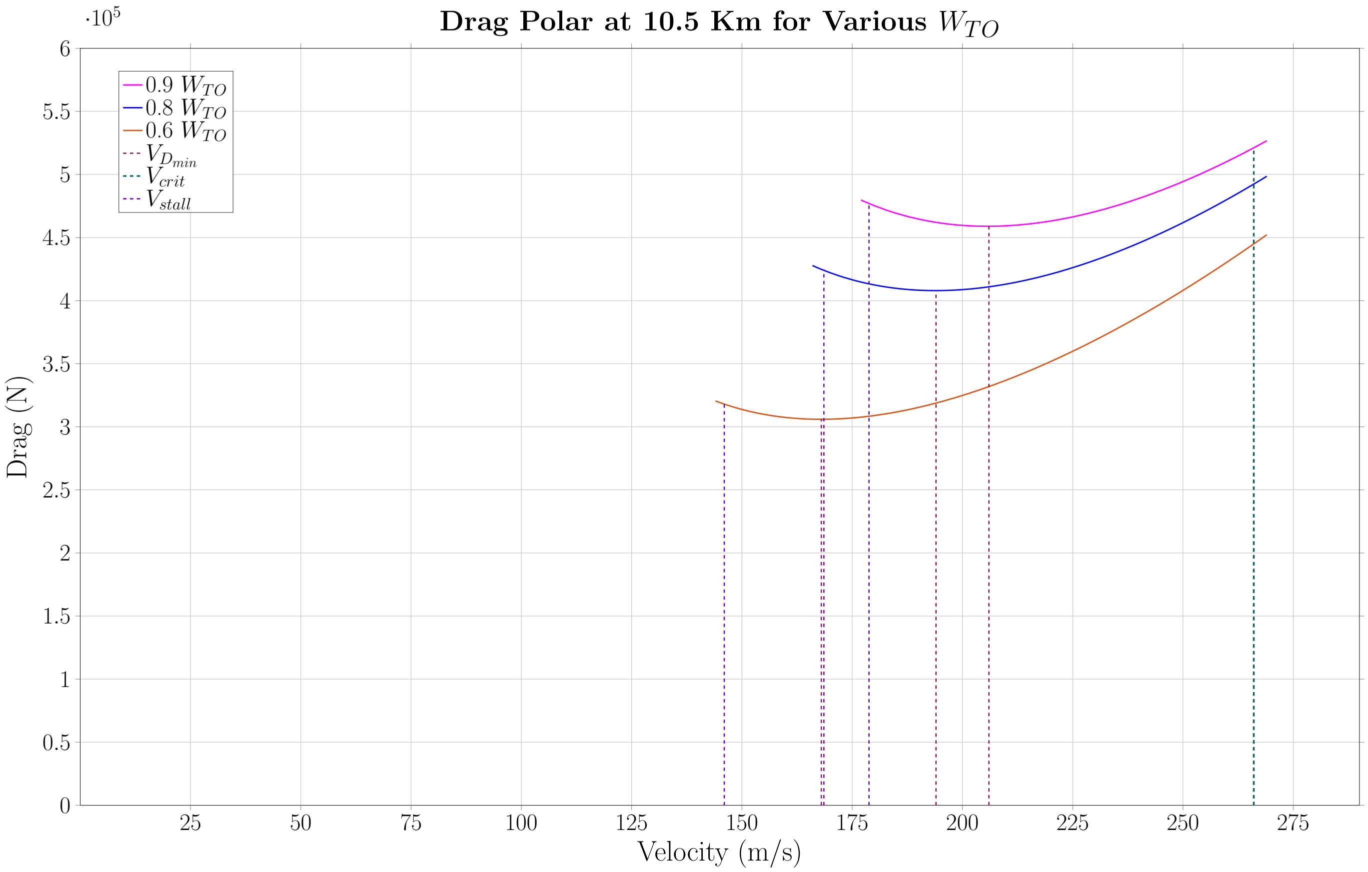
2.8 Drag Polar for 8.5 km



Parameter	Value
Altitude	0.5 km
V_{stall} at 0.9 W_{TO}	103.06 m/s
V_{stall} at 0.8 W_{TO}	97.17 m/s
V_{stall} at 0.6 W_{TO}	84.15 m/s
$V_{D_{min}}$ at 0.9 W_{TO}	156 m/s
$V_{D_{min}}$ at 0.8 W_{TO}	147 m/s
$V_{D_{min}}$ at 0.6 W_{TO}	127 m/s
V_{crit} at 0.9 W_{TO}	273.80 m/s
V_{crit} at 0.8 W_{TO}	273.80 m/s
V_{crit} at 0.6 W_{TO}	273.80 m/s

Table 8: Data for 8.5 km

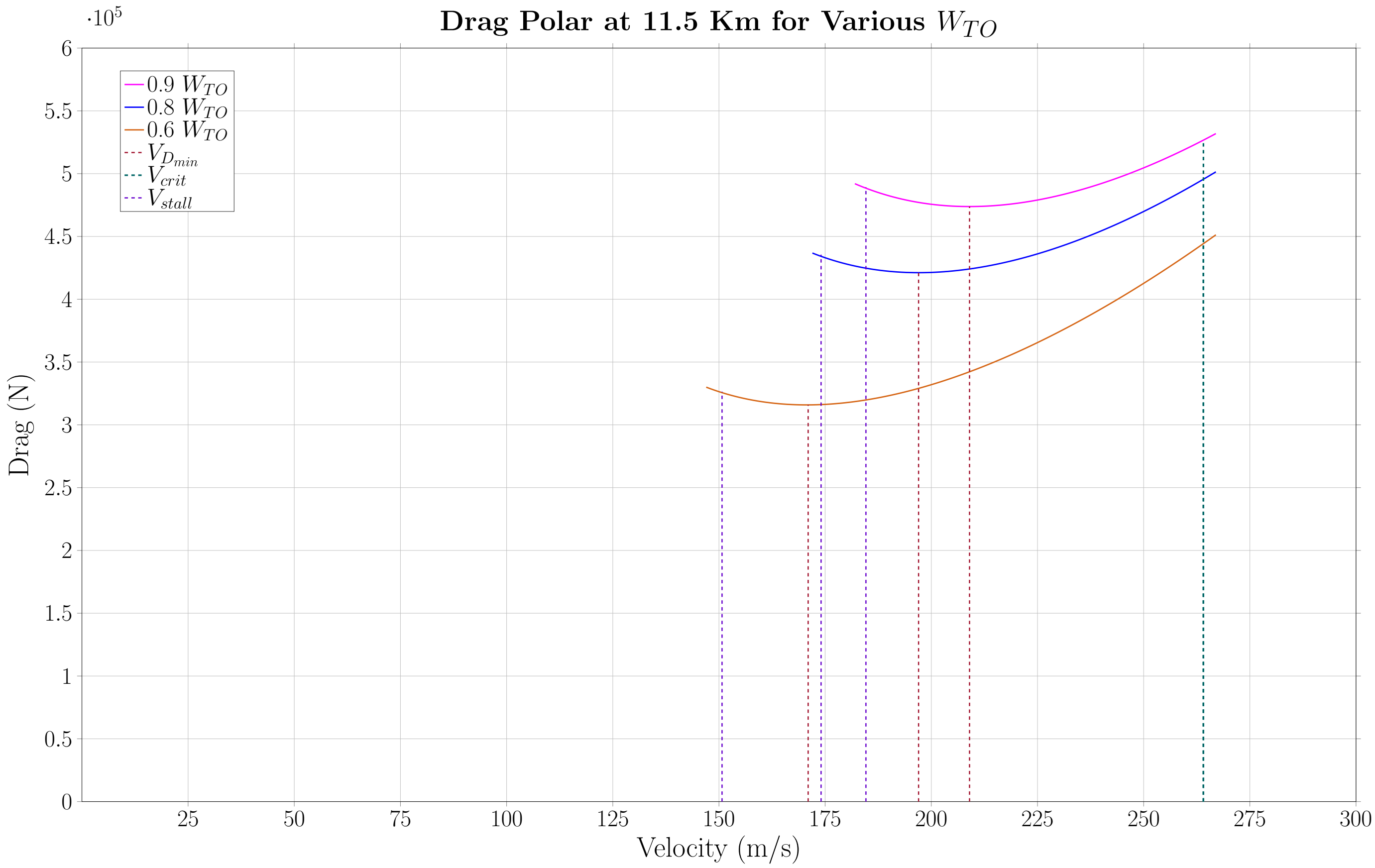
2.9 Drag Polar for 10.5 km



Parameter	Value
Altitude	0.5 km
V_{stall} at 0.9 W_{TO}	103.06 m/s
V_{stall} at 0.8 W_{TO}	97.17 m/s
V_{stall} at 0.6 W_{TO}	84.15 m/s
$V_{D_{min}}$ at 0.9 W_{TO}	156 m/s
$V_{D_{min}}$ at 0.8 W_{TO}	147 m/s
$V_{D_{min}}$ at 0.6 W_{TO}	127 m/s
V_{crit} at 0.9 W_{TO}	266.05 m/s
V_{crit} at 0.8 W_{TO}	266.05 m/s
V_{crit} at 0.6 W_{TO}	266.05 m/s

Table 9: Data for 10.5 km

2.10 Drag Polar for 11.5 km



Parameter	Value
Altitude	0.5 km
V_{stall} at 0.9 W_{TO}	103.06 m/s
V_{stall} at 0.8 W_{TO}	97.17 m/s
V_{stall} at 0.6 W_{TO}	84.15 m/s
$V_{D_{min}}$ at 0.9 W_{TO}	156 m/s
$V_{D_{min}}$ at 0.8 W_{TO}	147 m/s
$V_{D_{min}}$ at 0.6 W_{TO}	127 m/s
V_{crit} at 0.9 W_{TO}	264.07 m/s
V_{crit} at 0.8 W_{TO}	264.07 m/s
V_{crit} at 0.6 W_{TO}	264.07 m/s

Table 10: Data for 11.5 km

2.11 Inferences

It is inferred that at constant take-off weight (W_{TO}), the minimum drag (D_{min}) is constant. Further, the critical velocity boundary (V_{crit}) is constant for a given altitude since it depends on the speed of sound at that respective altitude.

3 Flight Envelope (V-h Plot)

3.1 Preliminary Calculations

An aircraft's level flight envelope signifies the limits to which an aircraft must adhere at all times to maintain safe operational flight. It is a plot of the altitude (h) versus the velocity (V) and is used to determine the safe flight limits of an aircraft. The boundaries of this envelope are defined by the minimum and maximum velocities of the aircraft (V1 and V2, respectively).

The flight envelope and, in extension, the analysis of the aircraft at a given height and throttle setting was carried out for three take-off weights and six altitudes. The weights considered for the analysis were 0.9 W_{TO}, 0.8 W_{TO} and 0.6 W_{TO}.

The altitudes at which the drag was estimated were 0.5 km, 3 km, 5.5 km, 8.5 km, 10.5 km and 11.5 km. On each polar, the V_{stall},q_{max} and the V_{crit} boundaries were marked to signify the flight envelope limits.

The equation for level, steady flight,

$$D = AV^2 + {}^{B}\!/_{V^2} = T_{ASL}\sigma^m \tag{8}$$

where A = ${}^{C_{D_0}\rho S}\!/_{2}$ and B = ${}^{2kW^2}\!/_{\rho S}$. T_{ASL} is the thrust at sea level, σ is the density ratio and m $\leq$ 1. A quadratic equation in V^2 is obtained,

$$AV^4 - \left(T_{ASL}\sigma^m\right)V^2 + B = 0 \tag{9}$$

Solving this, two values of V are obtained,

$$V^2 = \frac{(T_{ASL}\sigma^m) \pm \sqrt{((T_{ASL}\sigma^m) - 4AB}}{2A} \tag{10}$$

At the absolute ceiling, we get one velocity value if,

$$\left(T_{ASL}\sigma^m_{abs}\right)^2 = 4AB = 4kC_{D_0}W^2 \tag{11}$$

From equation 11 we get σ_{abs} as,

$$\sigma_{abs} = \frac{2\sqrt{kC_{D_0}}}{\left({}^{T_{ASL}}\!/_{W}\right)^m} \tag{12}$$

From the above equation, the density of that particular altitude can be obtained by,

$$\sigma = \frac{\rho_h}{\rho_{SL}} \tag{13}$$

Hence, the absolute altitude can be calculated from the density at the altitude using ISA.
The dynamic head (q) is given by,

$$q = \frac{1}{2}\rho V^2 \tag{14}$$

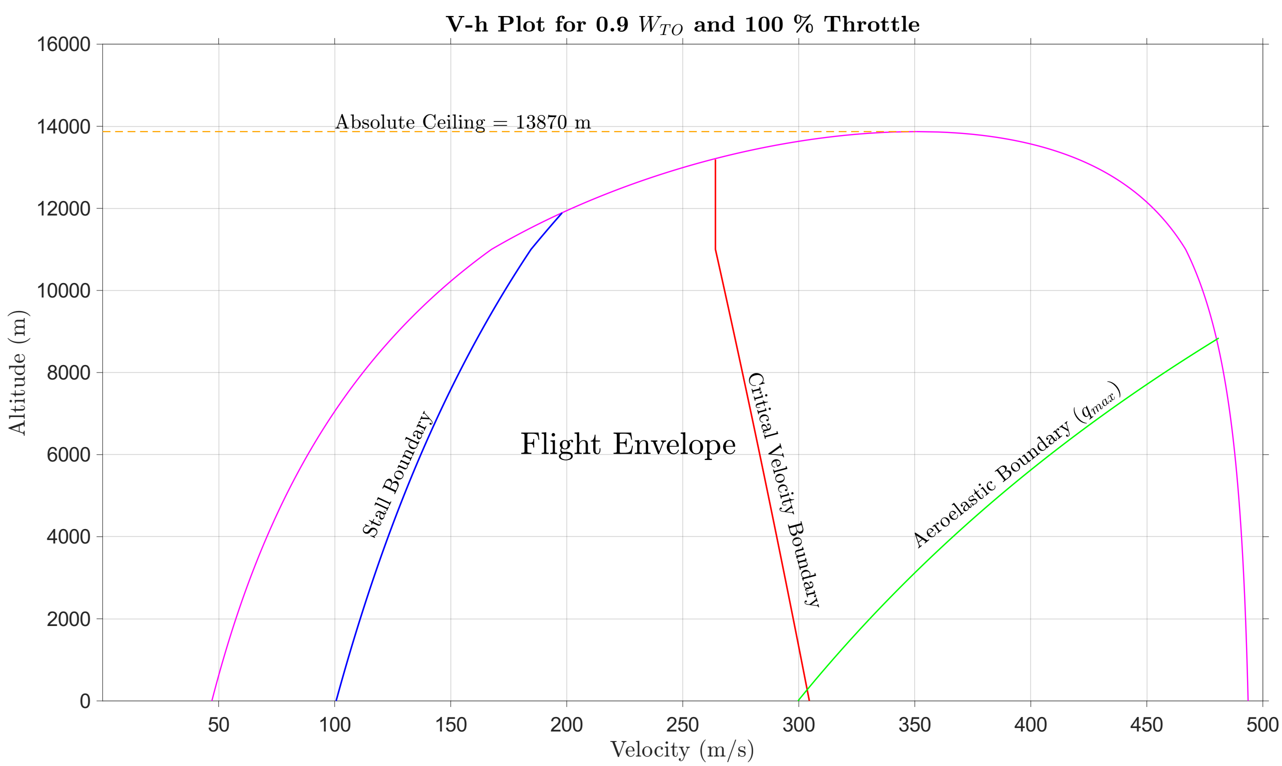
To plot the aeroelastic or the q_{max} boundary, the density is varied based on altitude, and the velocity can be obtained since $q = q_{max}$ is constant.

The stall velocity V_{stall} was calculated using the relation,

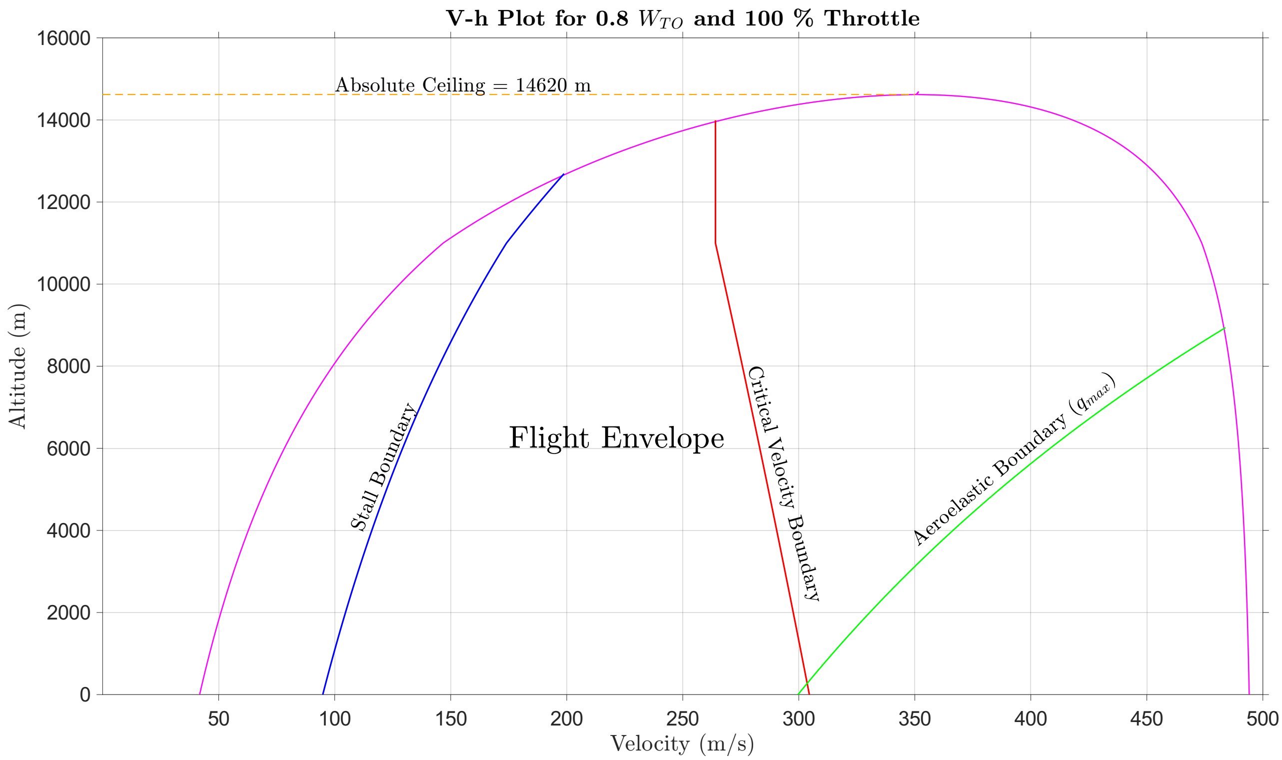
$$V_{stall} = \sqrt{\frac{2W_{TO}}{\rho S C_{L_{max}}}} \tag{15}$$

The critical velocity (V_{crit}) was calculated from the initial value at sea level by varying the speed of sound according to the altitude.

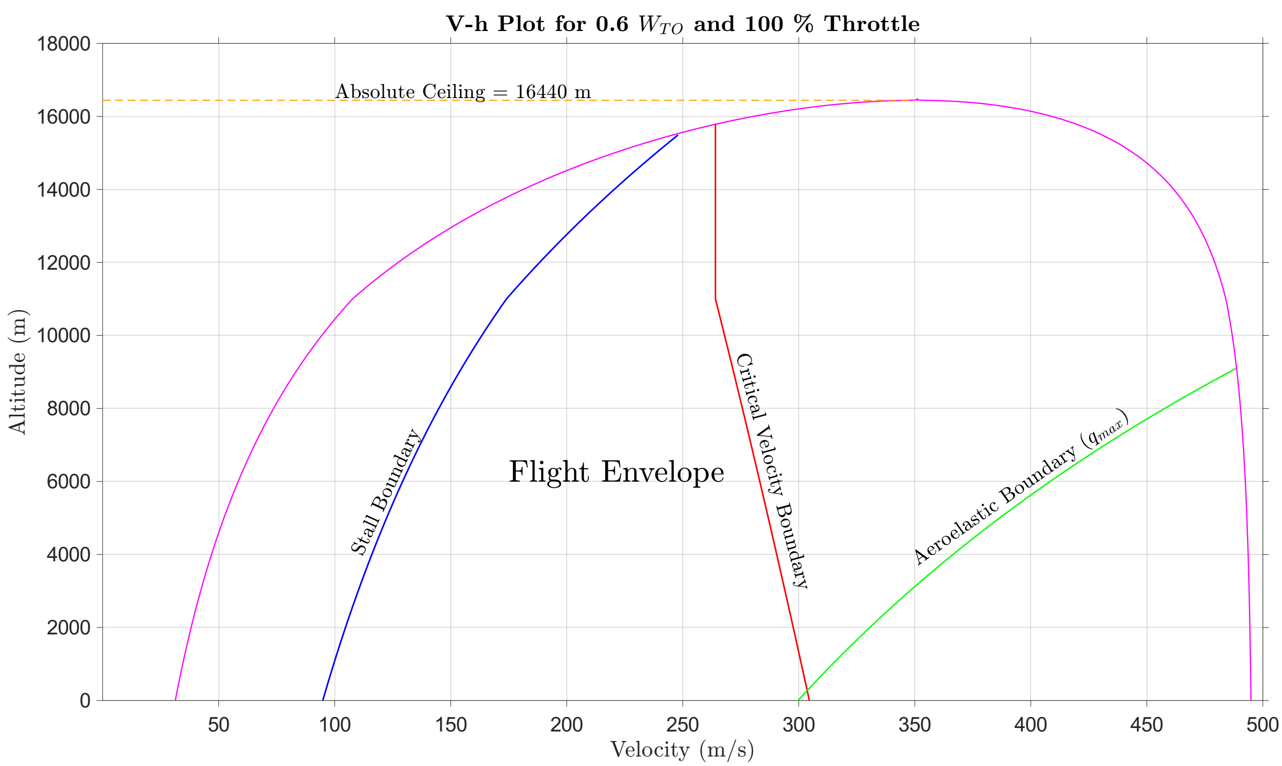
3.2 V-h Plot for 0.9 W_{TO} and 100% Throttle



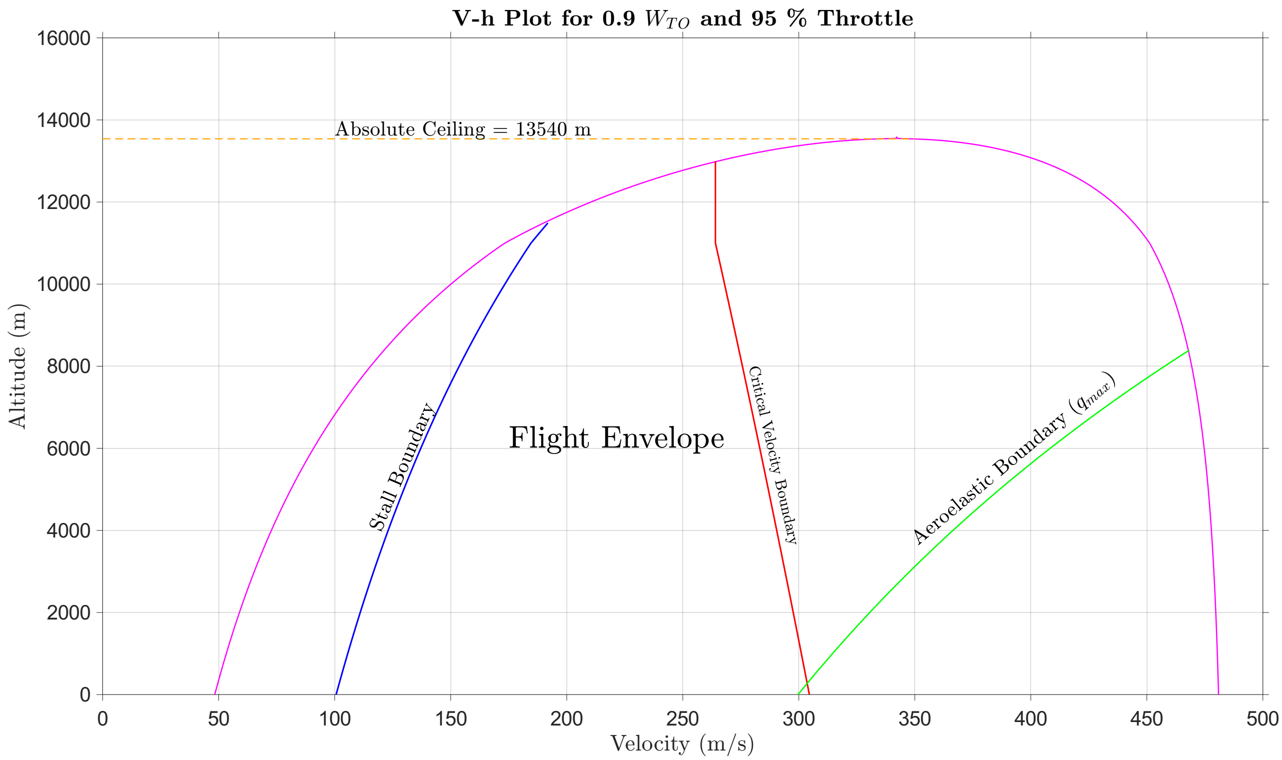
3.3 V-h Plot for 0.8 W_{TO} and 100% Throttle



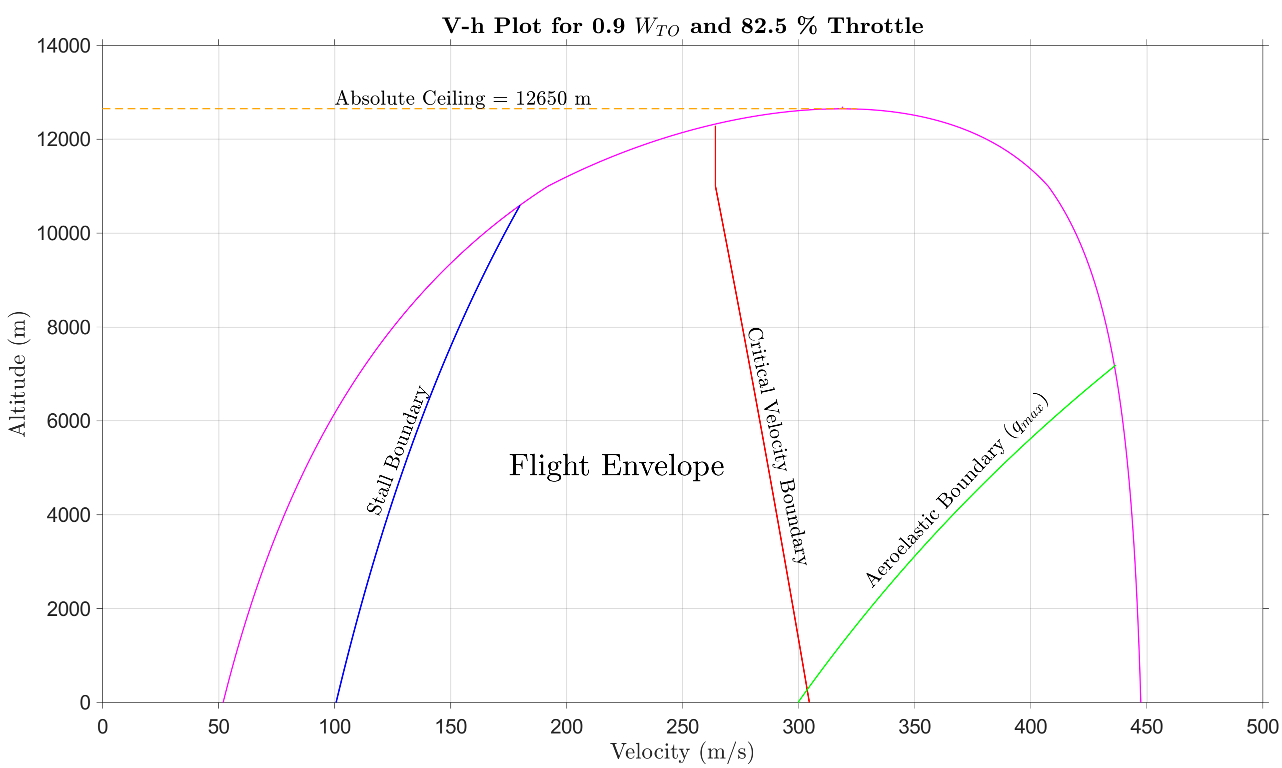
3.4 V-h Plot for 0.6 W_{TO} and 100% Throttle



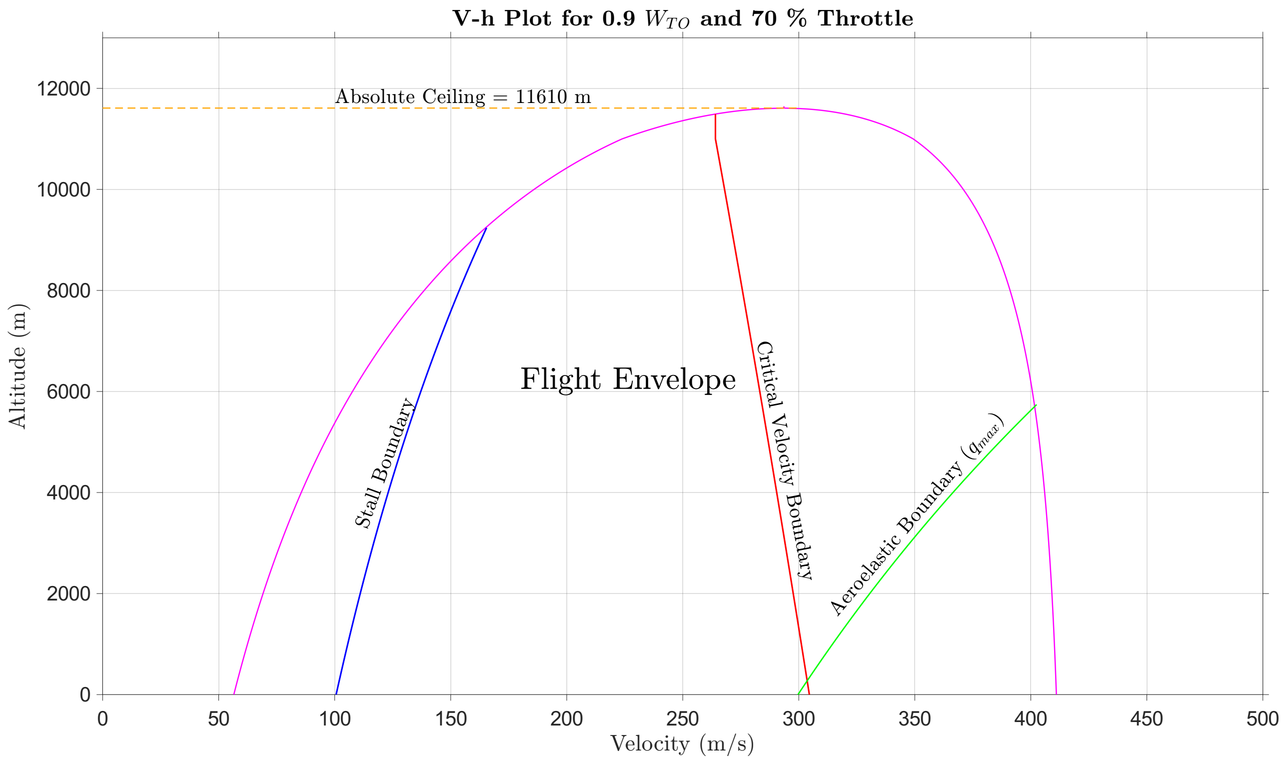
3.5 V-h Plot for 0.9 W_{TO} and 95% Throttle



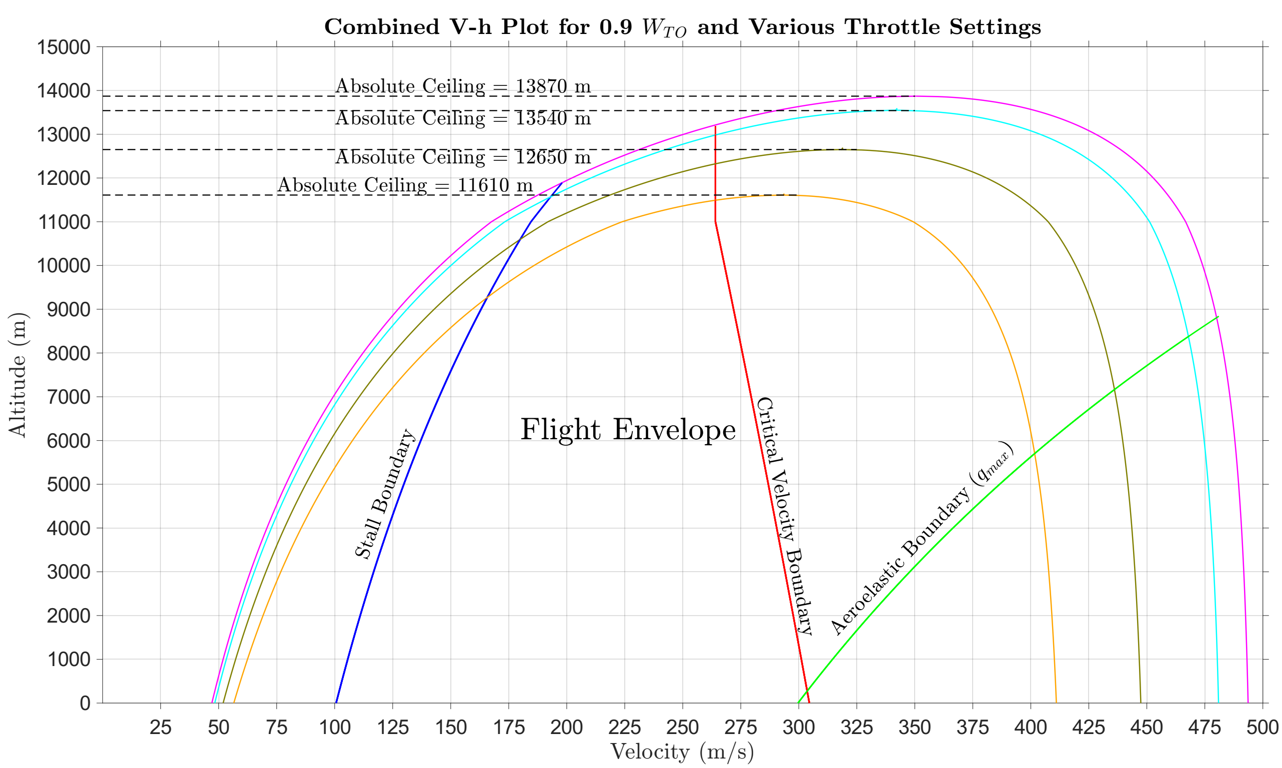
3.6 V-h Plot for 0.9 W_{TO} and 82.5% Throttle



3.7 V-h Plot for 0.9 W_{TO} and 70% Throttle



3.8 Combined V-h Plot for 0.9 W_{TO}



3.9 Inferences

It is inferred that the absolute ceiling (h_{abs}) varies with a change in take-off weight W_{TO} and the throttle percentage. The absolute ceiling (h_{abs}) is inversely proportional to take-off weight W_{TO} and directly proportional to the throttle percentage.

4 Rate Of Climb (R/C)

4.1 Preliminary Calculations

The rate of climb and, by extension, the analysis of the aircraft at a given height was carried out for three take-off weights and six altitudes. The weights considered for the analysis were 0.9 W_{TO}, 0.8 W_{TO} and 0.6 W_{TO}.

The altitudes at which the drag was estimated were 0.5 km, 3 km, 5.5 km, 8.5 km, 10.5 km and 11.5 km. The V_{stall} and the V_{crit} boundaries were marked to signify the flight envelope limits on each polar. The throttle setting for the plots in this section was considered to be 100%

The power available for flight (P_{avb}) is given by,

$$P_{avb} = Thrust \times V \tag{16}$$

The power required for flight (P_{reqd}) is given by,

$$P_{reqd} = Drag \times V \tag{17}$$

The power difference for flight (ΔP) is given by,

$$\Delta P = P_{avb} - P_{reqd} \tag{18}$$

Hence the Rate of Climb (R/C) can be obtained as,

$$R/C = \frac{\Delta P}{W} \tag{19}$$

The Best Rate of Climb at a given altitude is the maximum rate of climb corresponding to that altitude. The Best Rate of Climb from sea level (SL) to an altitude, say h, is given by,

$$(R/C)_{SL \to h} = \frac{(R/C)_{SL} + (R/C)_h}{2} \tag{20}$$

The density ratio at the absolute altitude σ_{abs} can be written as,

$$\sigma_{abs} = \frac{2\sqrt{kC_{D_0}}}{\left({}^{T_{ASL}}/_{W}\right)^m} \tag{21}$$

From the above equation, the density of that particular altitude can be obtained by,

$$\sigma = \frac{\rho_h}{\rho_h} \tag{22}$$

Hence, the absolute altitude can be calculated from the density at the altitude using ISA.
The stall velocity V_{stall} was calculated using the relation,

$$V_{stall} = \sqrt{\frac{2W_{TO}}{\rho S C_{L_{max}}}} \tag{23}$$

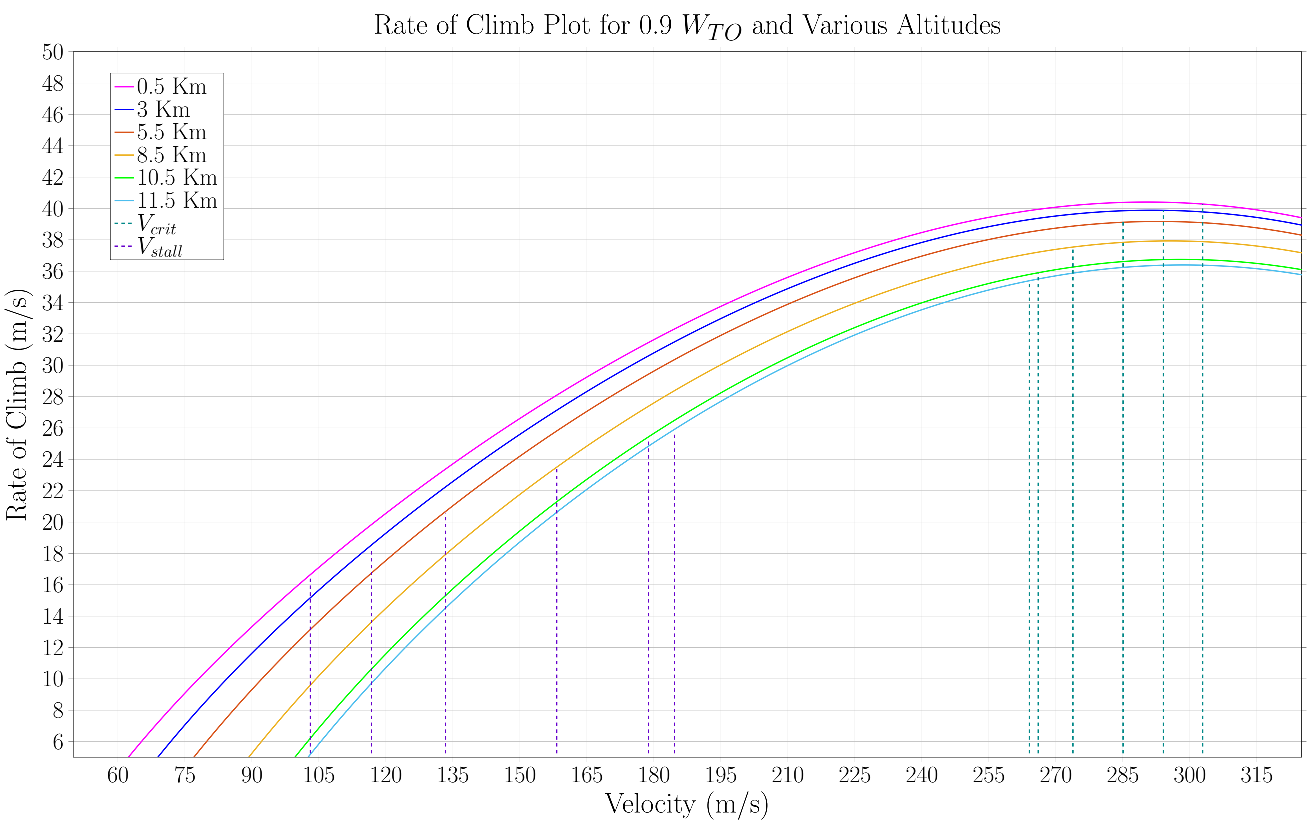
The critical velocity (V_{crit}) was calculated from the initial value at sea level by varying the speed of sound according to the altitude.

The time to climb can be calculated from the relation,

$$t = \int_a^b \frac{1}{(R/C)_{max}} \tag{24}$$

where a is the current altitude and b is the final altitude.

4.2 Rate Of Climb Plot for 0.9 W_{TO}

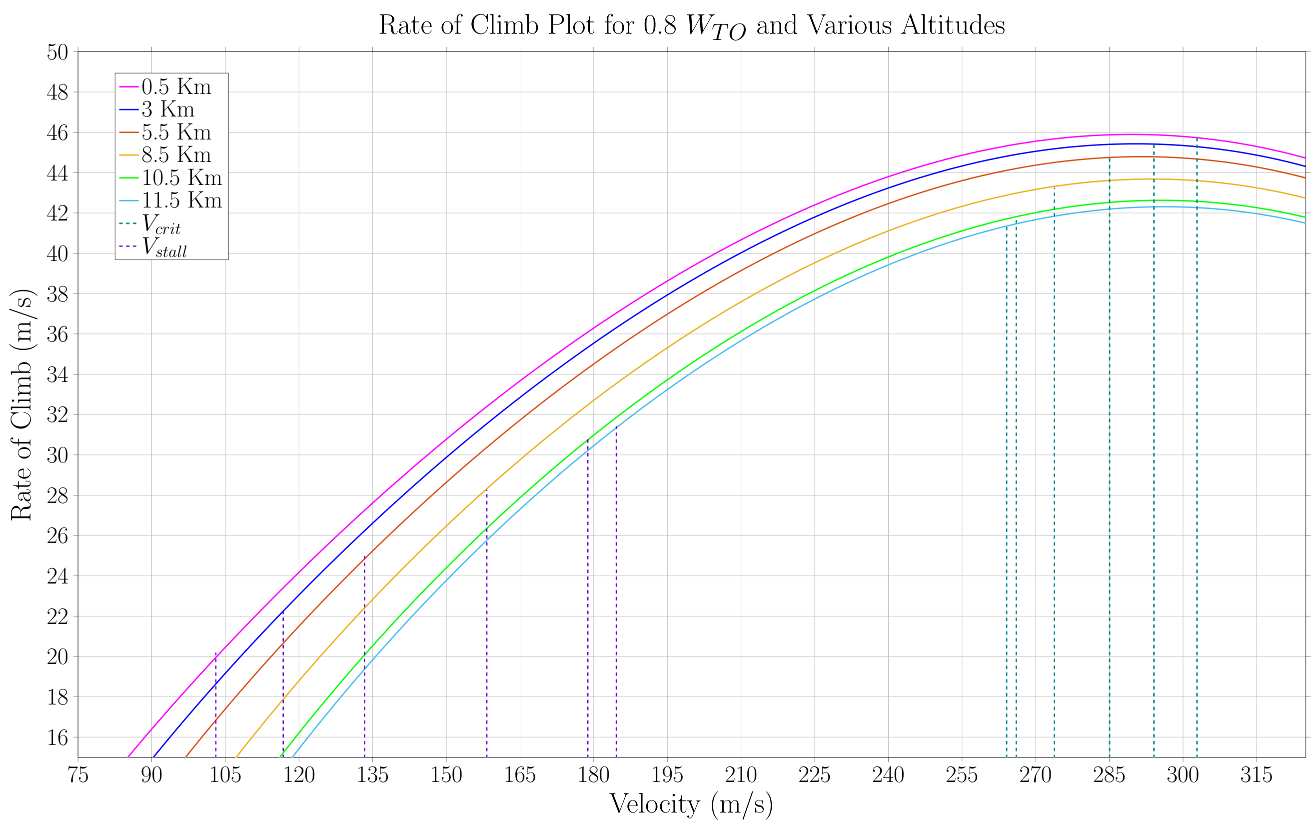


Parameter	Value
Take-off Weight (W_{TO})	6025.5 kN
V_{stall} at 0.5 km	103.06 m/s
V_{stall} at 3 km	116.78 m/s
V_{stall} at 5.5 km	133.36 m/s
V_{stall} at 8.5 km	158.24 m/s
V_{stall} at 10.5 km	178.81 m/s
V_{stall} at 11.5 km	184.60 m/s

Parameter	Value
Take-off Weight (W_{TO})	6025.5 kN
V_{crit} at 0.5 km	302.84 m/s
V_{crit} at 3 km	294.07 m/s
V_{crit} at 5.5 km	285.04 m/s
V_{crit} at 8.5 km	273.80 m/s
V_{crit} at 10.5 km	266.05 m/s
V_{crit} at 11.5 km	264.07 m/s

Table 11: Data for 0.9 W_{TO}

4.3 Rate Of Climb Plot for 0.8 W_{TO}

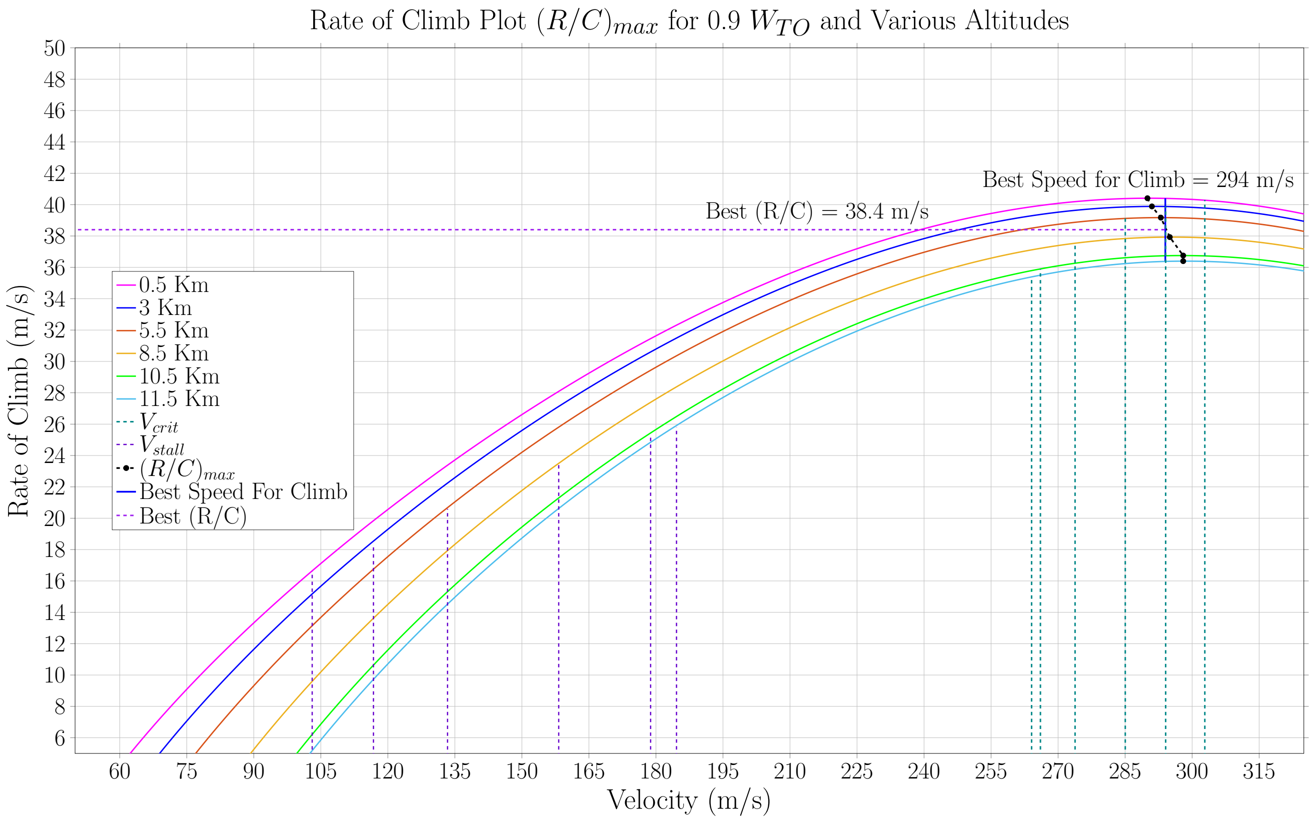


Parameter	Value
Take-off Weight (W_{TO})	5356 kN
V_{stall} at 0.5 km	97.17 m/s
V_{stall} at 3 km	110.10 m/s
V_{stall} at 5.5 km	125.73 m/s
V_{stall} at 8.5 km	149.19 m/s
V_{stall} at 10.5 km	168.58 m/s
V_{stall} at 11.5 km	174.04 m/s

Parameter	Value
Take-off Weight (W_{TO})	5356 kN
V_{crit} at 0.5 km	302.84 m/s
V_{crit} at 3 km	294.07 m/s
V_{crit} at 5.5 km	285.04 m/s
V_{crit} at 8.5 km	273.80 m/s
V_{crit} at 10.5 km	266.05 m/s
V_{crit} at 11.5 km	264.07 m/s

Table 12: Data for 0.8 W_{TO}

4.4 $(R/C)_{max}$ for 0.9 W_{TO}

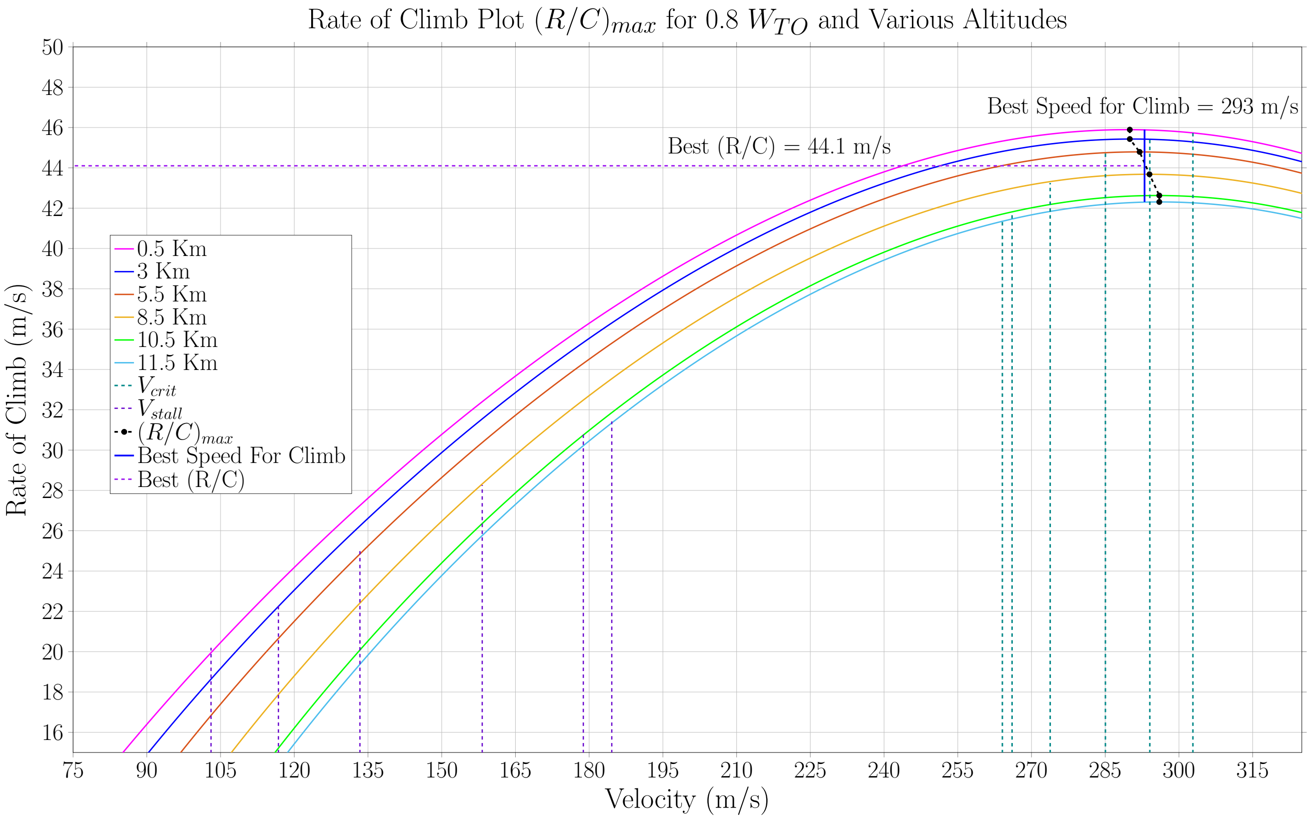


Parameter	Value
Take-off Weight (W_{TO})	6025.5 kN
V_{stall} at 0.5 km	103.06 m/s
V_{stall} at 3 km	116.78 m/s
V_{stall} at 5.5 km	133.36 m/s
V_{stall} at 8.5 km	158.24 m/s
V_{stall} at 10.5 km	178.81 m/s
V_{stall} at 11.5 km	184.60 m/s
$(R/C)_{max}$ at 0.5 km	40.41 m/s
$(R/C)_{max}$ at 3 km	39.88 m/s
$(R/C)_{max}$ at 5.5 km	39.17 m/s

Parameter	Value
Take-off Weight (W_{TO})	6025.5 kN
$(R/C)_{max}$ at 8.5 km	37.92 m/s
$(R/C)_{max}$ at 10.5 km	36.75 m/s
$(R/C)_{max}$ at 11.5 km	36.39 m/s
V_{crit} at 0.5 km	302.84 m/s
V_{crit} at 3 km	294.07 m/s
V_{crit} at 5.5 km	285.04 m/s
V_{crit} at 8.5 km	273.80 m/s
V_{crit} at 10.5 km	266.05 m/s
V_{crit} at 11.5 km	264.07 m/s

Table 13: Data for 0.9 W_{TO}

4.5 $(R/C)_{max}$ for 0.8 W_{TO}

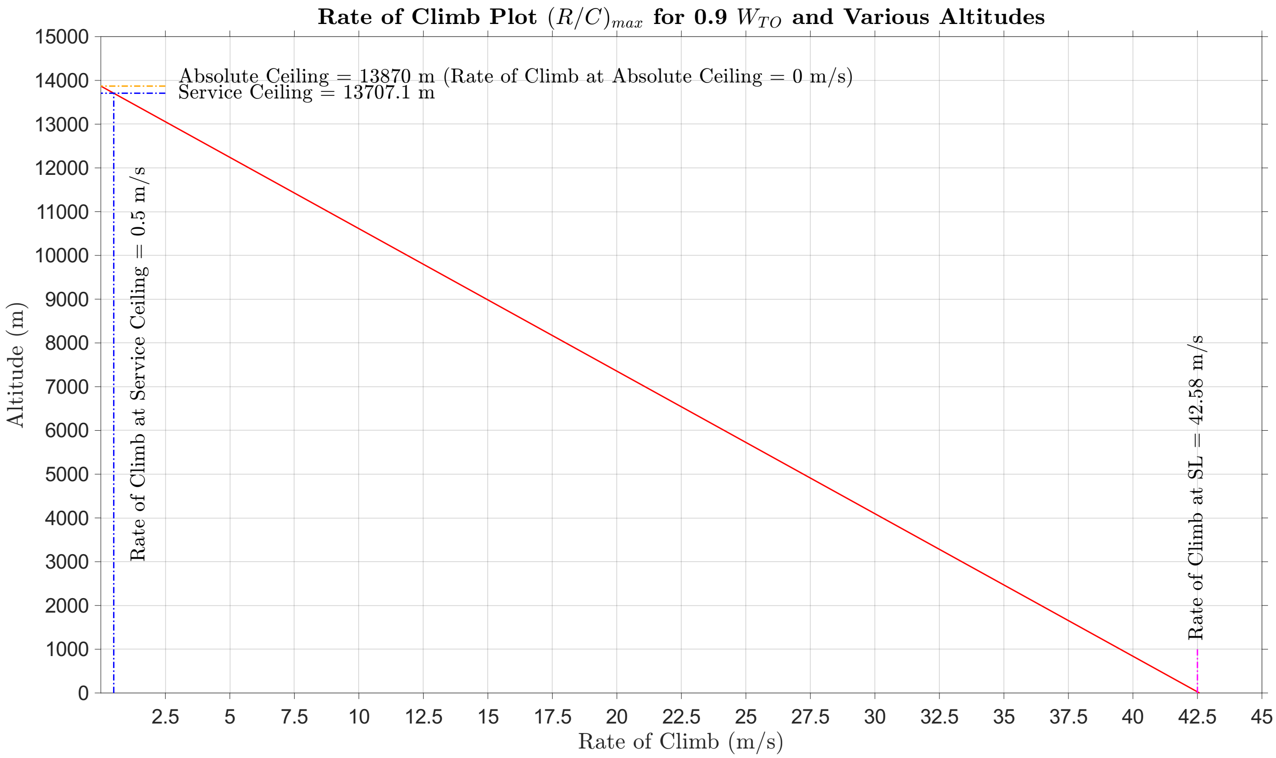


Parameter	Value
Take-off Weight (W_{TO})	5356 kN
V_{stall} at 0.5 km	97.17 m/s
V_{stall} at 3 km	110.10 m/s
V_{stall} at 5.5 km	125.73 m/s
V_{stall} at 8.5 km	149.19 m/s
V_{stall} at 10.5 km	168.58 m/s
V_{stall} at 11.5 km	174.04 m/s
$(R/C)_{max}$ at 0.5 km	45.89 m/s
$(R/C)_{max}$ at 3 km	45.43 m/s
$(R/C)_{max}$ at 5.5 km	44.79 m/s

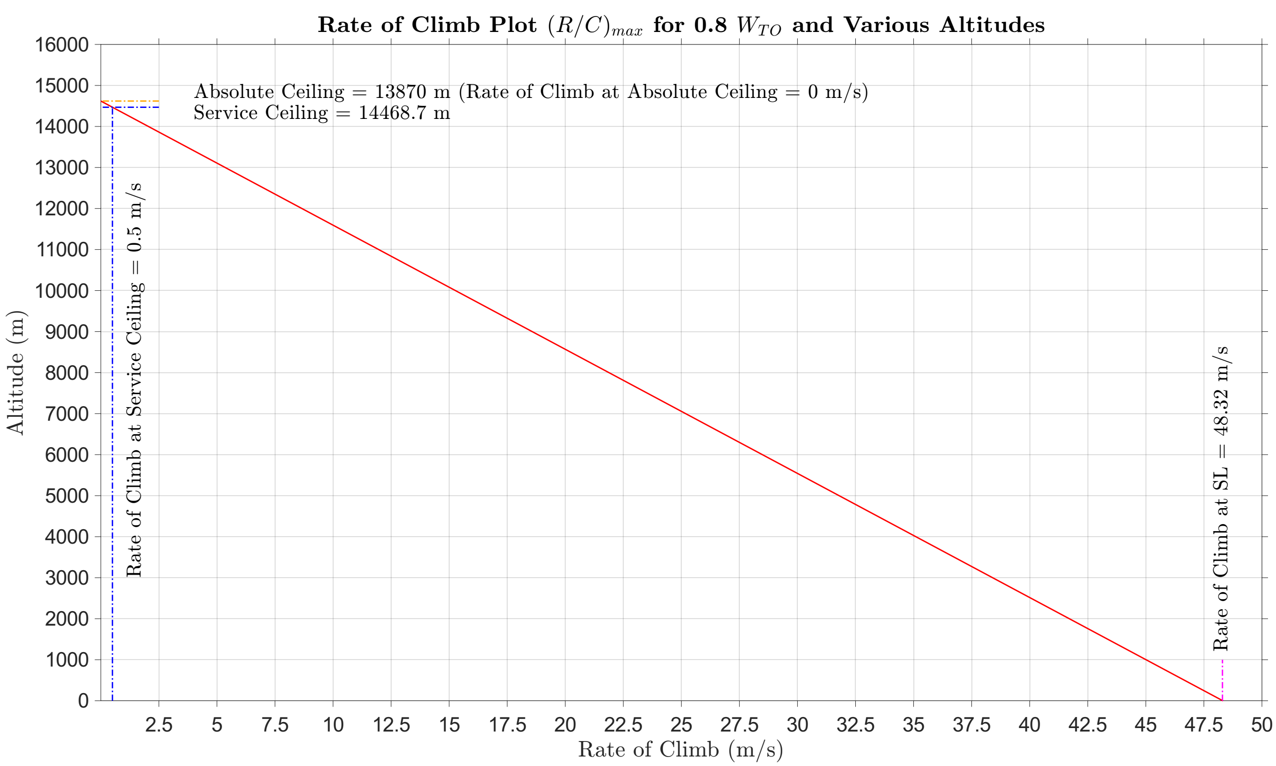
Parameter	Value
Take-off Weight (W_{TO})	5356 kN
$(R/C)_{max}$ at 8.5 km	43.68 m/s
$(R/C)_{max}$ at 10.5 km	42.63 m/s
$(R/C)_{max}$ at 11.5 km	42.31 m/s
V_{crit} at 0.5 km	302.84 m/s
V_{crit} at 3 km	294.07 m/s
V_{crit} at 5.5 km	285.04 m/s
V_{crit} at 8.5 km	273.80 m/s
V_{crit} at 10.5 km	266.05 m/s
V_{crit} at 11.5 km	264.07 m/s

Table 14: Data for 0.8 W_{TO}

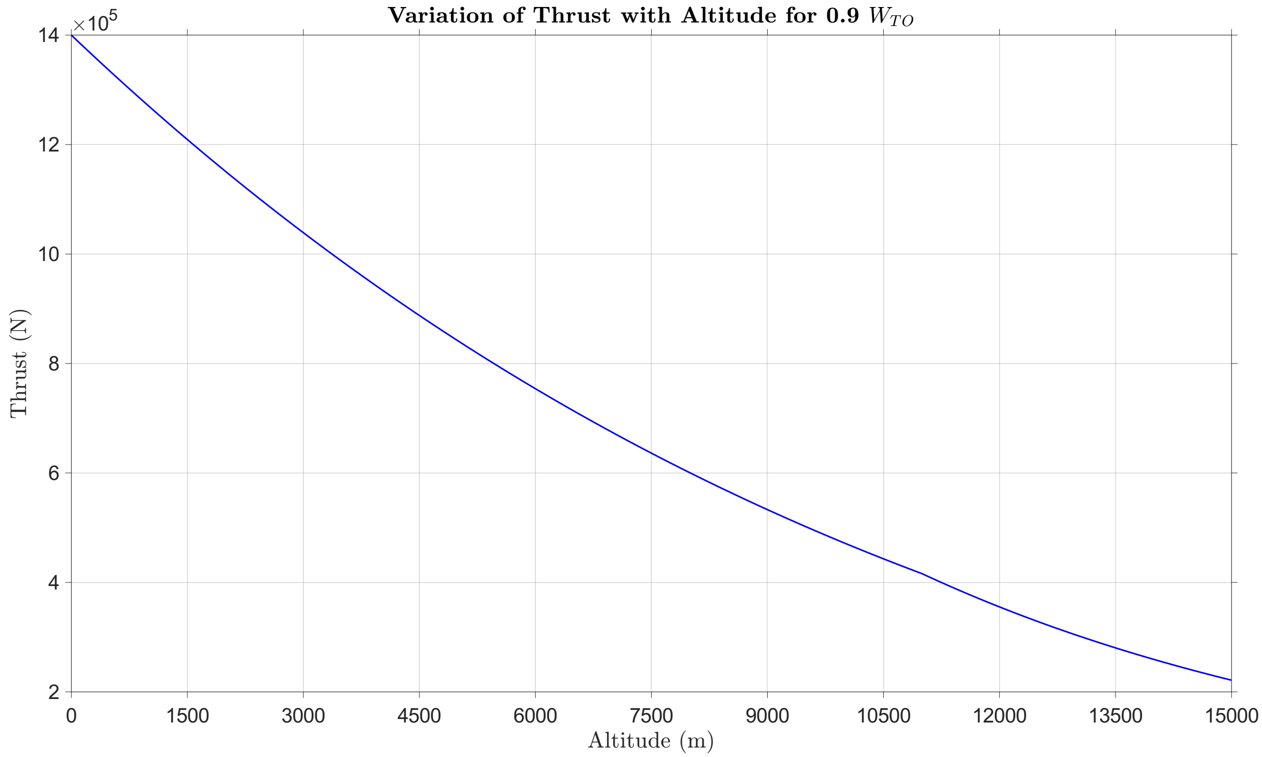
4.6 h v/s $(R/C)_{max}$ for 0.9 W_{TO}



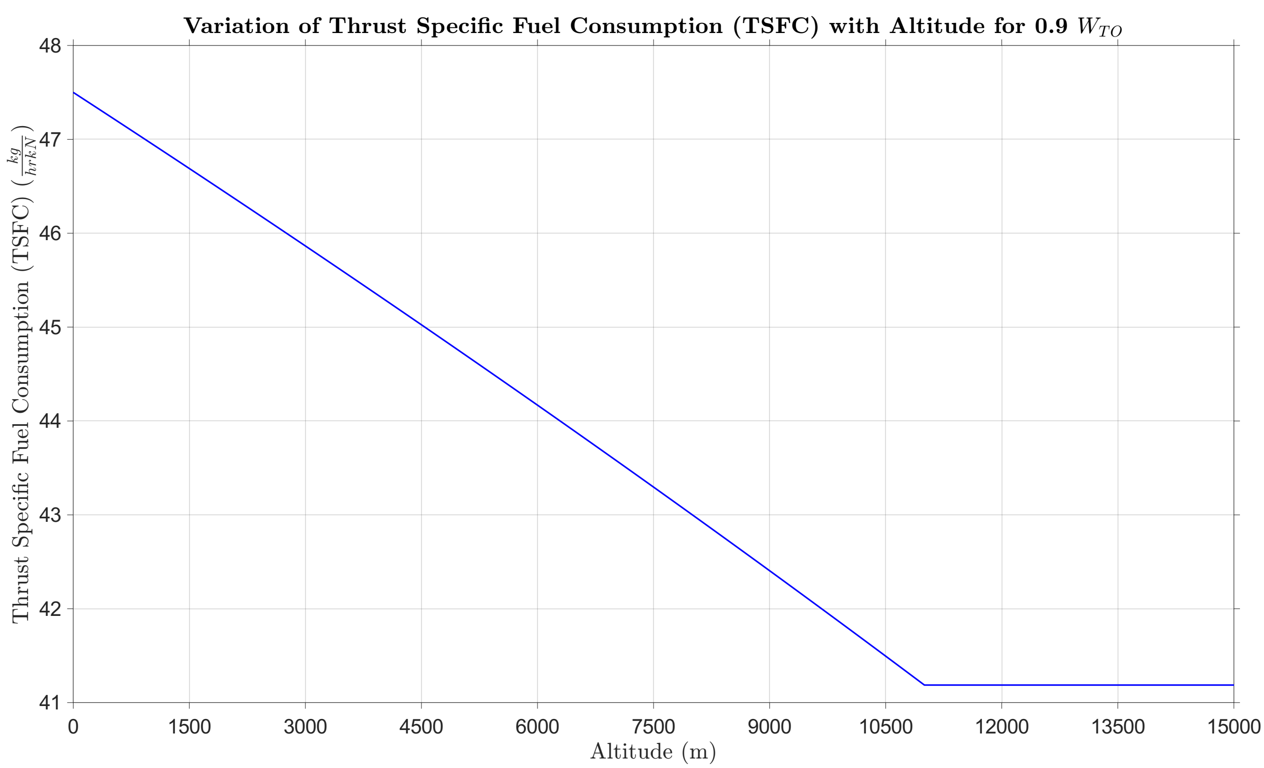
4.7 h v/s $(R/C)_{max}$ for 0.8 W_{TO}



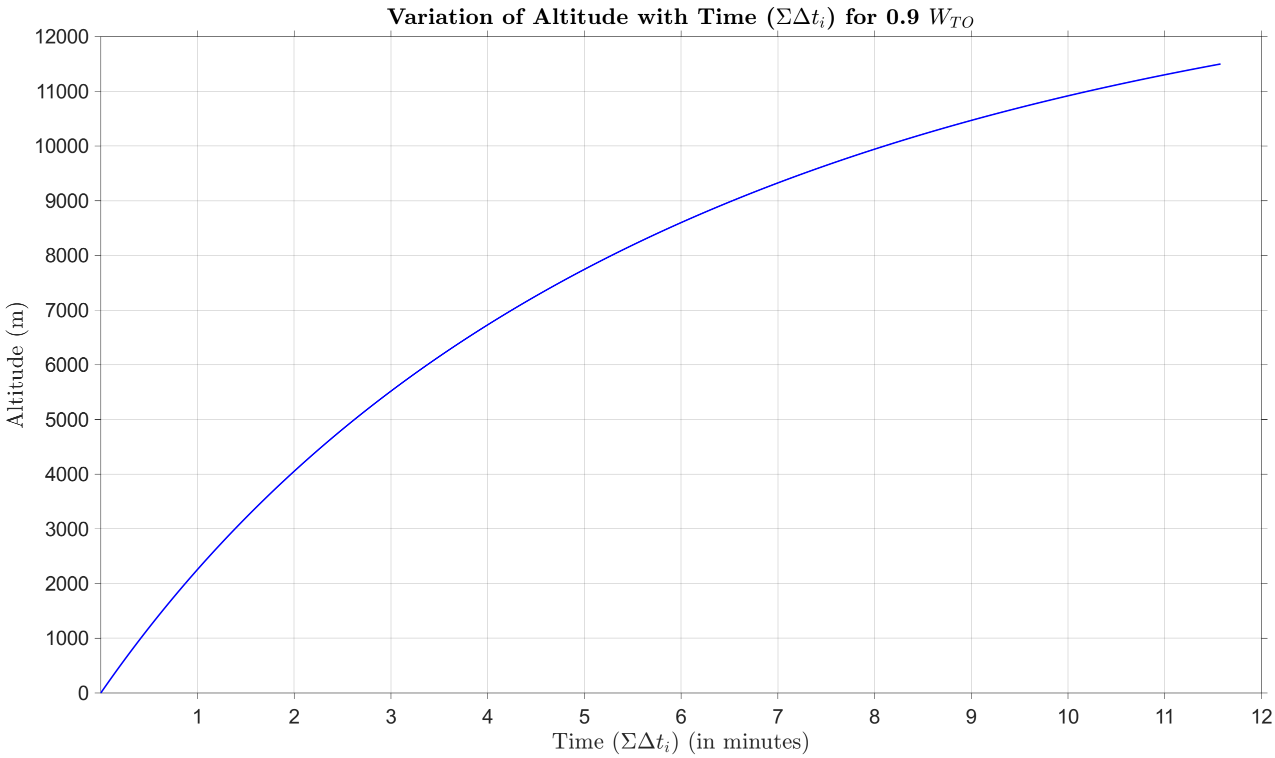
4.8 Thrust v/s Altitude for 0.9 W_{TO}



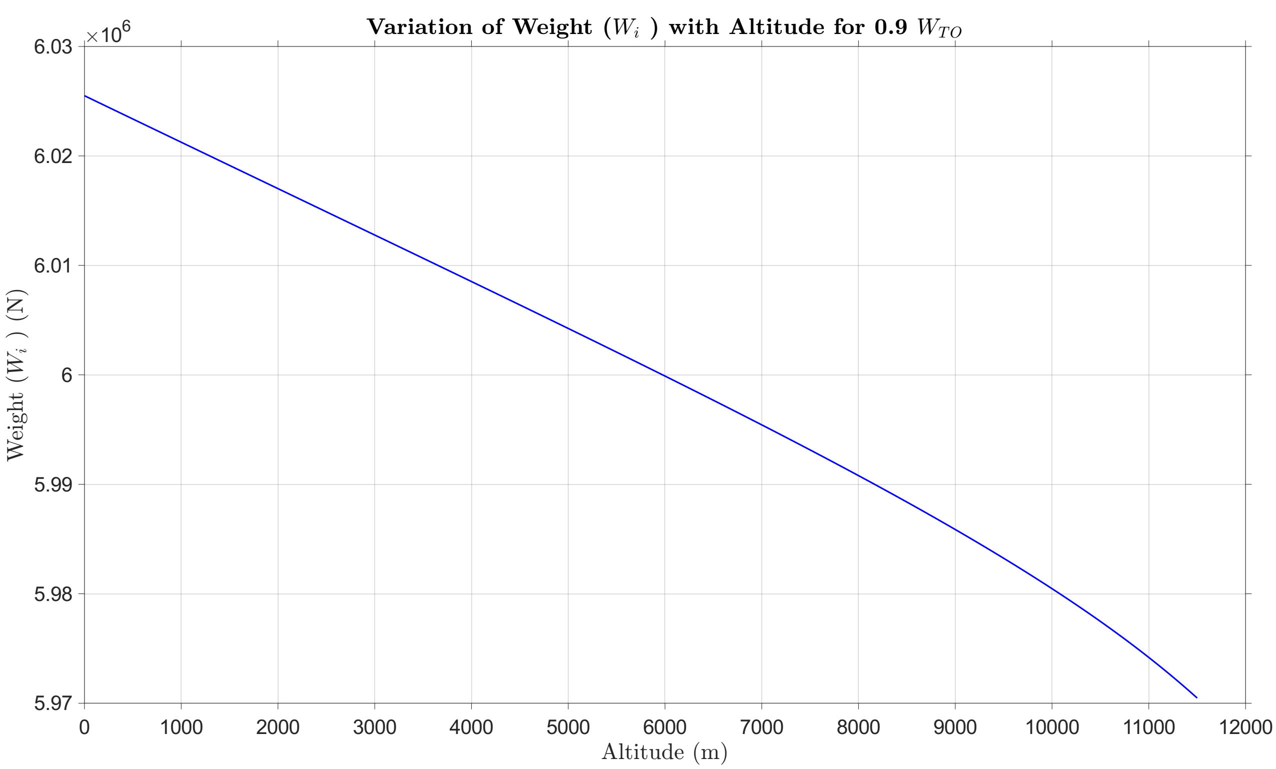
4.9 TSFC v/s Altitude for 0.9 W_{TO}



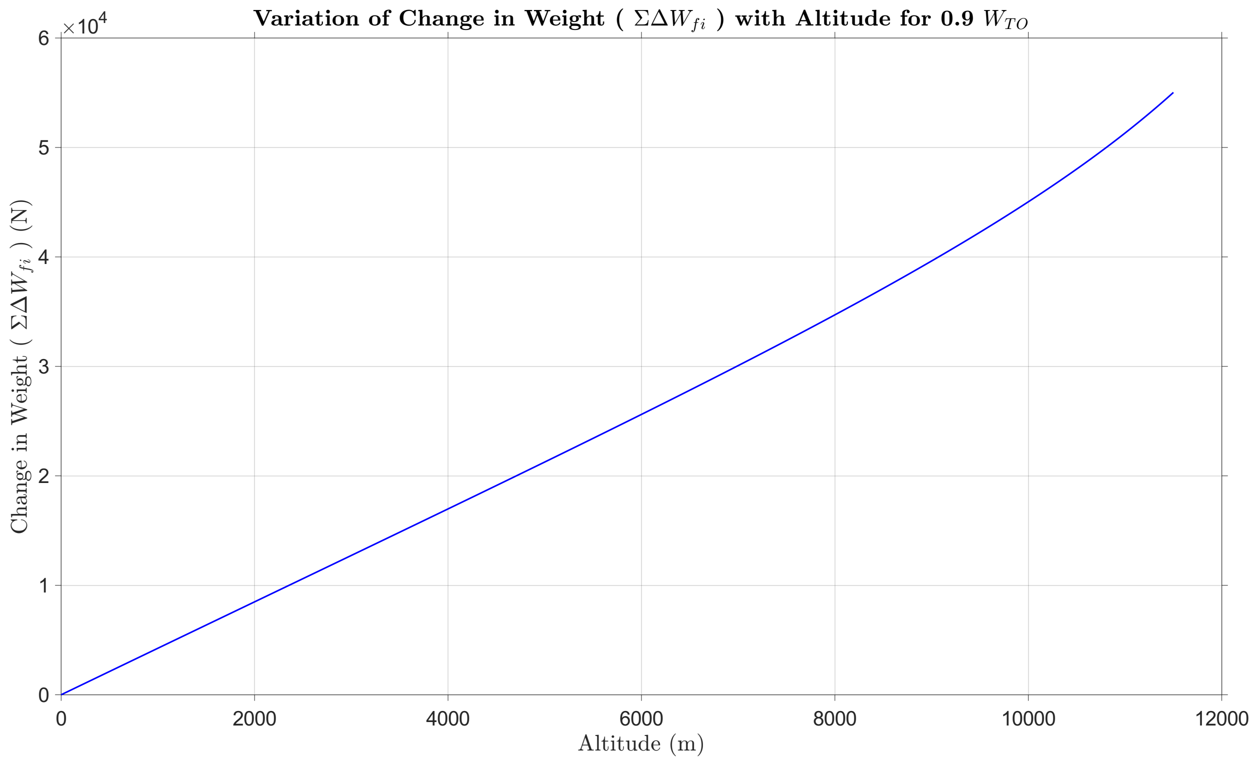
4.10 Variation of Altitude with Time ($\Sigma\Delta t_i$) for 0.9 W_{TO}



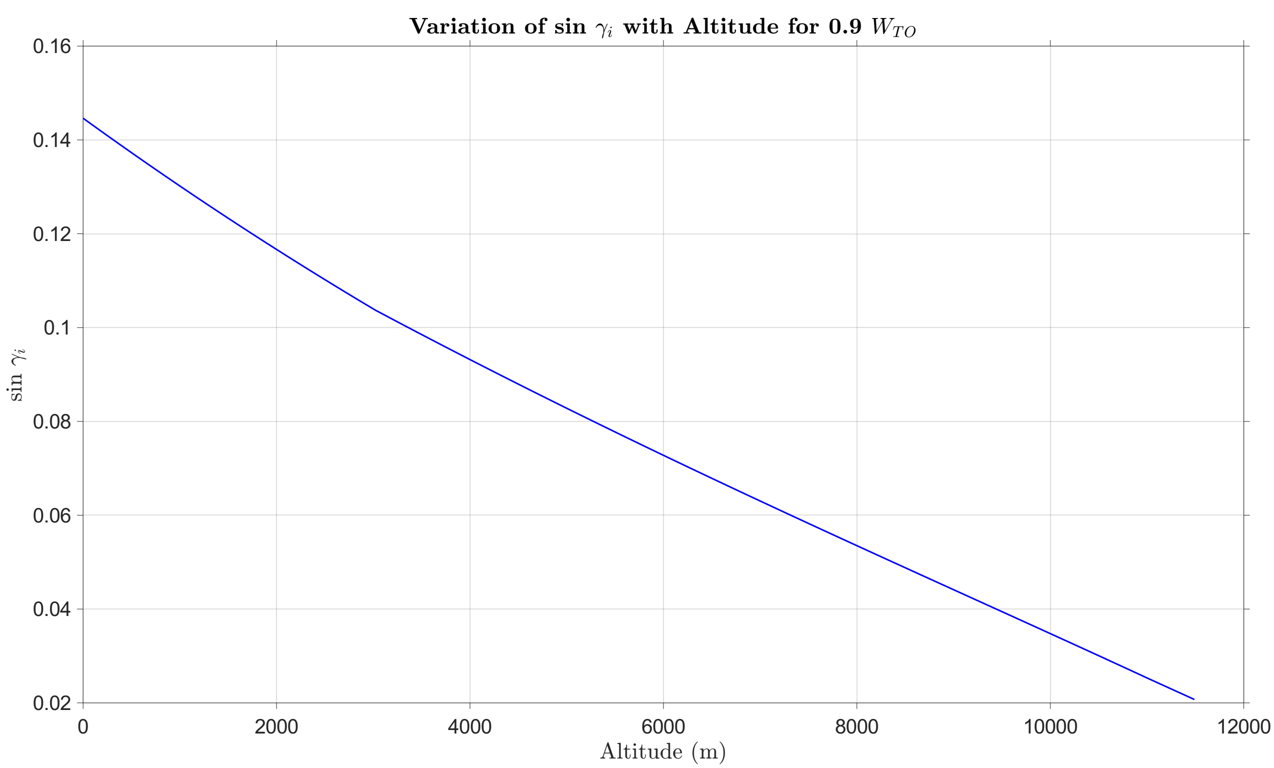
4.11 Variation of Weight (W_i) with Altitude for 0.9 W_{TO}



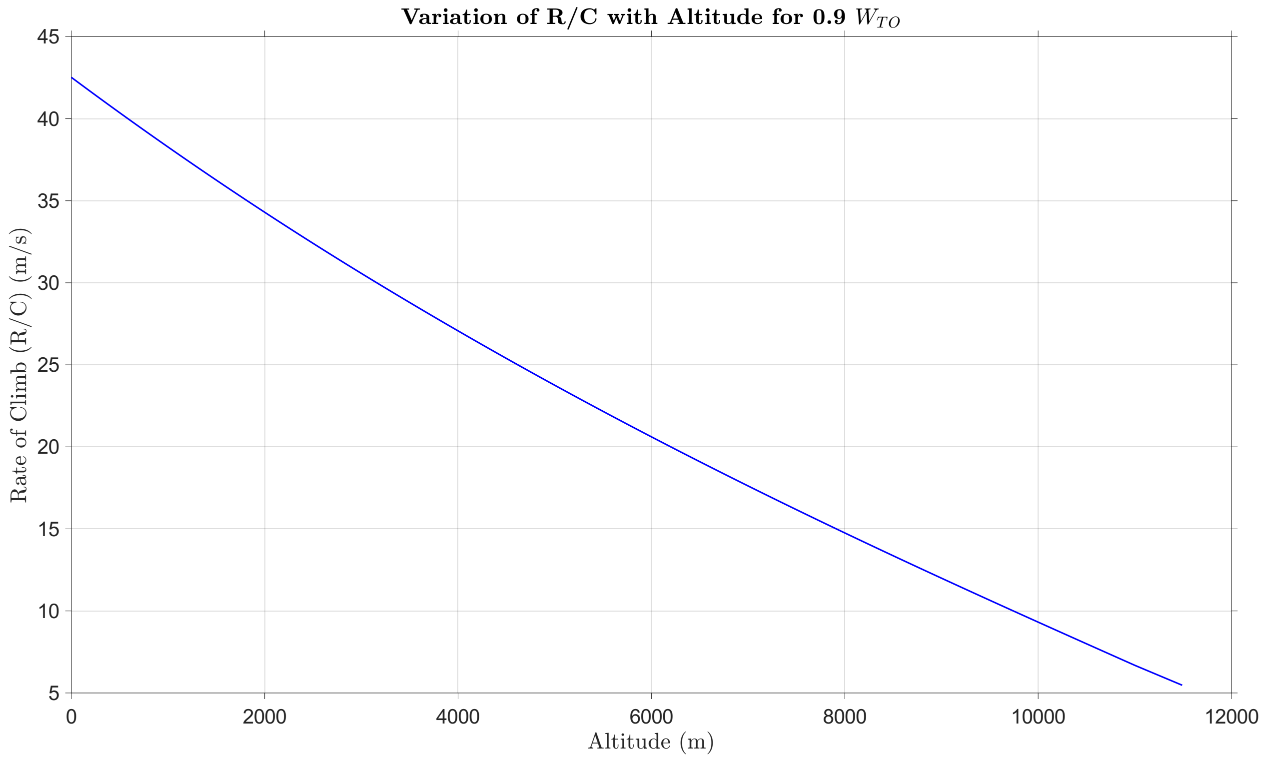
4.12 Variation of Change in Weight ($\Sigma\Delta W_{fi}$) with Altitude for 0.9 W_{TO}



4.13 Variation of sin γ_i with Altitude for 0.9 W_{TO}



4.14 Variation of R/C with Altitude for 0.9 W_{TO}



4.15 Time to Climb and Fuel to Climb

The estimation of the fuel to climb and the time to climb was done using the iterative method described in reference 4 (see the reference section). The formulae used in this approach are (for climb segments i = 1 to N),

$$\Delta h = h/N \tag{25}$$

From ISA,

$$h_i = 44300(1 - \sigma_i^{0.235}) \tag{26}$$

Hence,

$$\sigma_i = [1 - (h_i/44300)]^{\frac{1}{0.235}} \tag{27}$$

Hence the dynamic pressure (q) can be quantified as,

$$q_i = \sigma_i q_{SL} \tag{28}$$

From ISA,

$$\theta_i = \frac{(288.16 - 0.0065h_i)}{288.16} \tag{29}$$

The thrust-specific fuel consumption for a turbofan aircraft (c_T) can be calculated using,

$$(c_T)_i = (c_T)_{SL}\sqrt{\theta} \tag{30}$$

The weights for i = 1 to i = n-1 are given by,

$$W_1 = W_0 \tag{31}$$

and,

$$W_{i+1} = W_i - (\Delta W_f)_i \tag{32}$$

Thus C_L can be calculated,

$$(C_L)_i = \frac{W_i}{q_i S} \tag{33}$$

Further, C_D can be calculated,

$$(C_D)_i = C_{D_0} + k(C_{L_i})^2 \tag{34}$$

From C_D, the drag can be calculated as,

$$D_i = C_{D_i} q_i S \tag{35}$$

To calculate the rate of climb,

$$sin(\gamma_i) = \frac{[T_{SL}\sigma_i - D_i]}{W_i} \tag{36}$$

Hence,

$$(R/C)_i = V sin(\gamma_i) \tag{37}$$

The incremental time is given by,

$$\Delta t_i = \frac{\Delta h}{(R/C)_i} \tag{38}$$

The incremental fuel weight is given by,

$$(\Delta W_f)_i = [T_{SL}\sigma_i]\,(c_T)_i \Delta t_i \tag{39}$$

This resulted in the following conclusions,

$$T_c = 11.57 \ \ minutes \tag{40}$$

$$F_c = 5502.62 \ \ N \tag{41}$$

Where T_c is the Time to climb, and F_c is the Fuel to climb.

4.16 Inferences

The Rate of Climb for various altitudes were plotted, and the best rate of climb and the best climb speed were obtained. Further, the variation of thrust and TSFC with altitude were plotted. The thrust has an exponential relation with altitude, whereas the TSFC varies linearly till 11 km, after which it is constant. These results conform to the general trend of the ISA model. Further, the time of climb was also calculated and was found to have decreased with a decrease in take-off weight (W_{TO}).

5 Turn Performance

5.1 Preliminary Calculations

The turn performance was analysed for steady, coordinated turning flight. The main factors affecting turn performance are the turn rate (ω), the radius of turn (R) and the load factor (n). The stall, structural and propulsive boundaries lift the turn capabilities of the aircraft. Two quantities that need elucidation are the sustained and attained turn rates, represented by STR and ATR, respectively.

The attained turn rate (ATR) corresponds to the turn rate at the corner speed. In contrast, the maximum sustained turn rate (STR) corresponds to the maximum turn rate on the propulsive boundary. The turn performance analyses were carried at two weights, namely 0.8 W_{TO} and 0.9 W_{TO}. These were carried out at two altitudes of 0.5 Km and 5 Km, respectively. The turn rate (ω) is given by,

$$\omega = \frac{g\sqrt{n^2-1}}{V} \tag{42}$$

Where n is the load factor and is given by,

$$n = \frac{L}{W} \tag{43}$$

It is also given by,

$$n = \sqrt{\left[\frac{\frac{1}{2}\rho_\infty V_\infty^2}{K\,(W/S)}\left(\frac{T}{W} - \frac{1}{2}\rho_\infty V_\infty^2 \frac{C_{D_0}}{W/S}\right)\right]} \tag{44}$$

The turn rate is also given by,

$$\omega = \frac{V}{R} \tag{45}$$

The stall boundary is given by,

$$V_{stall} = \sqrt{\frac{2nW}{\rho S C_{L_{max}}}} \tag{46}$$

The sustained turn rate boundary is given by,

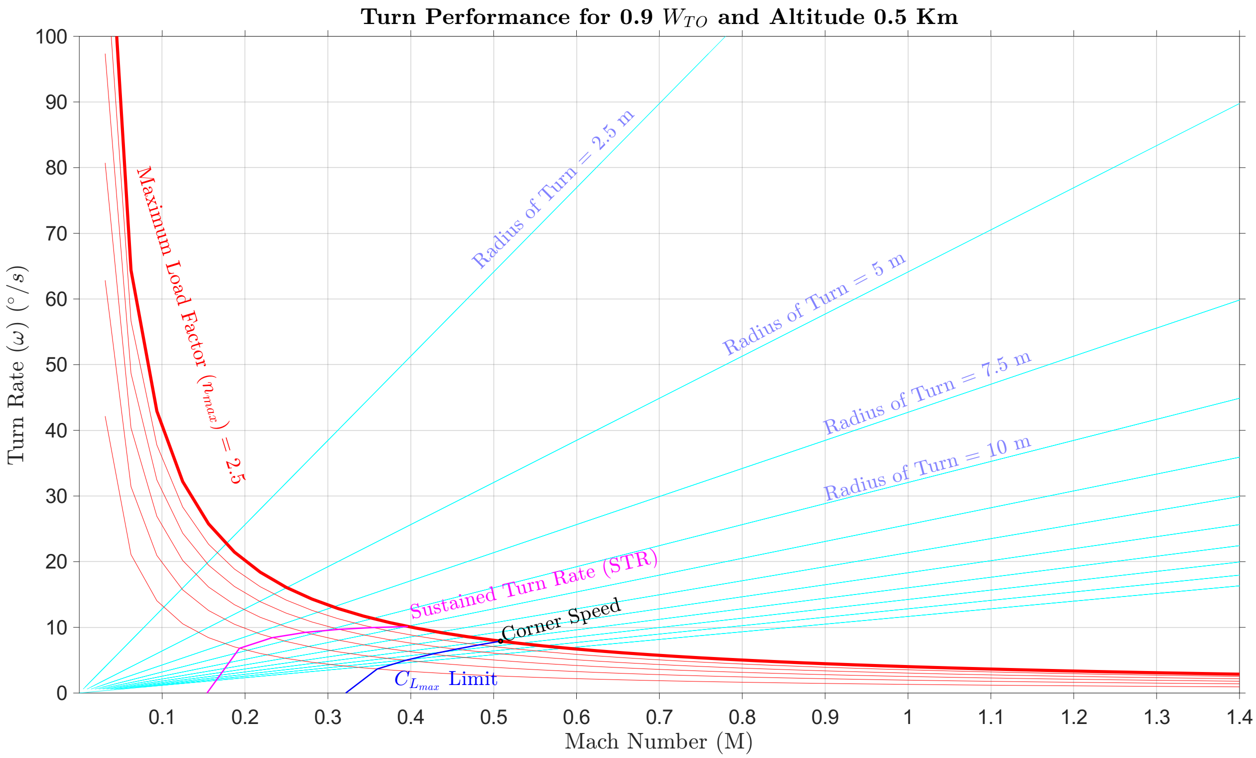
$$AV^4 - TV^2 + Bn^2 = 0 \tag{47}$$

where A = $C_{D_0}\rho S/2$ and B = $2kW^2/\rho S$. The bank angle boundary (ϕ_{max}) was plotted using the relation,

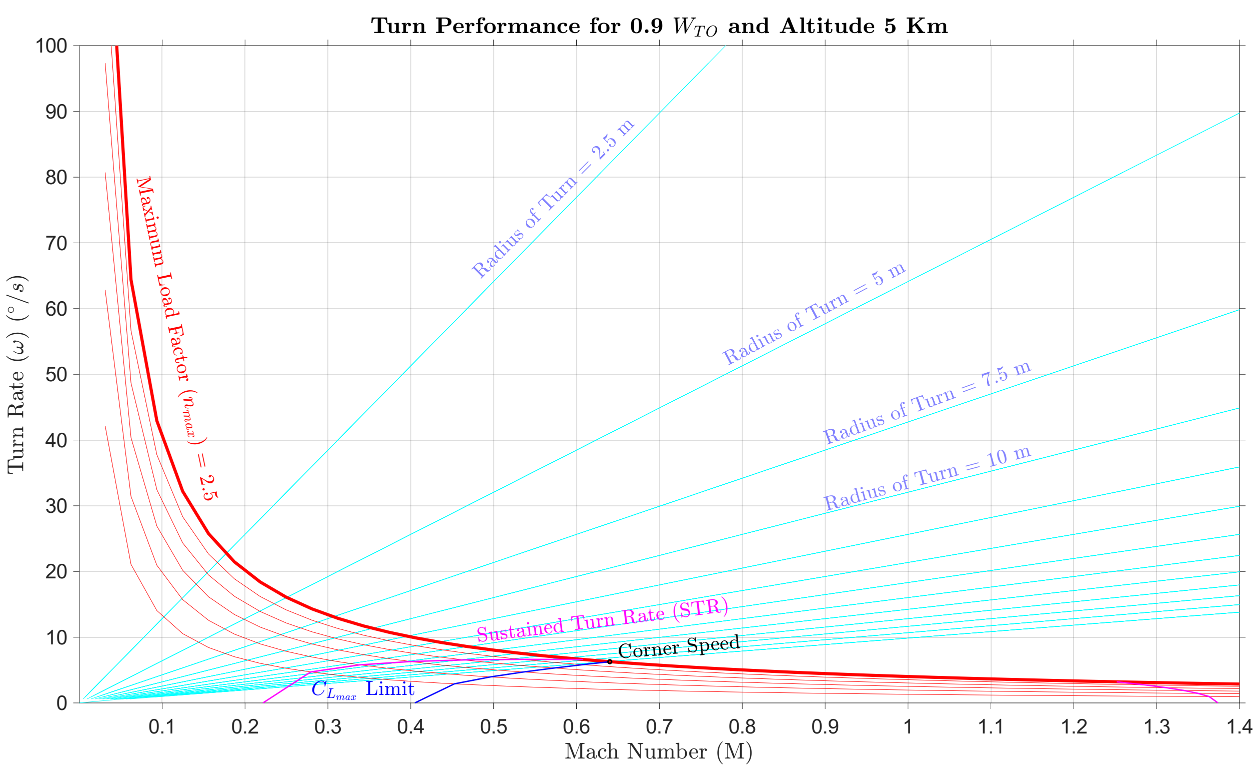
$$\phi = tan^{-1}(\sqrt{n^2-1}) \tag{48}$$

The maximum load factor (structural limit), according to the constraints of the problem, was assigned a value of 2.5 (n_{max}).

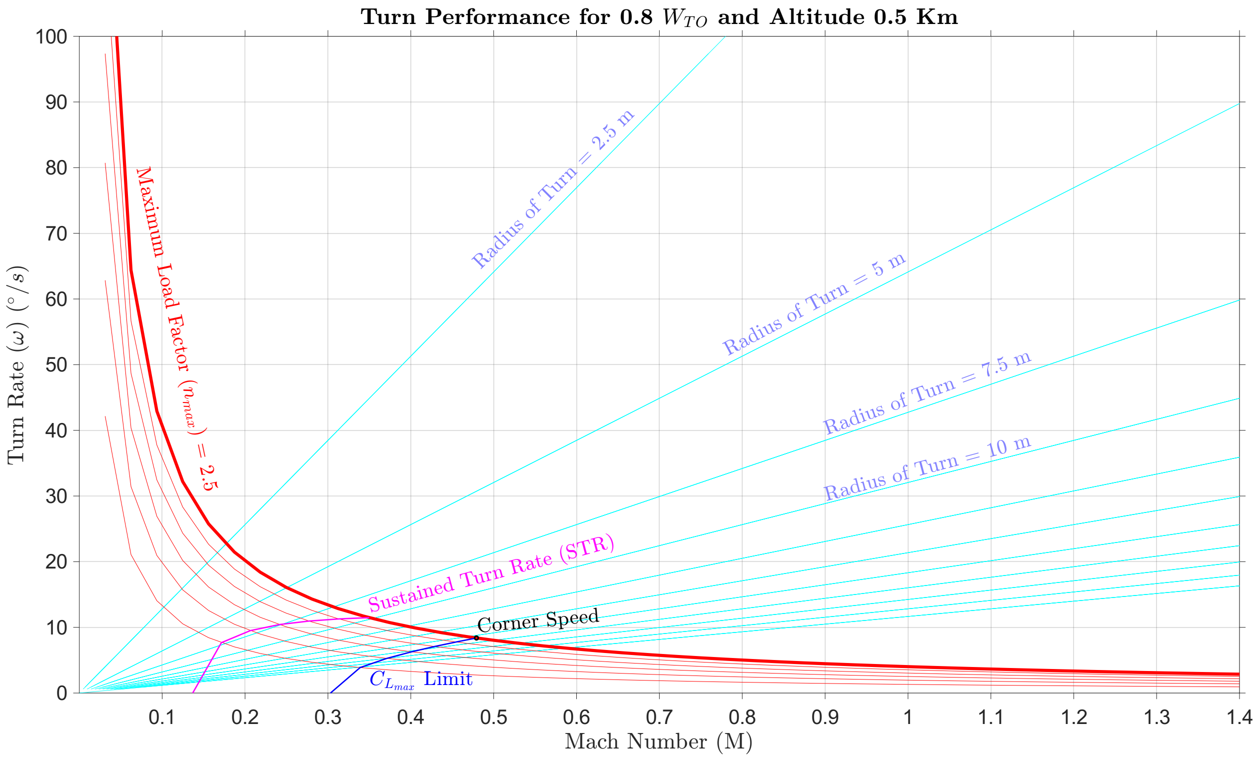
5.2 Turn Performance for 0.9 W_{TO} and Altitude 0.5 Km



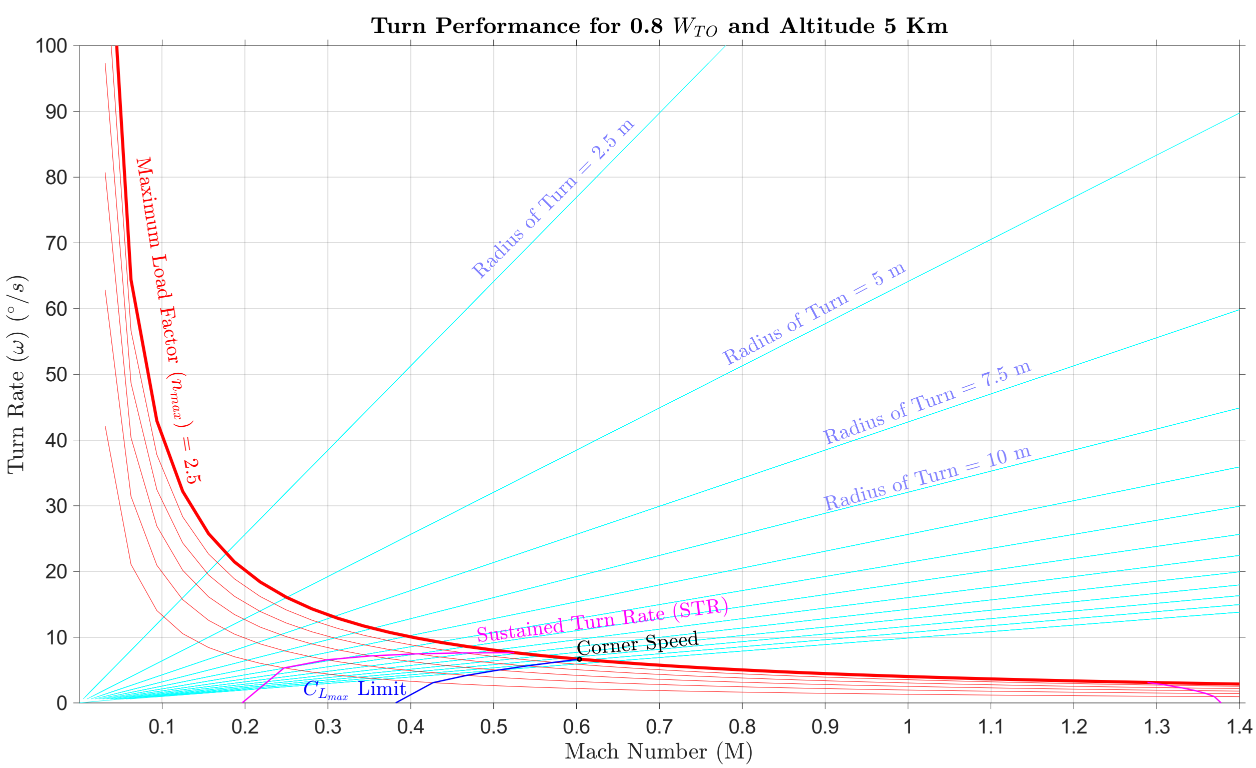
5.3 Turn Performance for 0.9 W_{TO} and Altitude 5 Km



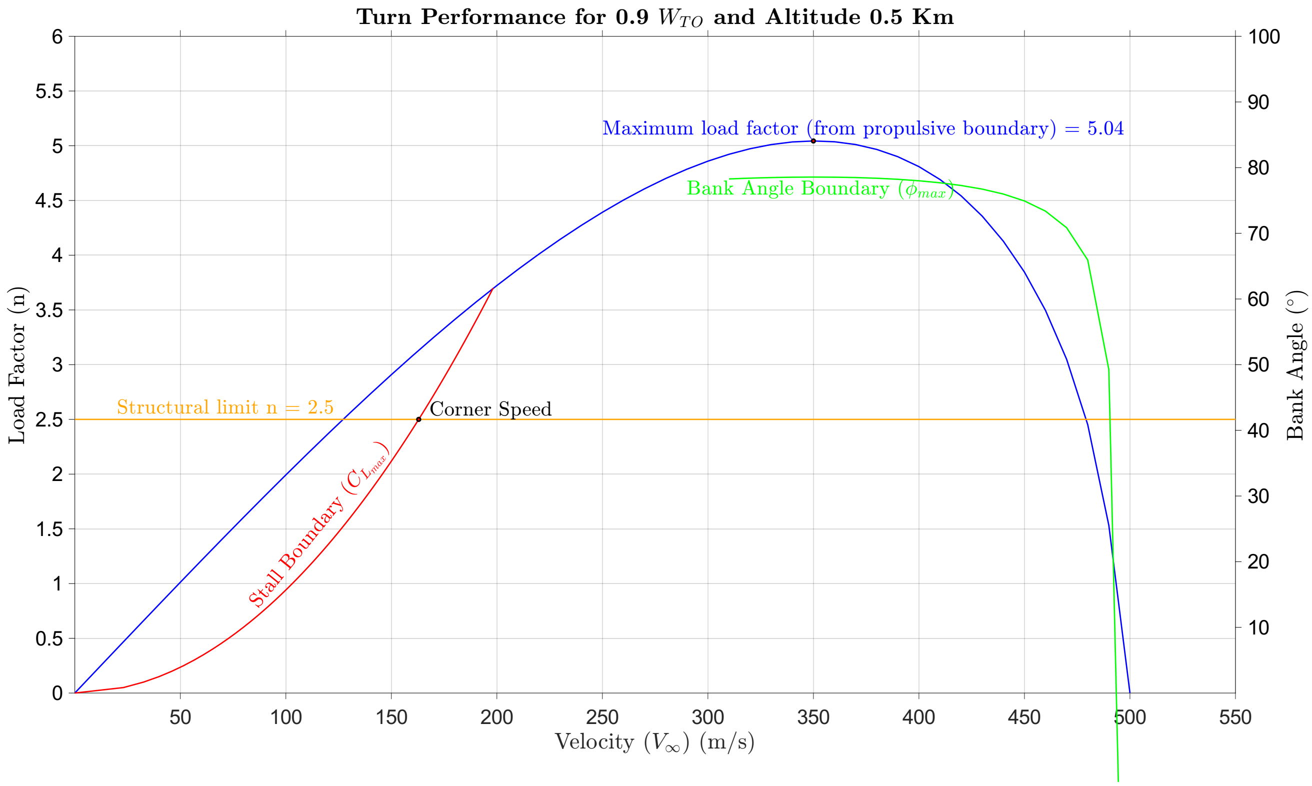
5.4 Turn Performance for 0.8 W_{TO} and Altitude 0.5 Km



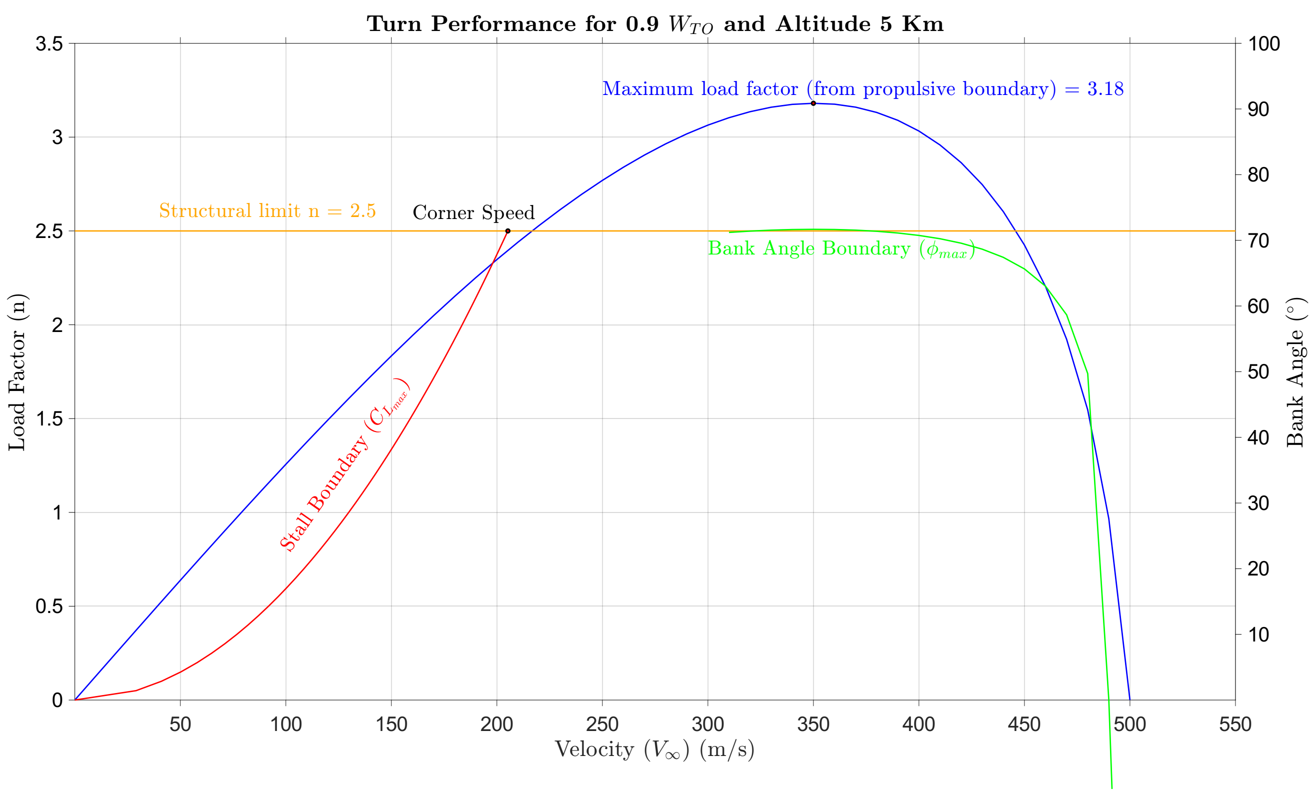
5.5 Turn Performance for 0.8 W_{TO} and Altitude 5 Km



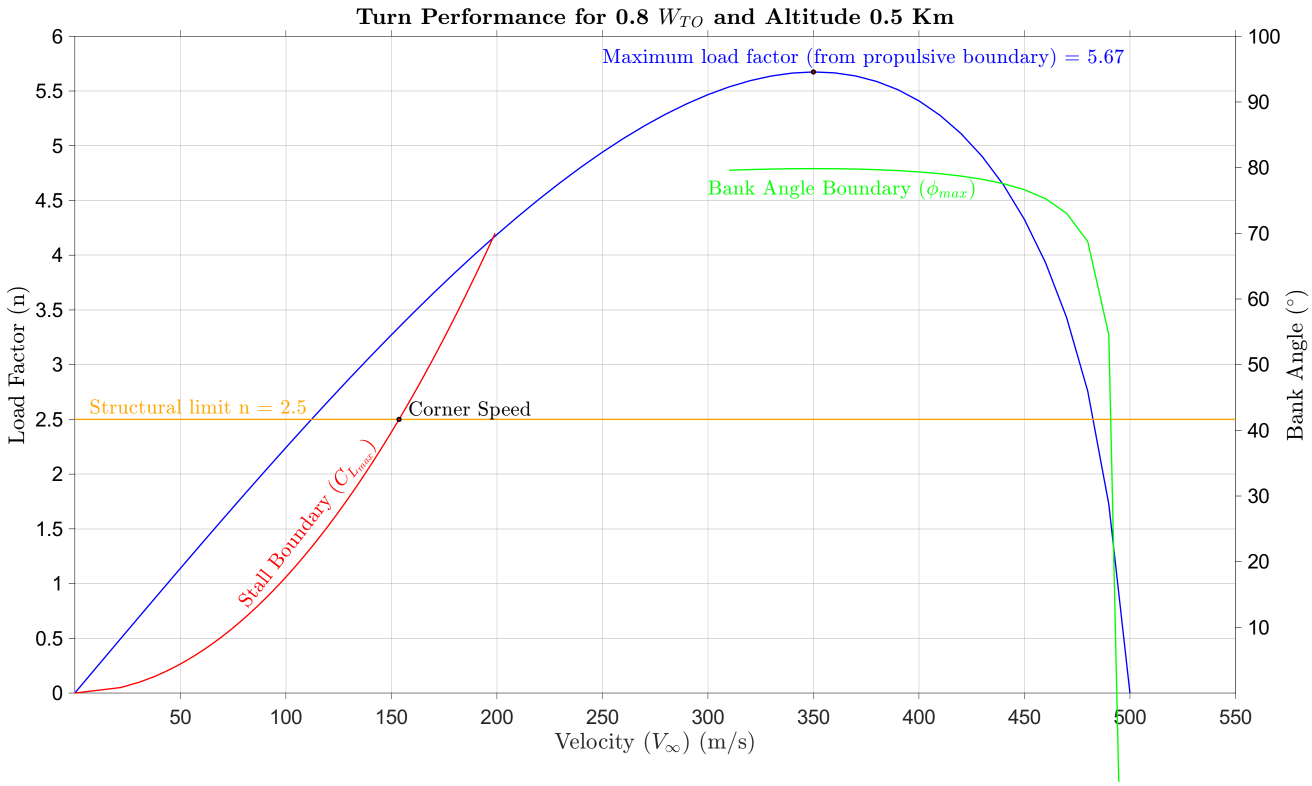
5.6 Turn Performance for 0.9 W_{TO} and Altitude 0.5 Km



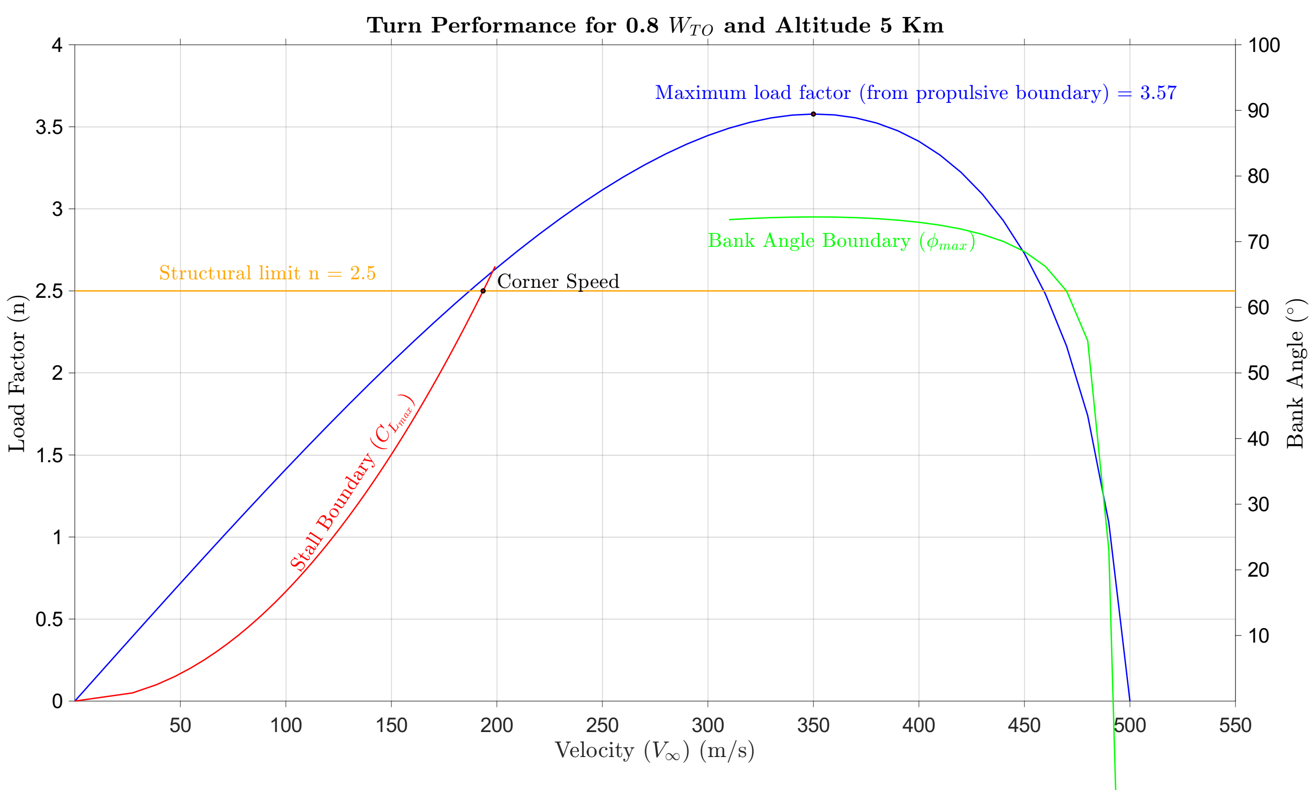
5.7 Turn Performance for 0.9 W_{TO} and Altitude 5 Km



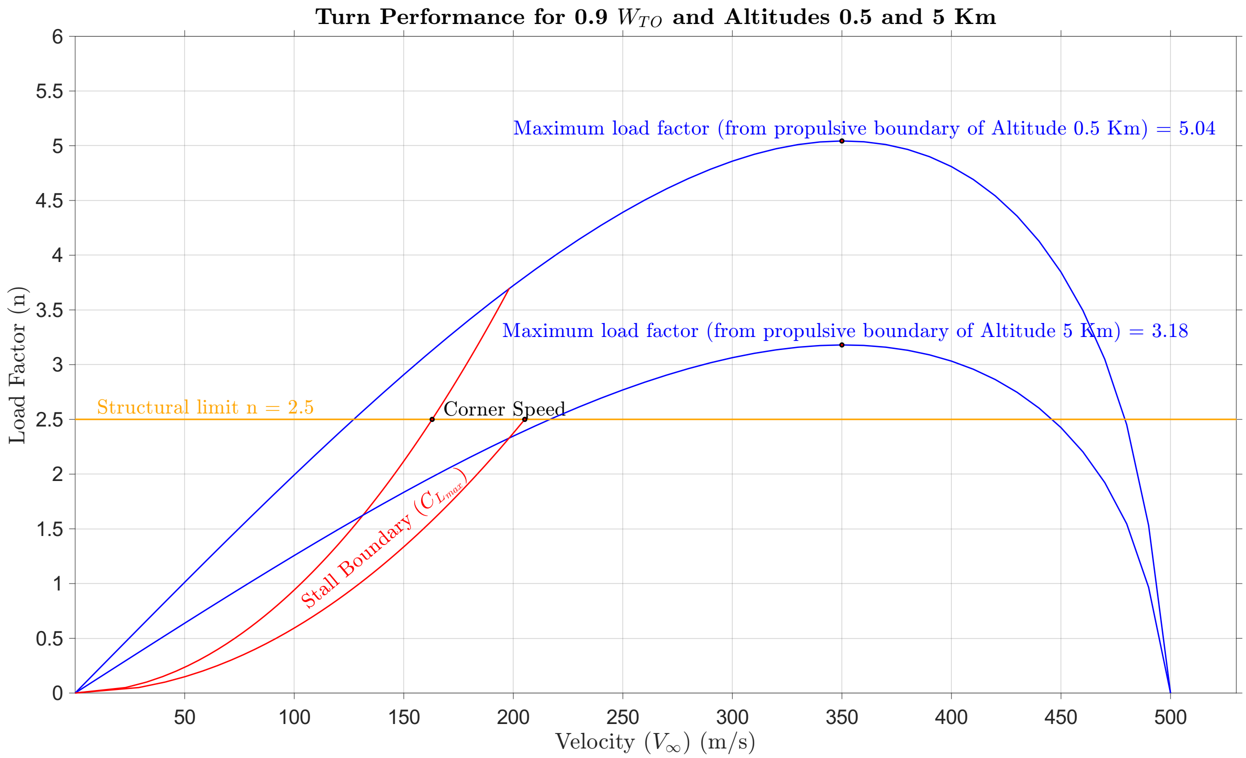
5.8 Turn Performance for 0.8 W_{TO} and Altitude 0.5 Km



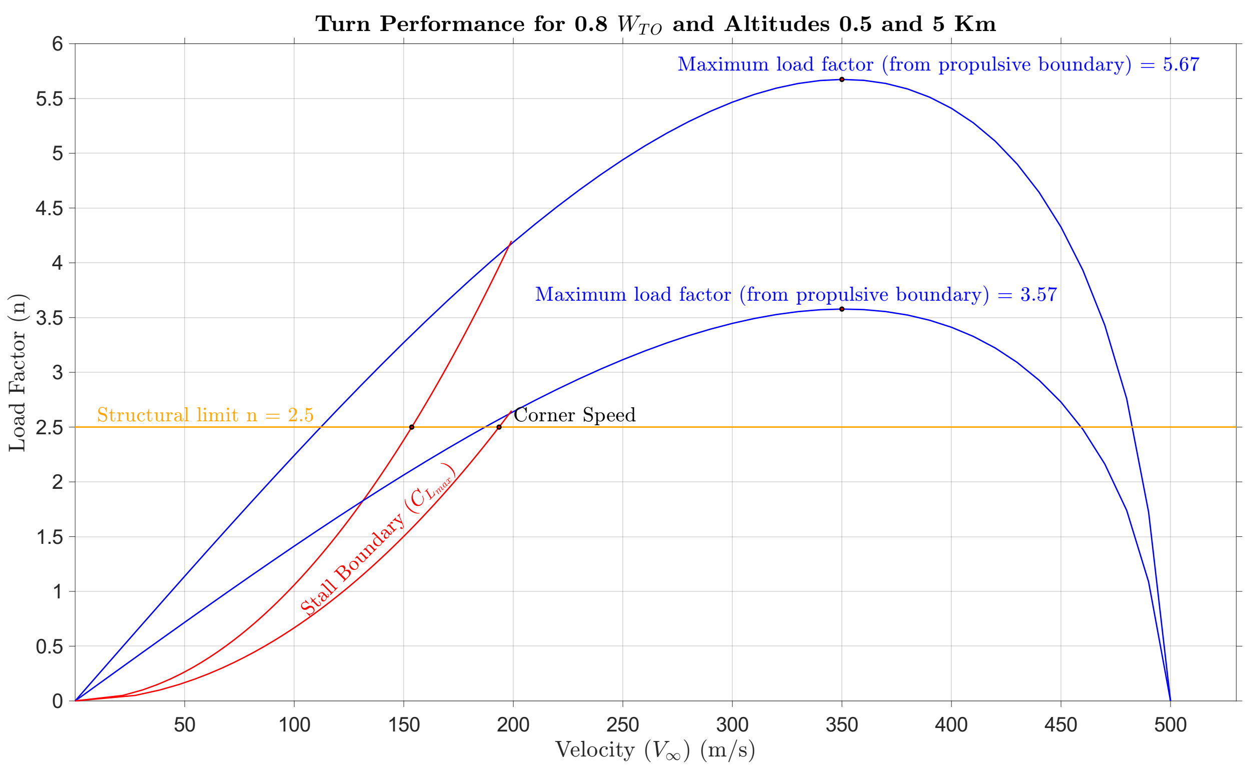
5.9 Turn Performance for 0.8 W_{TO} and Altitude 5 Km



5.10 Turn Performance for 0.9 W_{TO} and Altitudes 0.5 and 5 Km



5.11 Turn Performance for 0.8 W_{TO} and Altitudes 0.5 and 5 Km



5.12 Turn Performance Characteristics

Parameter	Value
n_{max}	2.5
Corner Speed	Mach 0.51
ATR	7.90 $°/s$
STR	10.13 $°/s$

Parameter	Value
n_{max}	2.5
Corner Speed	Mach 0.64
ATR	6.28 $°/s$
STR	6.61 $°/s$

Table 15: Data for 0.9 W_{TO} corresponding to 0.5 km and 5 km (left to right)

Parameter	Value
n_{max}	2.5
Corner Speed	Mach 0.48
ATR	8.38 $°/s$
STR	11.71 $°/s$

Parameter	Value
n_{max}	2.5
Corner Speed	Mach 0.60
ATR	6.66 $°/s$
STR	7.58 $°/s$

Table 16: Data for 0.8 W_{TO} corresponding to 0.5 km and 5 km (left to right)

5.13 Inferences

The turn performance polars (ω versus V and n versus V) were plotted for ranging values of take-off weights W_{TO} and altitudes. The attained turn rate corresponds to the turn rate at the corner speed in all the above polars. The maximum load factor from the propulsive boundary was found to decrease with an increase in altitude. The aircraft's turn performance was analysed, and the operational limits were determined.

6 Take Off Performance

6.1 Preliminary calculations

The aircraft's take-off performance was analysed using the iterative method described in reference [6]. The performance was analysed at $0.9W_{TO}$ and $0.8W_{TO}$ at a take-off altitude of 0.5 km. It was assumed that partial flaps are deflected during take-off, and the suitable constraints were applied. The time step integrated Pamadi's method is as follows,

$$\Delta t = 0.25\ s \tag{49}$$

$$q_i S = \frac{1}{2}\rho V_i^2 S \tag{50}$$

Thus lift and drag can be calculated,

$$L_i = C_L q_i S \tag{51}$$

$$D_i = C_D q_i S \tag{52}$$

Hence acceleration can be calculated,

$$a_i = \frac{[T - D - \mu(W - L_i)] \times g}{W} \tag{53}$$

The change in velocity is given by,

$$\Delta V_i = a_i \Delta t \tag{54}$$

The change in distance is given by,

$$\Delta s_i = V_i\, \Delta t + \frac{1}{2} a_i\, \Delta t^2 \tag{55}$$

The velocity at the end of each iteration is given by,

$$V_{i+1} = V_i + \Delta V_i \tag{56}$$

Similarly, the distance at the end of each iteration is given by,

$$s_{i+1} = s_i + \Delta s_i \tag{57}$$

Similarly, the time at the end of each iteration is given by,

$$t_{i+1} = t_i + \Delta t_i \tag{58}$$

This is used to calculate the ground acceleration distance. The rotation distance for 3 seconds is given by,

$$s_{rot} = 3 \times V_{rot} \tag{59}$$

where,

$$V_{rot} = 1.2 \times V_{stall} \tag{60}$$

The distance to climb is given by,

$$s_{climb} = \frac{10.7}{\tan \gamma} \tag{61}$$

where,

$$\sin \gamma = \frac{T - D}{W} \tag{62}$$

The time to climb is given by,

$$t_{climb} = \frac{10.7}{V_{rot} \tan \gamma} \tag{63}$$

Therefore the total time and distance for take-off are given by,

$$t = t_{gr\ accn} + t_{rot} + t_{climb} \tag{64}$$

$$s = s_{gr\ accn} + s_{rot} + s_{climb} \tag{65}$$

The take-off distance for a multi-engine aircraft as per the Federal Aviation Regulations (FAR) is taken as the higher of the two following distances,

* 115% of the distance required to clear 35 ft (10.7 m) obstruction with all engines operating (AEO).

* Balanced Field Length with one engine inoperative (OEI) (to be estimated for the failure of most critical of the engines).

6.2 Take-Off Characteristics for All Engines Operating (AEO)

Parameter	Value
Take-off Time	48.82 s
Take-off Distance	2,316.51 m

Parameter	Value
Take-off Time	41.04 s
Take-off Distance	1,898.68 m

Table 17: Data for 0.9 W_{TO} corresponding to 0.5 km and 1.5 km (left to right)

Parameter	Value
Take-off Time	41.03 s
Take-off Distance	1,858.59 m

Table 18: Data for 0.8 W_{TO} corresponding to 0.5 km

6.3 Take-Off Characteristics for One Engine Inoperative (OEI)

6.3.1 Accelerate Stop Distance Required (ASDR)

Velocity	ASDR	Time
0.65 V_R	1,663.4 m	55.25 s
0.70 V_R	2,000.8 m	61.00 s
0.75 V_R	2,256.2 m	65.50 s
0.80 V_R	2,480.3 m	69.50 s
0.85 V_R	2,698.8 m	73.50 s
0.90 V_R	2,911.6 m	77.50 s
0.95 V_R	3,118.5 m	81.50 s
V_R	3,341.4 m	85.75 s

Velocity	ASDR	Time
0.65 V_R	1,931.9 m	61.50 s
0.70 V_R	2,312.0 m	67.75 s
0.75 V_R	2,586.5 m	72.25 s
0.80 V_R	2,827.2 m	76.50 s
0.85 V_R	3,081.9 m	81.25 s
0.90 V_R	3,326.0 m	85.75 s
0.95 V_R	3,559.2 m	90.50 s
V_R	3,781.4 m	95.00 s

Table 19: Data for 0.9 W_{TO} corresponding to 0.5 km and 1.5 km (left to right)

Where ${V_R}_{0.5\,km} = 87.45$ m/s and ${V_R}_{1.5\,km} = 91.86$ m/s.

6.3.2 Take-Off Distance Required (TODR)

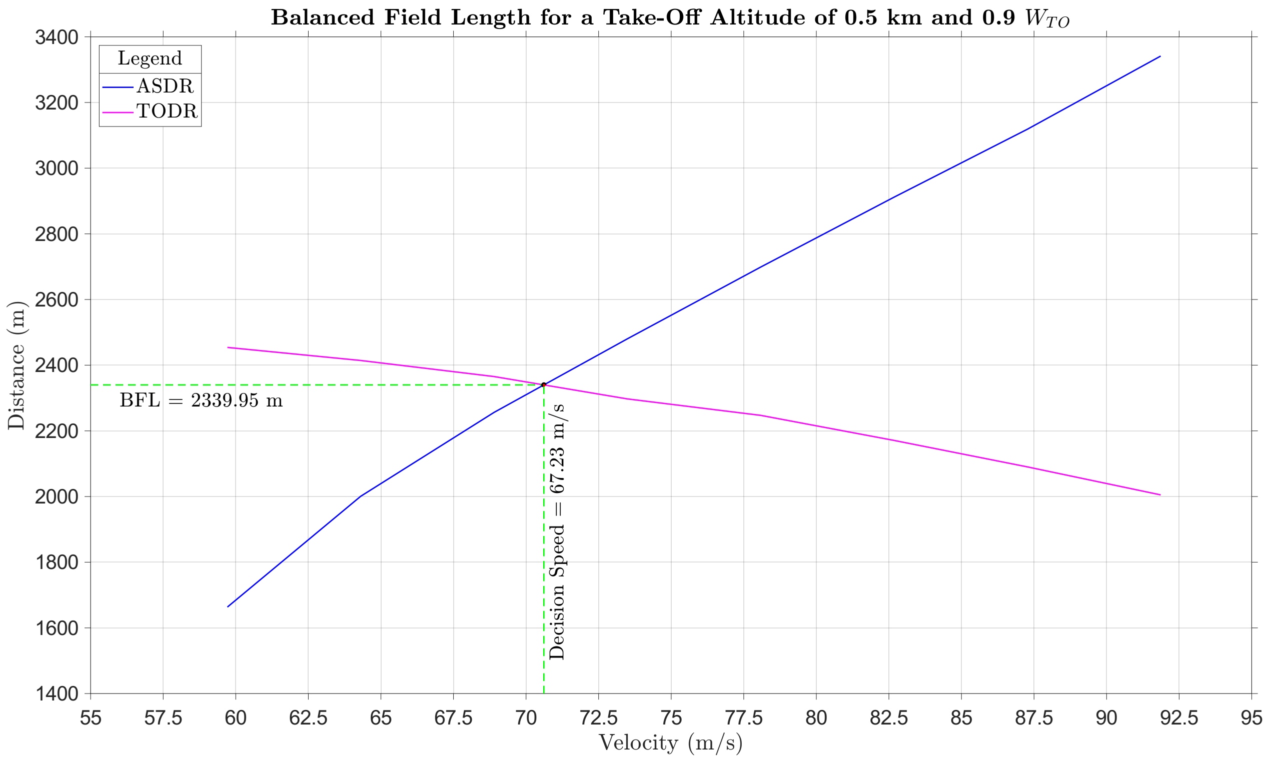
Velocity	TODR	Time
0.65 V_R	2,454.1 m	51.50 s
0.70 V_R	2,414.3 m	50.75 s
0.75 V_R	2,365.4 m	50.00 s
0.80 V_R	2,297.3 m	49.00 s
0.85 V_R	2,247.2 m	48.25 s
0.90 V_R	2,170.9 m	47.25 s
0.95 V_R	2,090.3 m	46.25 s
V_R	2,005.0 m	45.25 s

Velocity	TODR	Time
0.65 V_R	3,053.6 m	60.75 s
0.70 V_R	2,991.2 m	59.75 s
0.75 V_R	2,925.3 m	58.75 s
0.80 V_R	2,837.2 m	57.50 s
0.85 V_R	2,762.3 m	56.50 s
0.90 V_R	2,660.2 m	55.25 s
0.95 V_R	2,576.4 m	54.25 s
V_R	2,464.8 m	53.00 s

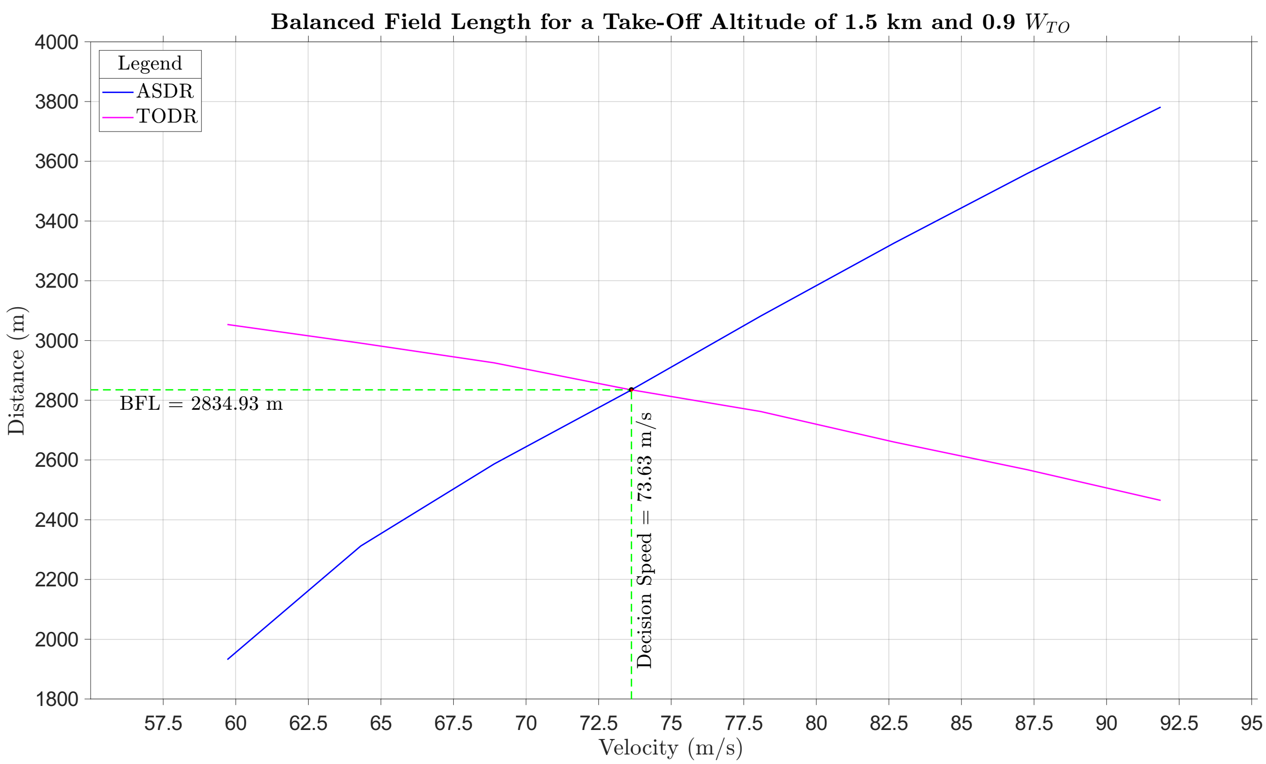
Table 20: Data for 0.9 W_{TO} corresponding to 0.5 km and 1.5 km (left to right)

Where ${V_R}_{0.5\,km} = 87.45$ m/s and ${V_R}_{1.5\,km} = 91.86$ m/s.

6.4 Balanced Field Length for a Take-Off Altitude of 0.5 km and 0.9 W_{TO}



6.5 Balanced Field Length for a Take-Off Altitude of 1.5 km and 0.9 W_{TO}



6.6 Take-Off Distance from FAR

Take off distance calculated using FAR for 0.5 km and 0.9 W_{TO} is,

$$s = 2,663.98\,m$$

Take off distance calculated using FAR for 1.5 km and 0.9 W_{TO} is,

$$s = 2,834.93\,m$$

6.7 Inferences

The take-off distance for AEO at 0.5 km for 0.9 W_{TO} and 0.8 W_{TO} was calculated. Further, the take-off distance for AEO at 1.5 km for 0.9 W_{TO} was also calculated. A scenario of one engine failure (OEI) was analysed at different failure speeds, and the respective ASDR and TODR were calculated. This was done for 1.5 km and 0.9 W_{TO}. It was observed that ASDR increases with velocity while the TODR decreases withand increase in velocity. It was also observed that the take-off distance for the same take-off weight (W_{TO}) decreases with an increase in altitude. Conversely, the ASDR and TODR increased with altitude for the same take-off weight (W_{TO}).

7 Landing Performance

7.1 Preliminary Calculations

The modified Pamadi's approach was used to calculate the landing distance (see reference [7]). Since the take-off performance analyses were conducted at 0.5 km, this value was retained for the landing performance analyses for the sake of consistency. The deceleration levels were limited to 0.25g. The obstacle height is considered to be 50 ft. The approach distance is given by,

$$s_a = \frac{15.2}{\tan \gamma_a} \tag{66}$$

where,

$$\gamma_a = \sin^{-1}\left(\frac{C_D/C_{L_{max}}}{T/W}\right) \tag{67}$$

γ_a is in radians. For a civil transport aircraft, γ_a is 3°. The approach speed is given by,

$$V_a = 1.3 \times V_{stall} \tag{68}$$

The flare distance is given by,

$$s_f = 0.1248 \times V_{stall}^2 \times \gamma_f \tag{69}$$

where,

$$\gamma_f = \gamma_a \tag{70}$$

The rotation distance is given by,

$$s_r = 3 \times V_a \tag{71}$$

The braking distance is given by,

$$s_b = \frac{V_a^2}{2a} \tag{72}$$

Hence the landing distance is given by,

$$s = s_a + s_f + s_r + s_b \tag{73}$$

7.2 Landing Distance

The landing distance calculated using modified Pamadi's method at 0.5 km and 0.8 W_{TO}

$$s = 1771.73\,m$$

The landing distance calculated using modified Pamadi's method at 0.5 km and 0.6 W_{TO}

$$s = 1428.53\,m$$

7.3 Inferences

The landing distance was calculated using the modified Pamadi's method. It was observed that with a decrease in the weight of the aircraft, the landing distance was reduced.

8 Payload v/s Range Trade-Off

8.1 Preliminary Calculations

The methodology used corresponds to the methodology elucidated in reference [9]. The total fuel capacity was considered to be 130% of the fuel weight (W_{fuel}). The fuel burnt to reach the cruise altitude was assumed to be 5% of the fuel weight. The weight at the end of the cruise was assumed to be 7% of the fuel weight. Thus the following relations were derived,

$$W_A = W_{TO} - 0.05\,W_{Fuel} \tag{74}$$

$$W_B = W_{TO} - 0.93\,W_{Fuel} \tag{75}$$

$$W_E = W_{TO} - 0.05\,W_{Fuel} \tag{76}$$

$$W_C = W_{TO} - 1.23\,W_{Fuel} \tag{77}$$

$$W_F = W_{TO} \; - \; (1/3)(W_{PL})_E - 0.05\,W_{Fuel} \tag{78}$$

$$W_G = W_{TO} \; - \; (1/3)(W_{PL})_E - 1.23\,W_{Fuel} \tag{79}$$

$$W_H = W_{TO} \; - \; (2/3)(W_{PL})_E - 0.05\,W_{Fuel} \tag{80}$$

$$W_I = W_{TO} \; - \; (2/3)(W_{PL})_E - 1.23\,W_{Fuel} \tag{81}$$

$$W_O = W_{TO} \; - \; (W_{PL})_E - 0.05\,W_{Fuel} \tag{82}$$

$$W_O = W_{TO} \; - \; (W_{PL})_E - 1.23\,W_{Fuel} \tag{83}$$

The range equation of a turbofan engine-powered aircraft is given by,

$$R = \frac{2}{c_t}\sqrt{\frac{2}{\rho_\infty S}}\frac{C_L^{1/2}}{C_D}\left(\sqrt{W_0} - \sqrt{W_1}\right) \tag{84}$$

The speed for maximum range cruise corresponds to $(D/V)_{min}$ and is quantified as,

$$V_{R_{max}} = V_{(C_L^{1/2}/C_D)_{max}} = \sqrt{\frac{2}{\rho_\infty}\frac{W}{S}\sqrt{\frac{3k}{C_{D_0}}}} \tag{85}$$

$C_{L_{opt}}$ (C_L for $(L/D)_{max}$) is given by,

$$C_{L_{opt}} = \sqrt{\frac{C_{D_0}}{k}} \tag{86}$$

Thus $V_{R_{max}}$ can be written as,

$$V_{R_{max}} = V_{(C_L^{1/2}/C_D)_{max}} = \sqrt{\frac{2}{\rho_\infty}\frac{W}{S}\frac{\sqrt{3}}{C_{L_{opt}}}} \tag{87}$$

$(C_L^{1/2}/C_D)_{max}$ is also given by,

$$\left(\frac{C_L^{1/2}}{C_D}\right)_{max} = \frac{3}{4}\left(\frac{1}{3kC_{D_0}^3}\right)^{\frac{1}{4}} \tag{88}$$

Hence the range for a jet aircraft can be written as,

$$R = \frac{2}{c_t}\sqrt{\frac{2}{\rho_\infty S}}\frac{3}{4}\left(\frac{1}{3kC_{D_0}^3}\right)^{\frac{1}{4}}\left(\sqrt{W_0} - \sqrt{W_1}\right) \tag{89}$$

The Breguet Range is given by,

$$R = \frac{V_\infty}{c_t}\frac{L}{D}\ln\frac{W_0}{W_1} \tag{90}$$

C_D for $(L/D)_{max}$ is given by,

$$C_D = 2C_{D_0} \tag{91}$$

Thus $(L/D)_{max}$ is given by,

$$\left(\frac{L}{D}\right)_{max} = \frac{1}{2\sqrt{C_{D_0}k}} \tag{92}$$

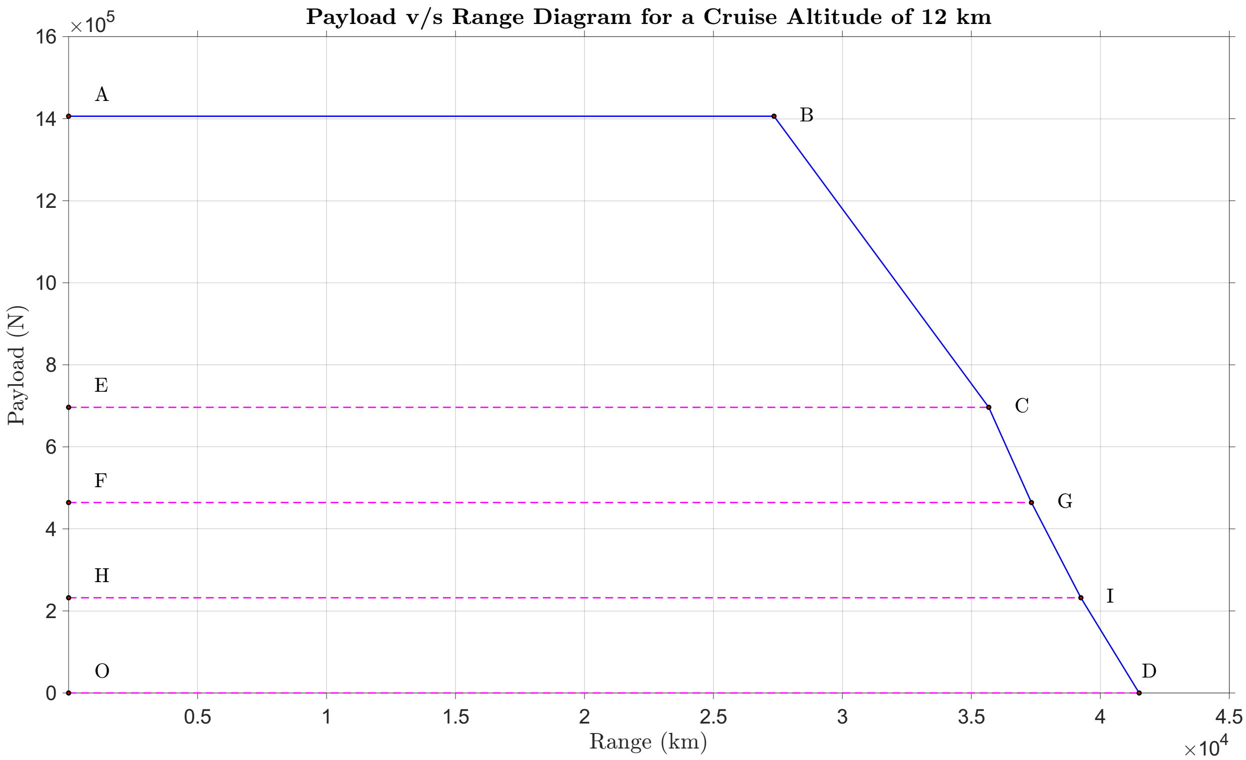
The following results were obtained,

$$V_{R_{max}} = 314.19\, m/s \tag{93}$$

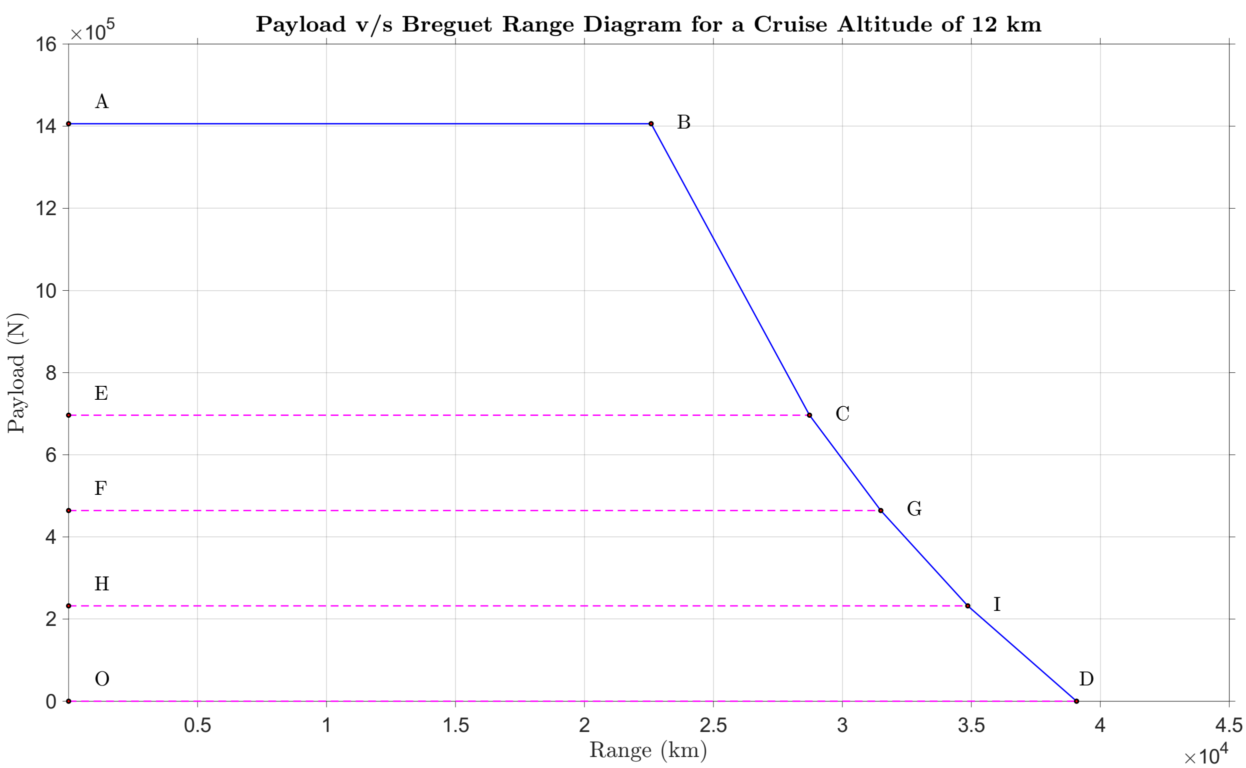
$$V_{crit} = 264.09\, m/s \tag{94}$$

From the above relations, it is observed that the velocity for the maximum range exceeds the critical velocity. Hence the critical velocity was taken for all the range calculations.

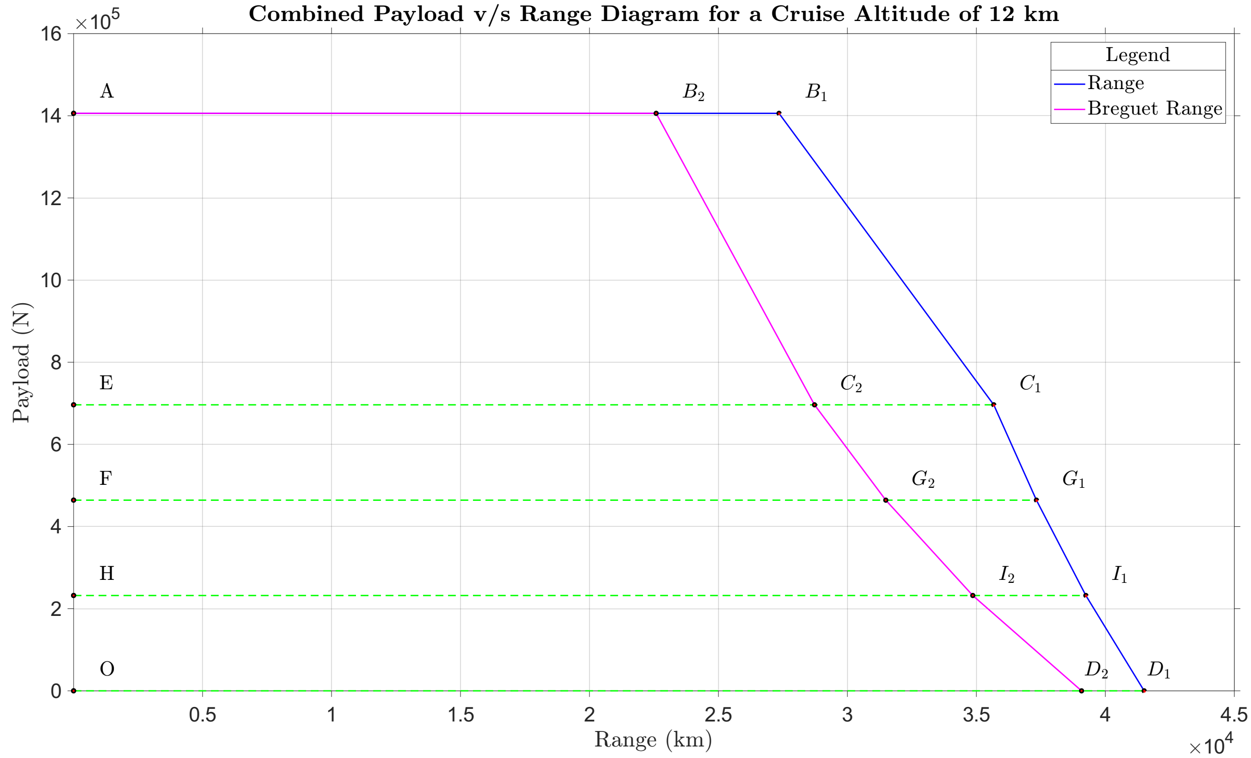
8.2 Payload v/s Range Diagram for a Cruise Altitude of 12 km



8.3 Payload v/s Breguet Range Diagram for a Cruise Altitude of 12 km



8.4 Combined Payload v/s Range Diagram for a Cruise Altitude of 12 km



8.5 Key Findings

The following parameters were used,

$$W_{OE} = 2725\, kN \tag{95}$$

$$W_{PL} = 1406\, kN \tag{96}$$

$$W_{Fuel} = 2365.5\, kN \tag{97}$$

$$W_{TO} = 6496.5\, kN \tag{98}$$

$$S = 845\, m^2 \tag{99}$$

For maximum range,

$$C_{L_{R\,max}} = 0.2893 \tag{100}$$

$$\left(\frac{C_L^{1/2}}{C_D}\right)_{max} = 36.6736 \tag{101}$$

The TSFC is given by,

$$c_{t_{SL}} = 1.2943e^{-04} \tag{102}$$

$$c_{t_{12\,km}} = 1.1224e^{-04} \tag{103}$$

The ferry range of the aircraft was calculated to be 41506.45 km. The design range of the aircraft is 14800 km. However, upon calculation it was found that the range of segment AB, the segment corresponding to the design range, was 27349.11 km. This difference in the ranges could be caused due to several factors.

The W_{TO} considered only 95% of the payload and the fuel weights. Further provisions were given for loiter time, two climbs and diversions taking into the safety aspects of the aircraft. Further, the engine performance data assumed could vary in contrast to actual engine data. The following equation is derived from the basic thermodynamic principles of jet engine operation, and it assumes that the engine is operating at its maximum efficiency. This was used to determine engine TSFC at an altitude (θ can be determined from ISA).

$$c_T = 49.5\sqrt{\theta} \tag{104}$$

The study conducted above showed that the Breguet range (assuming constant speed) was lower when compared to the range achieved from the constant altitude/C_L approach (range for jet aircraft). Considering the piloting technique, constant speed flight would be less intensive and fuel inefficient. Constant altitude flight, on the other hand, would need continuous velocity adjustment due to the decreasing aircraft weight over time and would be more intensive. That being said, this technique of flying would be fuel efficient, and the maximum range can be achieved.

9 Conclusion

The performance analysis on the assigned aircraft, the Airbus A380 800M, was conducted. The drag polar, the flight envelope and the rate of climb polar were generated. The turn, take-off and landing performances were analysed. In the take-off performance, several scenarios were considered, including the AEO and OEI at several failure speeds, and meaningful conclusions were drawn. Finally, a payload versus range trade-off study was conducted. Suitable inferences were drawn along the way, which led to significant results. This concludes a comprehensive study conducted on seven aspects of the aircraft characteristics.

10 References

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11 Appendix

11.1 List of Tables

11.2 List of Figures

Figure	Description	Figure	Description
7	Drag Polar for 5.5 km	30	Variation of R/C with Altitude for 0.9 W_{TO}
8	Drag Polar for 8.5 km	31	Turn Performance for 0.9 W_{TO} and Altitude 0.5 Km
9	Drag Polar for 10.5 km	32	Turn Performance for 0.9 W_{TO} and Altitude 5 Km
10	Drag Polar for 11.5 km	33	Turn Performance for 0.8 W_{TO} and Altitude 0.5 Km
11	V-h Plot for 0.9 W_{TO} and 100% Throttle	34	Turn Performance for 0.8 W_{TO} and Altitude 5 Km
12	V-h Plot for 0.8 W_{TO} and 100% Throttle	35	Turn Performance for 0.9 W_{TO} and Altitude 0.5 Km
13	V-h Plot for 0.6 W_{TO} and 100% Throttle	36	Turn Performance for 0.9 W_{TO} and Altitude 5 Km
14	V-h Plot for 0.9 W_{TO} and 95% Throttle	37	Turn Performance for 0.8 W_{TO} and Altitude 0.5 Km
15	V-h Plot for 0.9 W_{TO} and 82.5% Throttle	38	Turn Performance for 0.8 W_{TO} and Altitude 5 Km
16	V-h Plot for 0.9 W_{TO} and 70% Throttle	39	Turn Performance for 0.9 W_{TO} and Altitudes 0.5 and 5 Km
17	Combined V-h Plot for 0.9 W_{TO}	40	Turn Performance for 0.8 W_{TO} and Altitudes 0.5 and 5 Km
18	Rate Of Climb Plot for 0.9 W_{TO}	41	Balanced Field Length for a Take-Off Altitude of 0.5 km and 0.9 W_{TO}
19	Rate Of Climb Plot for 0.8 W_{TO}	42	Balanced Field Length for a Take-Off Altitude of 1.5 km and 0.9 W_{TO}
20	$(R/C)_{max}$ for 0.9 W_{TO}	43	Payload v/s Range Diagram for a Cruise Altitude of 12 km
21	$(R/C)_{max}$ for 0.8 W_{TO}	44	Payload v/s Breguet Range Diagram for a Cruise Altitude of 12 km
22	h v/s $(R/C)_{max}$ for 0.9 W_{TO}	45	Combined Payload v/s Range Diagram for a Cruise Altitude of 12 km
23	h v/s $(R/C)_{max}$ for 0.8 W_{TO}		

11.3 List of Symbols and Abbreviations

Symbol	Description	Symbol	Description
FM	Flight Mechanics	S	Planform Area
AR	Aspect Ratio	q_∞	Dynamic Pressure
V_∞	Freestream Velocity	M_{crit}	Critical Mach Number
V_{stall}	Stall Velocity	V_{crit}	Critical Velocity
h	Altitude	C_L	Coefficient of Lift
C_D	Coefficient of Drag	C_{D_i}	Coefficient of Induced Drag
C_{D_0}	Coefficient of Parasitic Drag	e	Oswald's Efficiency Factor
TSFC	Thrust Specific Fuel Consumption	$C_{L_{max}}$	Maximum Coefficient of Lift
$V_{D_{min}}$	Velocity at Minimum Drag	D_{min}	Minimum Drag
W_{TO}	Take-off Weight	ρ	Density
σ	Density Ratio	θ	Temperature Ratio
h_{abs}	Absolute Ceiling	P_{avb}	Power Available
P_{reqd}	Power Required	R/C	Rate of Climb
$(R/C)_{max}$	Maximum Rate of Climb	ω	Turn rate
n_{max}	Maximum Load Factor (n)	ϕ	Bank Angle
n	Load Factor	R	Radius of Turn
W/S	Wing Loading	T/W	Thrust to Weight Ratio
g	Acceleration Due to Gravity	ISA	International Standard Atmosphere
STR	Sustained Turn Rate	ATR	Attained Turn Rate
c_T	TSFC of a turbofan aircraft	BFL	Balanced Field Length
ASDR	Accelerate Stop Distance Required	TODR	Take-Off Distance Required
μ	Coefficient of Rolliing Friction	ΔV	Incremental Velocity
Δt	Incremental Time	Δs	Incremental Distance
γ	Climb Angle	FAR	Federal Aviation Regulations
AEO	All Engines Operational	OEI	One Engine Inoperative
$V_{R_{max}}$	Velocity for Maximum Range	V_R	Rotation Velocity
HLD	High Lift Devices	W_{TO}	Take-Off Weight
$V_{R_{max}}$	Velocity for Maximum Range	W_{OE}	Operational Empty Weight
W_{Fuel}	Fuel Weight	W_{PL}	Payload Weight

11.4 MATLAB Code

```
import ISA.*
format short
import InterX.*
height = [0:10:20000];            % meters
[T, a, P, rho] = atmosisa(height);
%% DATA A380 800M
wto = 6695; %kN
WTO = 6695*1000; %N
WEmpty= 2725;  %kN
WPayLoad = 1480; %kN
WFuel = 2490;  %kN
% T = 350;   % *sigma  Thrust per Engine  sigmakN (sigma is density ratio at altitude h)
% No of Engines:4
TSFC_SL = 47.5; %root theta kg/hr/kN (theta is temperature ratio at altitude h)
S = 845; %m2
AR = 7.53;
e = 0.965;
Mcrit_orig = 0.895;
AL = 55; %kN/m2 Maximum permissible dynamic head (Aeroelastic limit)
q_max = AL*1000; %N/m2
CDo= 0.011; %Parasite drag coefficient
CLmax= 1.15;  %Aircraft CLmaxwithout HLD (plain wing)
CLmax_HLD_full = 1.85; %DeltaCLmaxfrom full HLD for landing
CLmax_HLD_part = 1.15;  %DeltaCLmaxfrom partial HLD for take off
CLmax_climb = 0.9; % CLmaxTO (CLmax for climb segment of take off)
CDo_Land_Gear =0.0042; % DELTA
CDo_Flap = 0.0034; % DELTA (for take off ground run and climb segments)
CL_Ground_Run = 0.12;
mu = 0.02;  %Rolling friction coefficient mu
n_max= 2.5;  %Load factor
% Seats: 3 Class 575 and 1 Class 853
Range = 14800; %km
Take_off_dist = 3000; %m
Rho_SL = 1.225;
T_SL = T(1);
k = 1/(pi*AR*e);
g = 9.81; % m/s2
%% PLOT 1
%% DRAG POLAR CALCULATION
% 0.9 WTO, 0.8 WTO and 0.6 WTO for 0.5, 3, 5.5, 8.5,10.5 & 11.5 km
[¬,a_1,¬, rho_1] = ISA(500);
[¬,a_2,¬, rho_2] = ISA(3000);
[¬,a_3,¬, rho_3] = ISA(5500);
[¬,a_4,¬, rho_4] = ISA(8500);
[¬,a_5,¬, rho_5] = ISA(10500);
[¬,a_6,¬, rho_6] = ISA(11000);
% Mcrit for diff altitudes
Mcrit_1 = 0.895*a_1;
Mcrit_2 = 0.895*a_2;
Mcrit_3 = 0.895*a_3;
Mcrit_4 = 0.895*a_4;
Mcrit_5 = 0.895*a_5;
Mcrit_6 = 0.895*a_6;
% Density ratio
sigma_1 = rho_1/Rho_SL;
sigma_2 = rho_2/Rho_SL;
sigma_3 = rho_3/Rho_SL;
sigma_4 = rho_4/Rho_SL;
sigma_5 = rho_5/Rho_SL;
sigma_6 = rho_6/Rho_SL;
% V_stall Calculation
% 0.9 WTO
```

```
V_stall_1_9 = ((2*0.9*WTO)/(rho_1*S*CLmax))^0.5;
V_stall_2_9 = ((2*0.9*WTO)/(rho_2*S*CLmax))^0.5;
V_stall_3_9 = ((2*0.9*WTO)/(rho_3*S*CLmax))^0.5;
V_stall_4_9 = ((2*0.9*WTO)/(rho_4*S*CLmax))^0.5;
V_stall_5_9 = ((2*0.9*WTO)/(rho_5*S*CLmax))^0.5;
V_stall_6_9 = ((2*0.9*WTO)/(rho_6*S*CLmax))^0.5;
% 0.8 WTO
V_stall_1_8 = ((2*0.8*WTO)/(rho_1*S*CLmax))^0.5;
V_stall_2_8 = ((2*0.8*WTO)/(rho_2*S*CLmax))^0.5;
V_stall_3_8 = ((2*0.8*WTO)/(rho_3*S*CLmax))^0.5;
V_stall_4_8 = ((2*0.8*WTO)/(rho_4*S*CLmax))^0.5;
V_stall_5_8 = ((2*0.8*WTO)/(rho_5*S*CLmax))^0.5;
V_stall_6_8 = ((2*0.8*WTO)/(rho_6*S*CLmax))^0.5;
% 0.6 WTO
V_stall_1_6 = ((2*0.6*WTO)/(rho_1*S*CLmax))^0.5;
V_stall_2_6 = ((2*0.6*WTO)/(rho_2*S*CLmax))^0.5;
V_stall_3_6 = ((2*0.6*WTO)/(rho_3*S*CLmax))^0.5;
V_stall_4_6 = ((2*0.6*WTO)/(rho_4*S*CLmax))^0.5;
V_stall_5_6 = ((2*0.6*WTO)/(rho_5*S*CLmax))^0.5;
V_stall_6_6 = ((2*0.6*WTO)/(rho_6*S*CLmax))^0.5;
% A for various altitudes
A_0 = CDo*Rho_SL*S*0.5;
A_1 = CDo*rho_1*S*0.5;
A_2 = CDo*rho_2*S*0.5;
A_3 = CDo*rho_3*S*0.5;
A_4 = CDo*rho_4*S*0.5;
A_5 = CDo*rho_5*S*0.5;
A_6 = CDo*rho_6*S*0.5;
% B for various altitudes at 0.9 WTO
B_0_9 = (2*k*((0.9*WTO)^2))/(Rho_SL*S);
B_1_9 = (2*k*((0.9*WTO)^2))/(rho_1*S);
B_2_9 = (2*k*((0.9*WTO)^2))/(rho_2*S);
B_3_9 = (2*k*((0.9*WTO)^2))/(rho_3*S);
B_4_9 = (2*k*((0.9*WTO)^2))/(rho_4*S);
B_5_9 = (2*k*((0.9*WTO)^2))/(rho_5*S);
B_6_9 = (2*k*((0.9*WTO)^2))/(rho_6*S);
% B for various altitudes at 0.8 WTO
B_0_8 = (2*k*((0.8*WTO)^2))/(Rho_SL*S);
B_1_8 = (2*k*((0.8*WTO)^2))/(rho_1*S);
B_2_8 = (2*k*((0.8*WTO)^2))/(rho_2*S);
B_3_8 = (2*k*((0.8*WTO)^2))/(rho_3*S);
B_4_8 = (2*k*((0.8*WTO)^2))/(rho_4*S);
B_5_8 = (2*k*((0.8*WTO)^2))/(rho_5*S);
B_6_8 = (2*k*((0.8*WTO)^2))/(rho_6*S);
% B for various altitudes at 0.6 WTO
B_0_6 = (2*k*((0.6*WTO)^2))/(Rho_SL*S);
B_1_6 = (2*k*((0.6*WTO)^2))/(rho_1*S);
B_2_6 = (2*k*((0.6*WTO)^2))/(rho_2*S);
B_3_6 = (2*k*((0.6*WTO)^2))/(rho_3*S);
B_4_6 = (2*k*((0.6*WTO)^2))/(rho_4*S);
B_5_6 = (2*k*((0.6*WTO)^2))/(rho_5*S);
B_6_6 = (2*k*((0.6*WTO)^2))/(rho_6*S);
% Drag Calculation
V = 25:1:500;
% D for various altitudes at 0.9 WTO
D_0_9 = ((A_0).*(V.^2))+((B_0_9)./(V.^2));
D_1_9 = ((A_1).*(V.^2))+((B_1_9)./(V.^2));
D_2_9 = ((A_1).*(V.^2))+((B_2_9)./(V.^2));
D_3_9 = ((A_1).*(V.^2))+((B_3_9)./(V.^2));
D_4_9 = ((A_1).*(V.^2))+((B_4_9)./(V.^2));
D_5_9 = ((A_1).*(V.^2))+((B_5_9)./(V.^2));
D_6_9 = ((A_1).*(V.^2))+((B_6_9)./(V.^2));
% D for various altitudes at 0.8 WTO
D_0_8 = ((A_0).*(V.^2))+((B_0_8)./(V.^2));
D_1_8 = ((A_1).*(V.^2))+((B_1_8)./(V.^2));
```

```
D_2_8 = ((A_1).*(V.^2))+((B_2_8)./(V.^2));
D_3_8 = ((A_1).*(V.^2))+((B_3_8)./(V.^2));
D_4_8 = ((A_1).*(V.^2))+((B_4_8)./(V.^2));
D_5_8 = ((A_1).*(V.^2))+((B_5_8)./(V.^2));
D_6_8 = ((A_1).*(V.^2))+((B_6_8)./(V.^2));
% D for various altitudes at 0.6 WTO
D_0_6 = ((A_0).*(V.^2))+((B_0_6)./(V.^2));
D_1_6 = ((A_1).*(V.^2))+((B_1_6)./(V.^2));
D_2_6 = ((A_1).*(V.^2))+((B_2_6)./(V.^2));
D_3_6 = ((A_1).*(V.^2))+((B_3_6)./(V.^2));
D_4_6 = ((A_1).*(V.^2))+((B_4_6)./(V.^2));
D_5_6 = ((A_1).*(V.^2))+((B_5_6)./(V.^2));
D_6_6 = ((A_1).*(V.^2))+((B_6_6)./(V.^2));
% V_D_min for 0.9 WTO and various Altitudes
V_D_min_1_9 = (((2*(0.9*WTO))/(rho_1*S))*((k/CDo)^0.5))^0.5;
V_D_min_2_9 = (((2*(0.9*WTO))/(rho_2*S))*((k/CDo)^0.5))^0.5;
V_D_min_3_9 = (((2*(0.9*WTO))/(rho_3*S))*((k/CDo)^0.5))^0.5;
V_D_min_4_9 = (((2*(0.9*WTO))/(rho_4*S))*((k/CDo)^0.5))^0.5;
V_D_min_5_9 = (((2*(0.9*WTO))/(rho_5*S))*((k/CDo)^0.5))^0.5;
V_D_min_6_9 = (((2*(0.9*WTO))/(rho_6*S))*((k/CDo)^0.5))^0.5;
% V_D_min for 0.9 WTO and various Altitudes
V_D_min_1_8 = (((2*(0.8*WTO))/(rho_1*S))*((k/CDo)^0.5))^0.5;
V_D_min_2_8 = (((2*(0.8*WTO))/(rho_2*S))*((k/CDo)^0.5))^0.5;
V_D_min_3_8 = (((2*(0.8*WTO))/(rho_3*S))*((k/CDo)^0.5))^0.5;
V_D_min_4_8 = (((2*(0.8*WTO))/(rho_4*S))*((k/CDo)^0.5))^0.5;
V_D_min_5_8 = (((2*(0.8*WTO))/(rho_5*S))*((k/CDo)^0.5))^0.5;
V_D_min_6_8 = (((2*(0.8*WTO))/(rho_6*S))*((k/CDo)^0.5))^0.5;
% V_D_min for 0.9 WTO and various Altitudes
V_D_min_1_6 = (((2*(0.6*WTO))/(rho_1*S))*((k/CDo)^0.5))^0.5;
V_D_min_2_6 = (((2*(0.6*WTO))/(rho_2*S))*((k/CDo)^0.5))^0.5;
V_D_min_3_6 = (((2*(0.6*WTO))/(rho_3*S))*((k/CDo)^0.5))^0.5;
V_D_min_4_6 = (((2*(0.6*WTO))/(rho_4*S))*((k/CDo)^0.5))^0.5;
V_D_min_5_6 = (((2*(0.6*WTO))/(rho_5*S))*((k/CDo)^0.5))^0.5;
V_D_min_6_6 = (((2*(0.6*WTO))/(rho_6*S))*((k/CDo)^0.5))^0.5;
% Altitude plot
A_0 = CDo*Rho_SL*S*0.5;
B_0_9 = (2*k*((0.9*WTO)^2))/(Rho_SL*S);
B_0_8 = (2*k*((0.8*WTO)^2))/(Rho_SL*S);
B_0_6 = (2*k*((0.6*WTO)^2))/(Rho_SL*S);
% Drag 0.9 WTO and various altitudes
D_0_9_1 = ((A_0).*((V.*(sigma_1)^0.5).^2))+((B_0_9)./((V.*(sigma_1)^0.5).^2));
D_0_9_2 = ((A_0).*((V.*(sigma_2)^0.5).^2))+((B_0_9)./((V.*(sigma_2)^0.5).^2));
D_0_9_3 = ((A_0).*((V.*(sigma_3)^0.5).^2))+((B_0_9)./((V.*(sigma_3)^0.5).^2));
D_0_9_4 = ((A_0).*((V.*(sigma_4)^0.5).^2))+((B_0_9)./((V.*(sigma_4)^0.5).^2));
D_0_9_5 = ((A_0).*((V.*(sigma_5)^0.5).^2))+((B_0_9)./((V.*(sigma_5)^0.5).^2));
D_0_9_6 = ((A_0).*((V.*(sigma_6)^0.5).^2))+((B_0_9)./((V.*(sigma_6)^0.5).^2));
% Drag 0.8 WTO and various altitudes
D_0_8_1 = ((A_0).*((V.*(sigma_1)^0.5).^2))+((B_0_8)./((V.*(sigma_1)^0.5).^2));
D_0_8_2 = ((A_0).*((V.*(sigma_2)^0.5).^2))+((B_0_8)./((V.*(sigma_2)^0.5).^2));
D_0_8_3 = ((A_0).*((V.*(sigma_3)^0.5).^2))+((B_0_8)./((V.*(sigma_3)^0.5).^2));
D_0_8_4 = ((A_0).*((V.*(sigma_4)^0.5).^2))+((B_0_8)./((V.*(sigma_4)^0.5).^2));
D_0_8_5 = ((A_0).*((V.*(sigma_5)^0.5).^2))+((B_0_8)./((V.*(sigma_5)^0.5).^2));
D_0_8_6 = ((A_0).*((V.*(sigma_6)^0.5).^2))+((B_0_8)./((V.*(sigma_6)^0.5).^2));
% Drag 0.6 WTO and various altitudes
D_0_6_1 = ((A_0).*((V.*(sigma_1)^0.5).^2))+((B_0_6)./((V.*(sigma_1)^0.5).^2));
D_0_6_2 = ((A_0).*((V.*(sigma_2)^0.5).^2))+((B_0_6)./((V.*(sigma_2)^0.5).^2));
D_0_6_3 = ((A_0).*((V.*(sigma_3)^0.5).^2))+((B_0_6)./((V.*(sigma_3)^0.5).^2));
D_0_6_4 = ((A_0).*((V.*(sigma_4)^0.5).^2))+((B_0_6)./((V.*(sigma_4)^0.5).^2));
D_0_6_5 = ((A_0).*((V.*(sigma_5)^0.5).^2))+((B_0_6)./((V.*(sigma_5)^0.5).^2));
D_0_6_6 = ((A_0).*((V.*(sigma_6)^0.5).^2))+((B_0_6)./((V.*(sigma_6)^0.5).^2));
% % D_min at Various Weights
D_min_9 = (2*0.9*WTO)*((k*CDo)^0.5);
D_min_8 = (2*0.8*WTO)*((k*CDo)^0.5);
D_min_6 = (2*0.6*WTO)*((k*CDo)^0.5);
%% D_min indices
```

```
% 0.9 WTO
[D_min_1_9,index_1_9] = min(D_0_9_1);
[D_min_2_9,index_2_9] = min(D_0_9_2);
[D_min_3_9,index_3_9] = min(D_0_9_3);
[D_min_4_9,index_4_9] = min(D_0_9_4);
[D_min_5_9,index_5_9] = min(D_0_9_5);
[D_min_6_9,index_6_9] = min(D_0_9_6);

% 0.8 WTO
[D_min_1_8,index_1_8] = min(D_0_8_1);
[D_min_2_8,index_2_8] = min(D_0_8_2);
[D_min_3_8,index_3_8] = min(D_0_8_3);
[D_min_4_8,index_4_8] = min(D_0_8_4);
[D_min_5_8,index_5_8] = min(D_0_8_5);
[D_min_6_8,index_6_8] = min(D_0_8_6);

% 0.6 WTO
[D_min_1_6,index_1_6] = min(D_0_6_1);
[D_min_2_6,index_2_6] = min(D_0_6_2);
[D_min_3_6,index_3_6] = min(D_0_6_3);
[D_min_4_6,index_4_6] = min(D_0_6_4);
[D_min_5_6,index_5_6] = min(D_0_6_5);
[D_min_6_6,index_6_6] = min(D_0_6_6);

% Alt 1
[D_min_1_9_n,index_1_9_n] = min(D_1_9);
[D_min_1_8_n,index_1_8_n] = min(D_1_8);
[D_min_1_6_n,index_1_6_n] = min(D_1_6);

% Alt 2
[D_min_2_9_n,index_2_9_n] = min(D_2_9);
[D_min_2_8_n,index_2_8_n] = min(D_2_8);
[D_min_2_6_n,index_2_6_n] = min(D_2_6);

% Alt 3
[D_min_3_9_n,index_3_9_n] = min(D_3_9);
[D_min_3_8_n,index_3_8_n] = min(D_3_8);
[D_min_3_6_n,index_3_6_n] = min(D_3_6);

% Alt 4
[D_min_4_9_n,index_4_9_n] = min(D_4_9);
[D_min_4_8_n,index_4_8_n] = min(D_4_8);
[D_min_4_6_n,index_4_6_n] = min(D_4_6);

% Alt 5
[D_min_5_9_n,index_5_9_n] = min(D_5_9);
[D_min_5_8_n,index_5_8_n] = min(D_5_8);
[D_min_5_6_n,index_5_6_n] = min(D_5_6);

% Alt 6
[D_min_6_9_n,index_6_9_n] = min(D_6_9);
[D_min_6_8_n,index_6_8_n] = min(D_6_8);
[D_min_6_6_n,index_6_6_n] = min(D_6_6);
%% DRAG POLAR PLOT
%% 0.9 WTO
title("Drag Polar for Various Altitudes at 0.9 $W_{TO}$","Interpreter","latex",'FontSize',20)
hold on
% Curves
plot(V(78:280),D_0_9_1(78:280),'Color','magenta','LineWidth',1.2)
plot(V(88:270),D_0_9_2(88:270),'Color','blue','LineWidth',1.2)
plot(V(105:265),D_0_9_3(105:265),'Color',   "#D95319",'LineWidth',1.2)
plot(V(130:255),D_0_9_4(130:255),'Color',   "#EDB120",'LineWidth',1.2)
plot(V(150:245),D_0_9_5(150:245),'Color','green','LineWidth',1.2)
plot(V(160:243),D_0_9_6(160:243),'Color',"#4DBEEE",'LineWidth',1.2)
% V_D_min for legend
```

```
plot([V(index_1_9) V(index_1_9)],[0 D_min_1_9],'-.','Color',"#A2142F",'LineWidth',1.1)
% M_crit for legend
plot([Mcrit_1 Mcrit_1],[0 D_0_9_1(278)],'-.','Color',"#009899",'LineWidth',1.3)
% V_stall for legend
plot([V_stall_1_9 V_stall_1_9],[0 D_0_9_1(79)],'-.','Color',"#6600cc",'LineWidth',1.1)
% V_stall lines
plot([V_stall_2_9 V_stall_2_9],[0 D_0_9_2(92)],'-.','Color',"#6600cc",'LineWidth',1.1)
plot([V_stall_3_9 V_stall_3_9],[0 D_0_9_3(109)],'-.','Color',"#6600cc",'LineWidth',1.1)
plot([V_stall_4_9 V_stall_4_9],[0 D_0_9_4(134)],'-.','Color',"#6600cc",'LineWidth',1.1)
plot([V_stall_5_9 V_stall_5_9],[0 D_0_9_5(154)],'-.','Color',"#6600cc",'LineWidth',1.1)
plot([V_stall_6_9 V_stall_6_9],[0 D_0_9_6(160)],'-.','Color',"#6600cc",'LineWidth',1.1)
% D_min line
yline(264549,'--','Color','black','LineWidth',1.1)
% D_min text
text(40,240000,'$D_{min}$ = 264549 N','Interpreter','latex','FontSize',15)
% V_D_min line
plot([V(index_2_9) V(index_2_9)],[0 D_min_2_9],'-.','Color',"#A2142F",'LineWidth',1.1)
plot([V(index_3_9) V(index_3_9)],[0 D_min_3_9],'-.','Color',"#A2142F",'LineWidth',1.1)
plot([V(index_4_9) V(index_4_9)],[0 D_min_4_9],'-.','Color',"#A2142F",'LineWidth',1.1)
plot([V(index_5_9) V(index_5_9)],[0 D_min_5_9],'-.','Color',"#A2142F",'LineWidth',1.1)
plot([V(index_6_9) V(index_6_9)],[0 D_min_6_9],'-.','Color',"#A2142F",'LineWidth',1.1)
% M_crit line
plot([Mcrit_2 Mcrit_2],[0 D_0_9_2(270)],'-.','Color',"#009899",'LineWidth',1.3)
plot([Mcrit_3 Mcrit_3],[0 D_0_9_3(261)],'-.','Color',"#009899",'LineWidth',1.3)
plot([Mcrit_4 Mcrit_4],[0 D_0_9_4(249)],'-.','Color',"#009899",'LineWidth',1.3)
plot([Mcrit_5 Mcrit_5],[0 D_0_9_5(242)],'-.','Color',"#009899",'LineWidth',1.3)
plot([Mcrit_6 Mcrit_6],[0 D_0_9_6(240)],'-.','Color',"#009899",'LineWidth',1.3)
hold off
grid on
xlabel("Velocity (m/s)",'Interpreter','latex','FontSize',17)
ylabel("Drag (N)",'Interpreter','latex','FontSize',17)
xlim([0 340])
ylim([0 700000])
xticks(25:25:330)
leg1 = legend("0.5 Km","3 Km","5.5 Km","8.5 Km","10.5 Km","11.5 Km","$V_{D_{min}}$", ...
    "$V_{crit}$","$V_{stall}$",'Interpreter','latex','Location','northwest','FontSize',16);
title(leg1,'Legend')
ax = gca;
ax.TickDir = 'out';
ax.TickLength = [0.005 0.005];
grid on
set(gcf, 'Position', get(0,'ScreenSize'));
%% 0.8 WTO
title("Drag Polar for Various Altitudes at 0.8 $W_{TO}$","Interpreter","latex",'FontSize',20)
hold on
% Curves
plot(V(70:280),D_0_8_1(70:280),'Color','magenta','LineWidth',1.2)
plot(V(85:273),D_0_8_2(85:273),'Color','blue','LineWidth',1.2)
plot(V(100:263),D_0_8_3(100:263),'Color',   "#D85318",'LineWidth',1.2)
plot(V(123:253),D_0_8_4(123:253),'Color',   "#EDB120",'LineWidth',1.2)
plot(V(140:243),D_0_8_5(140:243),'Color','green','LineWidth',1.2)
plot(V(148:233),D_0_8_6(148:233),'Color',"#4DBEEE",'LineWidth',1.2)
% V_D_min for legend
plot([V(index_1_8) V(index_1_8)],[0 D_min_1_8],'-.','Color',"#A2142F",'LineWidth',1.1)
% M_crit for legend
plot([Mcrit_1 Mcrit_1],[0 D_0_8_1(278)],'-.','Color',"#008888",'LineWidth',1.3)
% V_stall for legend
plot([V_stall_1_8 V_stall_1_8],[0 D_0_8_1(72)],'-.','Color',"#6600cc",'LineWidth',1.1)
% V_stall lines
plot([V_stall_2_8 V_stall_2_8],[0 D_0_8_2(85)],'-.','Color',"#6600cc",'LineWidth',1.1)
plot([V_stall_3_8 V_stall_3_8],[0 D_0_8_3(100)],'-.','Color',"#6600cc",'LineWidth',1.1)
plot([V_stall_4_8 V_stall_4_8],[0 D_0_8_4(124)],'-.','Color',"#6600cc",'LineWidth',1.1)
plot([V_stall_5_8 V_stall_5_8],[0 D_0_8_5(144)],'-.','Color',"#6600cc",'LineWidth',1.1)
plot([V_stall_6_8 V_stall_6_8],[0 D_0_8_6(149)],'-.','Color',"#6600cc",'LineWidth',1.1)
% D_min line
```

```
yline(235145,'--','Color','black','LineWidth',1.1)
% D_min text
text(40,190000,'$D_{min}$ = 235145 N','Interpreter','latex','FontSize',14)
% V_D_min line
plot([V(index_2_8) V(index_2_8)],[0 D_min_2_8],'-.','Color',"#A2142F",'LineWidth',1.1)
plot([V(index_3_8) V(index_3_8)],[0 D_min_3_8],'-.','Color',"#A2142F",'LineWidth',1.1)
plot([V(index_4_8) V(index_4_8)],[0 D_min_4_8],'-.','Color',"#A2142F",'LineWidth',1.1)
plot([V(index_5_8) V(index_5_8)],[0 D_min_5_8],'-.','Color',"#A2142F",'LineWidth',1.1)
plot([V(index_6_8) V(index_6_8)],[0 D_min_6_8],'-.','Color',"#A2142F",'LineWidth',1.1)
% M_crit line
plot([Mcrit_2 Mcrit_2],[0 D_0_8_2(270)],'-.','Color',"#008888",'LineWidth',1.3)
plot([Mcrit_3 Mcrit_3],[0 D_0_8_3(261)],'-.','Color',"#008888",'LineWidth',1.3)
plot([Mcrit_4 Mcrit_4],[0 D_0_8_4(248)],'-.','Color',"#008888",'LineWidth',1.3)
plot([Mcrit_5 Mcrit_5],[0 D_0_8_5(242)],'-.','Color',"#008888",'LineWidth',1.3)
plot([Mcrit_6 Mcrit_6],[0 D_0_8_6(240)],'-.','Color',"#008888",'LineWidth',1.3)
hold off
grid on
xlabel("Velocity (m/s)",'Interpreter','latex','FontSize',17)
ylabel("Drag (N)",'Interpreter','latex','FontSize',17)
leg1 = legend("0.5 Km","3 Km","5.5 Km","8.5 Km","10.5 Km","11.5 Km","$V_{D_{min}}$", ...
    "$V_{crit}$","$V_{stall}$",'Interpreter','latex','Location','northwest','FontSize',16);
title(leg1,'Legend')
ax = gca;
ax.TickDir = 'out';
ax.TickLength = [0.005 0.005];
ylim([0 0.8e6])
xlim([0 340])
xticks(25:25:330)
grid on
set(gcf, 'Position', get(0,'ScreenSize'));
%% 0.6 WTO
hold on
title("Drag Polar for Various Altitudes at 0.6 $W_{TO}$","Interpreter","latex",'FontSize',20)
hold on
% Curves
plot(V(58:280),D_0_6_1(58:280),'Color','magenta','LineWidth',1.2)
plot(V(70:271),D_0_6_2(70:271),'Color','blue','LineWidth',1.2)
plot(V(83:263),D_0_6_3(83:263),'Color', "#D65316",'LineWidth',1.2)
plot(V(105:252),D_0_6_4(105:252),'Color',   "#EDB120",'LineWidth',1.2)
plot(V(120:243),D_0_6_5(120:243),'Color','green','LineWidth',1.2)
plot(V(125:241),D_0_6_6(125:241),'Color',"#4DBEEE",'LineWidth',1.2)
% V_D_min for legend
plot([V(index_1_6) V(index_1_6)],[0 D_min_1_6],'-.','Color',"#A2142F",'LineWidth',1.1)
% M_crit for legend
plot([Mcrit_1 Mcrit_1],[0 D_0_6_1(278)],'-.','Color',"#006666",'LineWidth',1.3)
% V_stall for legend
plot([V_stall_1_6 V_stall_1_6],[0 D_0_6_1(60)],'-.','Color',"#6600cc",'LineWidth',1.1)
% V_stall lines
plot([V_stall_2_6 V_stall_2_6],[0 D_0_6_2(71)],'-.','Color',"#6600cc",'LineWidth',1.1)
plot([V_stall_3_6 V_stall_3_6],[0 D_0_6_3(84)],'-.','Color',"#6600cc",'LineWidth',1.1)
plot([V_stall_4_6 V_stall_4_6],[0 D_0_6_4(105)],'-.','Color',"#6600cc",'LineWidth',1.1)
plot([V_stall_5_6 V_stall_5_6],[0 D_0_6_5(121)],'-.','Color',"#6600cc",'LineWidth',1.1)
plot([V_stall_6_6 V_stall_6_6],[0 D_0_6_6(126)],'-.','Color',"#6600cc",'LineWidth',1.1)
% D_min line
yline(176492,'--','Color','black','LineWidth',1.1)
% D_min text
text(40,150000,'$D_{min}$ = 176492 N','Interpreter','latex','FontSize',15)
% V_D_min line
plot([V(index_2_6) V(index_2_6)],[0 D_min_2_6],'-.','Color',"#A2142F",'LineWidth',1.1)
plot([V(index_3_6) V(index_3_6)],[0 D_min_3_6],'-.','Color',"#A2142F",'LineWidth',1.1)
plot([V(index_4_6) V(index_4_6)],[0 D_min_4_6],'-.','Color',"#A2142F",'LineWidth',1.1)
plot([V(index_5_6) V(index_5_6)],[0 D_min_5_6],'-.','Color',"#A2142F",'LineWidth',1.1)
plot([V(index_6_6) V(index_6_6)],[0 D_min_6_6],'-.','Color',"#A2142F",'LineWidth',1.1)
% M_crit line
plot([Mcrit_2 Mcrit_2],[0 D_0_6_2(270)],'-.','Color',"#006666",'LineWidth',1.3)
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```
plot([Mcrit_3 Mcrit_3],[0 D_0_6_3(261)],'-.','Color',"#006666",'LineWidth',1.3)
plot([Mcrit_4 Mcrit_4],[0 D_0_6_4(246)],'-.','Color',"#006666",'LineWidth',1.3)
plot([Mcrit_5 Mcrit_5],[0 D_0_6_5(242)],'-.','Color',"#006666",'LineWidth',1.3)
plot([Mcrit_6 Mcrit_6],[0 D_0_6_6(240)],'-.','Color',"#006666",'LineWidth',1.3)
hold off
xlabel("Velocity (m/s)",'Interpreter','latex','FontSize',17)
ylabel("Drag (N)",'Interpreter','latex','FontSize',17)
leg1 = legend("0.5 Km","3 Km","5.5 Km","8.5 Km","10.5 Km","11.5 Km","$V_{D_{min}}$", ...
    "$V_{crit}$","$V_{stall}$",'Interpreter','latex','Location','northwest','FontSize',16);
title(leg1,'Legend')
ax = gca;
ax.TickDir = 'out';
grid on
ax.TickLength = [0.005 0.005];
ylim([0 6.5e5])
xlim([0 340])
xticks(25:25:330)
set(gcf, 'Position', get(0,'ScreenSize'));
%% Alt 1
hold on
title("Drag Polar at 0.5 Km for Various $W_{TO}$","Interpreter","latex",'FontSize',20)
hold on
% Curves
plot(V(78:280),D_1_9(78:280),'Color','magenta','LineWidth',1.2)
plot(V(71:280),D_1_8(71:280),'Color','blue','LineWidth',1.2)
plot(V(60:280),D_1_6(60:280),'Color',"#D65316",'LineWidth',1.2)
% V_D_min for legend
plot([V(index_1_9_n) V(index_1_9_n)],[0 D_min_1_9_n],'-.','Color',"#A2142F",'LineWidth',1.1)
% M_crit for legend
plot([Mcrit_1 Mcrit_1],[0 D_1_9(278)],'-.','Color',"#006666",'LineWidth',1.3)
% V_stall for legend
plot([V_stall_1_9 V_stall_1_9],[0 D_1_9(79)],'-.','Color',"#6600cc",'LineWidth',1.1)
% V_stall lines
plot([V_stall_1_8 V_stall_1_8],[0 D_1_8(72)],'-.','Color',"#6600cc",'LineWidth',1.1)
plot([V_stall_1_6 V_stall_1_6],[0 D_1_6(60)],'-.','Color',"#6600cc",'LineWidth',1.1)
% V_D_min line
plot([V(index_1_8_n) V(index_1_8_n)],[0 D_min_1_8_n],'-.','Color',"#A2142F",'LineWidth',1.1)
plot([V(index_1_6_n) V(index_1_6_n)],[0 D_min_1_6_n],'-.','Color',"#A2142F",'LineWidth',1.1)
% M_crit line
plot([Mcrit_1 Mcrit_1],[0 D_1_8(278)],'-.','Color',"#006666",'LineWidth',1.3)
plot([Mcrit_1 Mcrit_1],[0 D_1_6(276)],'-.','Color',"#006666",'LineWidth',1.3)
hold off
grid on
xlabel("Velocity (m/s)",'Interpreter','latex','FontSize',17)
ylabel("Drag (N)",'Interpreter','latex','FontSize',17)
leg1 = legend("0.9 $W_{TO}$","0.8 $W_{TO}$","0.6 $W_{TO}$","$V_{D_{min}}$","$V_{crit}$", ...
    "$V_{stall}$",'Interpreter','latex','Location','northwest','FontSize',16);
title(leg1,'Legend')
ax = gca;
ax.TickDir = 'out';
grid on
ax.TickLength = [0.005 0.005];
xlim([0 340])
ylim([0 6.5e5])
xticks(25:25:330)
set(gcf, 'Position', get(0,'ScreenSize'));
%% Alt 2
hold on
title("Drag Polar at 3 Km for Various $W_{TO}$","Interpreter","latex",'FontSize',20)
hold on
% Curves
plot(V(88:272),D_2_9(88:272),'Color','magenta','LineWidth',1.2)
plot(V(85:272),D_2_8(85:272),'Color','blue','LineWidth',1.2)
plot(V(70:272),D_2_6(70:272),'Color',"#D65316",'LineWidth',1.2)
% V_D_min for legend
```

```
plot([V(index_2_9_n) V(index_2_9_n)],[0 D_min_2_9_n],'-.','Color',"#A2142F",'LineWidth',1.1)
% M_crit for legend
plot([Mcrit_2 Mcrit_2],[0 D_2_9(270)],'-.','Color',"#006666",'LineWidth',1.3)
%V_stall for legend
plot([V_stall_2_9 V_stall_2_9],[0 D_2_9(92)],'-.','Color',"#6600cc",'LineWidth',1.1)
% V_stall lines
plot([V_stall_2_8 V_stall_2_8],[0 D_2_8(86)],'-.','Color',"#6600cc",'LineWidth',1.1)
plot([V_stall_2_6 V_stall_2_6],[0 D_2_6(71)],'-.','Color',"#6600cc",'LineWidth',1.1)
% V_D_min line
plot([V(index_2_8_n) V(index_2_8_n)],[0 D_min_2_8_n],'-.','Color',"#A2142F",'LineWidth',1.1)
plot([V(index_2_6_n) V(index_2_6_n)],[0 D_min_2_6_n],'-.','Color',"#A2142F",'LineWidth',1.1)
% M_crit line
plot([Mcrit_2 Mcrit_2],[0 D_2_8(270)],'-.','Color',"#006666",'LineWidth',1.3)
plot([Mcrit_2 Mcrit_2],[0 D_2_6(270)],'-.','Color',"#006666",'LineWidth',1.3)
hold off
grid on
xlabel("Velocity (m/s)",'Interpreter','latex','FontSize',17)
ylabel("Drag (N)",'Interpreter','latex','FontSize',17)
leg1 = legend("0.9 $W_{TO}$","0.8 $W_{TO}$","0.6 $W_{TO}$","$V_{D_{min}}$","$V_{crit}$", ...
    "$V_{stall}$",'Interpreter','latex','Location','northwest','FontSize',16);
title(leg1,'Legend')
ax = gca;
ax.TickDir = 'out';
grid on
ax.TickLength = [0.005 0.005];
grid on
xlim([0 330])
ylim([0 7e5])
xticks(25:25:330)
set(gcf, 'Position', get(0,'ScreenSize'));
%% Alt 3
hold on
title("Drag Polar at 5.5 Km for Various $W_{TO}$","Interpreter","latex",'FontSize',20)
hold on
% Curves
plot(V(108:265),D_3_9(108:265),'Color','magenta','LineWidth',1.2)
plot(V(100:265),D_3_8(100:265),'Color','blue','LineWidth',1.2)
plot(V(83:265),D_3_6(83:265),'Color',"#D65316",'LineWidth',1.2)
% V_D_min for legend
plot([V(index_3_9_n) V(index_3_9_n)],[0 D_min_3_9_n],'-.','Color',"#A2142F",'LineWidth',1.1)
% M_crit for legend
plot([Mcrit_3 Mcrit_3],[0 D_3_9(261)],'-.','Color',"#006666",'LineWidth',1.3)
% V_stall for legend
plot([V_stall_3_9 V_stall_3_9],[0 D_3_9(109)],'-.','Color',"#6600cc",'LineWidth',1.1)
% V_stall lines
plot([V_stall_3_8 V_stall_3_8],[0 D_3_8(101)],'-.','Color',"#6600cc",'LineWidth',1.1)
plot([V_stall_3_6 V_stall_3_6],[0 D_3_6(84)],'-.','Color',"#6600cc",'LineWidth',1.1)
% V_D_min line
plot([V(index_3_8_n) V(index_3_8_n)],[0 D_min_3_8_n],'-.','Color',"#A2142F",'LineWidth',1.1)
plot([V(index_3_6_n) V(index_3_6_n)],[0 D_min_3_6_n],'-.','Color',"#A2142F",'LineWidth',1.1)
% M_crit line
plot([Mcrit_3 Mcrit_3],[0 D_3_8(100)],'-.','Color',"#006666",'LineWidth',1.3)
plot([Mcrit_3 Mcrit_3],[0 D_3_6(261)],'-.','Color',"#006666",'LineWidth',1.3)
hold off
grid on
xlabel("Velocity (m/s)",'Interpreter','latex','FontSize',17)
ylabel("Drag (N)",'Interpreter','latex','FontSize',17)
leg1 = legend("0.9 $W_{TO}$","0.8 $W_{TO}$","0.6 $W_{TO}$","$V_{D_{min}}$","$V_{crit}$", ...
    "$V_{stall}$",'Interpreter','latex','Location','northwest','FontSize',16);
title(leg1,'Legend')
ax = gca;
ax.TickDir = 'out';
grid on
ax.TickLength = [0.005 0.005];
xlim([0 320])
```

```
ylim([0 6.5e5])
xticks(25:25:330)
set(gcf, 'Position', get(0,'ScreenSize'));
%% Alt 4
hold on
title("Drag Polar at 8.5 Km for Various $W_{TO}$","Interpreter","latex",'FontSize',20)
hold on
% Curves
plot(V(133:253),D_4_9(133:253),'Color','magenta','LineWidth',1.2)
plot(V(123:253),D_4_8(123:253),'Color','blue','LineWidth',1.2)
plot(V(103:253),D_4_6(103:253),'Color', "#D65416",'LineWidth',1.2)
% V_D_min for legend
plot([V(index_4_9_n) V(index_4_9_n)],[0 D_min_4_9_n],'-.','Color',"#A2142F",'LineWidth',1.1)
% M_crit for legend
plot([Mcrit_4 Mcrit_4],[0 D_4_9(250)],'-.','Color',"#006666",'LineWidth',1.4)
% V_stall for legend
plot([V_stall_4_9 V_stall_4_9],[0 D_4_9(134)],'-.','Color',"#6600cc",'LineWidth',1.1)
% V_stall lines
plot([V_stall_4_8 V_stall_4_8],[0 D_4_8(124)],'-.','Color',"#6600cc",'LineWidth',1.1)
plot([V_stall_4_6 V_stall_4_6],[0 D_4_6(105)],'-.','Color',"#6600cc",'LineWidth',1.1)
% V_D_min line
plot([V(index_4_8_n) V(index_4_8_n)],[0 D_min_4_8_n],'-.','Color',"#A2142F",'LineWidth',1.1)
plot([V(index_4_6_n) V(index_4_6_n)],[0 D_min_4_6_n],'-.','Color',"#A2142F",'LineWidth',1.1)
% M_crit line
plot([Mcrit_4 Mcrit_4],[0 D_4_8(250)],'-.','Color',"#006666",'LineWidth',1.4)
plot([Mcrit_4 Mcrit_4],[0 D_4_6(250)],'-.','Color',"#006666",'LineWidth',1.4)
hold off
grid on
xlabel("Velocity (m/s)",'Interpreter','latex','FontSize',17)
ylabel("Drag (N)",'Interpreter','latex','FontSize',17)
leg1 = legend("0.9 $W_{TO}$","0.8 $W_{TO}$","0.6 $W_{TO}$","$V_{D_{min}}$","$V_{crit}$", ...
    "$V_{stall}$",'Interpreter','latex','Location','northwest','FontSize',16);
title(leg1,'Legend')
xlim([0 300])
ylim([0 6e5])
xticks(25:25:330)
set(gcf, 'Position', get(0,'ScreenSize'));
%% Alt 5
hold on
title("Drag Polar at 10.5 Km for Various $W_{TO}$","Interpreter","latex",'FontSize',20)
hold on
% Curves
plot(V(153:245),D_5_9(153:245),'Color','magenta','LineWidth',1.2)
plot(V(142:245),D_5_8(142:245),'Color','blue','LineWidth',1.2)
plot(V(120:245),D_5_6(120:245),'Color',"#D65516",'LineWidth',1.2)
% V_D_min for legend
plot([V(index_5_9_n) V(index_5_9_n)],[0 D_min_5_9_n],'-.','Color',"#A2142F",'LineWidth',1.1)
% M_crit for legend
plot([Mcrit_5 Mcrit_5],[0 D_5_9(242)],'-.','Color',"#006666",'LineWidth',1.4)
% V_stall for legend
plot([V_stall_5_9 V_stall_5_9],[0 D_5_9(154)],'-.','Color',"#6600cc",'LineWidth',1.1)
% V_stall lines
plot([V_stall_5_8 V_stall_5_8],[0 D_5_8(144)],'-.','Color',"#6600cc",'LineWidth',1.1)
plot([V_stall_5_6 V_stall_5_6],[0 D_5_6(121)],'-.','Color',"#6600cc",'LineWidth',1.1)
% V_D_min line
plot([V(index_5_8_n) V(index_5_8_n)],[0 D_min_5_8_n],'-.','Color',"#A2142F",'LineWidth',1.1)
plot([V(index_5_6_n) V(index_5_6_n)],[0 D_min_5_6_n],'-.','Color',"#A2142F",'LineWidth',1.1)
% M_crit line
plot([Mcrit_5 Mcrit_5],[0 D_5_8(242)],'-.','Color',"#006666",'LineWidth',1.4)
plot([Mcrit_5 Mcrit_5],[0 D_5_6(121)],'-.','Color',"#006666",'LineWidth',1.4)
hold off
grid on
h=gca;
h.XAxis.TickLength = [0 0];
h.YAxis.TickLength = [0 0];
```

```
xlabel("Velocity (m/s)",'Interpreter','latex','FontSize',17)
ylabel("Drag (N)",'Interpreter','latex','FontSize',17)
leg1 = legend("0.9 $W_{TO}$","0.8 $W_{TO}$","0.6 $W_{TO}$","$V_{D_{min}}$","$V_{crit}$", ...
    "$V_{stall}$",'Interpreter','latex','Location','northwest','FontSize',16);
title(leg1,'Legend')
ax = gca;
ax.TickDir = 'out';
grid on
ax.TickLength = [0.005 0.005];
xlim([0 290])
ylim([0 6e5])
xticks(25:25:330)
set(gcf, 'Position', get(0,'ScreenSize'));
%% Alt 6
hold on
title("Drag Polar at 11.5 Km for Various $W_{TO}$","Interpreter","latex",'FontSize',20)
% Curves
plot(V(158:243),D_6_9(158:243),'Color','magenta','LineWidth',1.2)
plot(V(148:243),D_6_8(148:243),'Color','blue','LineWidth',1.2)
plot(V(123:243),D_6_6(123:243),'Color', "#D66616",'LineWidth',1.2)
% V_D_min for legend
plot([V(index_6_9_n) V(index_6_9_n)],[0 D_min_6_9_n],'-.','Color',"#A2142F",'LineWidth',1.1)
% M_crit for legend
plot([Mcrit_6 Mcrit_6],[0 D_6_9(240)],'-.','Color',"#006666",'LineWidth',1.4)
% V_stall for legend
plot([V_stall_6_9 V_stall_6_9],[0 D_6_9(160)],'-.','Color',"#6600cc",'LineWidth',1.1)
% V_stall lines
plot([V_stall_6_8 V_stall_6_8],[0 D_6_8(149)],'-.','Color',"#6600cc",'LineWidth',1.1)
plot([V_stall_6_6 V_stall_6_6],[0 D_6_6(126)],'-.','Color',"#6600cc",'LineWidth',1.1)
% V_D_min line
plot([V(index_6_8_n) V(index_6_8_n)],[0 D_min_6_8_n],'-.','Color',"#A2142F",'LineWidth',1.1)
plot([V(index_6_6_n) V(index_6_6_n)],[0 D_min_6_6_n],'-.','Color',"#A2142F",'LineWidth',1.1)
% M_crit line
plot([Mcrit_6 Mcrit_6],[0 D_6_8(240)],'-.','Color',"#006666",'LineWidth',1.4)
plot([Mcrit_6 Mcrit_6],[0 D_6_6(240)],'-.','Color',"#006666",'LineWidth',1.4)
hold off
grid on
h=gca;
h.XAxis.TickLength = [0 0];
h.YAxis.TickLength = [0 0];
xlabel("Velocity (m/s)",'Interpreter','latex','FontSize',17)
ylabel("Drag (N)",'Interpreter','latex','FontSize',17)
leg1 = legend("0.9 $W_{TO}$","0.8 $W_{TO}$","0.6 $W_{TO}$","$V_{D_{min}}$","$V_{crit}$", ...
    "$V_{stall}$",'Interpreter','latex','Location','northwest','FontSize',16);
title(leg1,'Legend')
ax = gca;
ax.TickDir = 'out';
grid on
ax.TickLength = [0.005 0.005];
xlim([0 300])
ylim([0 6e5])
xticks(25:25:330)
set(gcf, 'Position', get(0,'ScreenSize'));
%% PLOT 2 - h-V CALCULATION
Tasl = 350*4;
v_q = sqrt((2*q_max)./rho);
%% 0.9 WTO and 100% Throttle
% Calculations
sigma_9_100 = (2*(k*CDo)^0.5)/(Tasl/(0.9*wto));
rho_9_a = sigma_9_100*Rho_SL;
A = CDo.*rho.*S.*0.5;
B = (2*k*((0.9*wto*1000)^2))./(rho.*S);
h_abs_9 = height(1388);
sigma = rho./Rho_SL;
v = [];
```

```
for i=1:1388
    v1 = sqrt(((Tasl*1000*sigma(i))+sqrt(((Tasl*1000*sigma(i))^2)-(4*A(i)*B(i))))/(2*A(i)));
    v = [v v1];
end
for i=1:1388
    v2 = sqrt(((Tasl*1000*sigma(i))-sqrt(((Tasl*1000*sigma(i))^2)-(4*A(i)*B(i))))/(2*A(i)));
    v = [v v2];
end

% Boundaries
v_stall_9 = ((2*0.9*wto*1000)./(rho(1:1190).*S.*CLmax)).^0.5;
v_crit_9 = 0.895*a(1:1320);

% Plot
hold on
title("\textbf{V-h Plot for 0.9 $W_{TO}$ and 100 \% Throttle}","Interpreter","latex",'FontSize',30)
plot(v(1:1388),height(1:1388),'Color','magenta','LineWidth',1.2)
plot(v(1389:2776),height(1:1388),'Color','magenta','LineWidth',1.2)
plot(v_stall_9,height(1:1190),'Color','blue','LineWidth',1.5)
plot(v_crit_9,height(1:1320),'Color','red','LineWidth',1.5)
plot(v_q(1:885),height(1:885),'Color','green','LineWidth',1.3)
xlabel("Velocity (m/s)",'Interpreter','latex','FontSize',25)
ylabel("Altitude (m)",'Interpreter','latex','FontSize',25)
plot([0 350],[h_abs_9 h_abs_9],'--','Color',"#FFA500",'LineWidth',1.1)
ylim([0 16000])
xlim([0 500])
% Text
text(115,4000,'Stall Boundary','Interpreter','latex','FontSize',20,'Rotation',65)
text(350,3800,'Aeroelastic Boundary ($q_{max}$)','Interpreter','latex','FontSize',20,'Rotation',38)
text(180,6200,'Flight Envelope','Interpreter','latex','FontSize',30,'Rotation',0)
text(280,8000,'Critical Velocity Boundary','Interpreter','latex','FontSize',20,'Rotation',-75)
text(100,h_abs_9+200,'Absolute Ceiling = 13870 m','Interpreter','latex','FontSize',20,'Rotation',0)
hold off
xticks(50:50:500)
grid on
set(gcf, 'Position', get(0,'ScreenSize'));
set(gca,'Box','on');
ax = gca;
ax.TickDir = 'out';
ax.FontSize = 20;
ax.TickLength = [0.005 0.005];
%% 0.8 WTO and 100% Throttle
% Calculations
sigma_8_100 = (2*(k*CDo)^0.5)/(Tasl/(0.8*wto));
rho_8_a = sigma_8_100*Rho_SL;
A = CDo.*rho.*S.*0.5;
B = (2*k*((0.8*wto*1000)^2))./(rho.*S);
sigma = rho./Rho_SL;
h_abs_8 = height(1463);
v = [];
for i=1:1470
    v1 = sqrt(((Tasl*1000*sigma(i))+sqrt(((Tasl*1000*sigma(i))^2)-(4*A(i)*B(i))))/(2*A(i)));
    v = [v v1];
end
for i=1:1470
    v2 = sqrt(((Tasl*1000*sigma(i))-sqrt(((Tasl*1000*sigma(i))^2)-(4*A(i)*B(i))))/(2*A(i)));
    v = [v v2];
end

% Boundaries
v_stall_8 = ((2*0.8*wto*1000)./(rho(1:1270).*S.*CLmax)).^0.5;
v_crit_8 = 0.895*a(1:1400);

% Plot
hold on
```

```
title("\textbf{V-h Plot for 0.8 $W_{TO}$ and 100 \% Throttle}","Interpreter","latex",'FontSize',30)
plot(v(1:1470),height(1:1470),'Color','magenta','LineWidth',1.2)
plot(v(1471:2940),height(1:1470),'Color','magenta','LineWidth',1.2)
plot(v_stall_8,height(1:1270),'Color','blue','LineWidth',1.5)
plot(v_crit_8,height(1:1400),'Color','red','LineWidth',1.5)
plot(v_q(1:895),height(1:895),'Color','green','LineWidth',1.3)
xlabel("Velocity (m/s)",'Interpreter','latex','FontSize',25)
ylabel("Altitude (m)",'Interpreter','latex','FontSize',25)
plot([0 350],[h_abs_8 h_abs_8],'--','Color',"#FFA500",'LineWidth',1.1)
ylim([0 16000])
xlim([0 500])
% Text
text(110,4000,'Stall Boundary','Interpreter','latex','FontSize',20,'Rotation',67)
text(350,3700,'Aeroelastic Boundary ($q_{max}$)','Interpreter','latex','FontSize',20,'Rotation',40)
text(175,6200,'Flight Envelope','Interpreter','latex','FontSize',30,'Rotation',0)
text(280,8000,'Critical Velocity Boundary','Interpreter','latex','FontSize',20,'Rotation',-75)
text(100,h_abs_8+200,'Absolute Ceiling = 14620 m','Interpreter','latex','FontSize',20,'Rotation',0)
hold off
xticks(50:50:500)
ax = gca;
ax.TickDir = 'out';
ax.TickLength = [0.005 0.005];
grid on
set(gcf, 'Position', get(0,'ScreenSize'));
set(gca,'Box','on');
ax = gca;
ax.TickDir = 'out';
ax.FontSize = 20;
ax.TickLength = [0.005 0.005];
%% 0.6 WTO and 100% Throttle
% Calculations
sigma_6_100 = (2*(k*CDo)^0.5)/(Tasl/(0.6*wto));
rho_6_a = sigma_6_100*Rho_SL;
A = CDo.*rho.*S.*0.5;
B = (2*k*((0.6*wto*1000)^2))./(rho.*S);
h_abs_6 = 16440;
sigma = rho./Rho_SL;
v = [];
for i=1:1650
    v1 = sqrt(((Tasl*1000*sigma(i))+sqrt(((Tasl*1000*sigma(i))^2)-(4*A(i)*B(i))))/(2*A(i)));
    v = [v v1];
end
for i=1:1650
    v2 = sqrt(((Tasl*1000*sigma(i))-sqrt(((Tasl*1000*sigma(i))^2)-(4*A(i)*B(i))))/(2*A(i)));
    v = [v v2];
end

% Boundaries
v_stall_8 = ((2*0.8*wto*1000)./(rho(1:1550).*S.*CLmax)).^0.5;
v_crit_8 = 0.895*a(1:1580);

% Plot
hold on
title("\textbf{V-h Plot for 0.6 $W_{TO}$ and 100 \% Throttle}","Interpreter","latex",'FontSize',30)
plot(v(1:1650),height(1:1650),'Color','magenta','LineWidth',1.2)
plot(v(1651:3300),height(1:1650),'Color','magenta','LineWidth',1.2)
plot(v_stall_8,height(1:1550),'Color','blue','LineWidth',1.5)
plot(v_crit_8,height(1:1580),'Color','red','LineWidth',1.5)
plot(v_q(1:910),height(1:910),'Color','green','LineWidth',1.3)
xlabel("Velocity (m/s)",'Interpreter','latex','FontSize',25)
ylabel("Altitude (m)",'Interpreter','latex','FontSize',25)
plot([0 350],[h_abs_6 h_abs_6],'--','Color',"#FFA500",'LineWidth',1.1)
ylim([0 18000])
xlim([0 500])
% Text
```

```
text(110,4000,'Stall Boundary','Interpreter','latex','FontSize',20,'Rotation',65)
text(350,3800,'Aeroelastic Boundary ($q_{max}$)','Interpreter','latex','FontSize',20,'Rotation',35)
text(175,6200,'Flight Envelope','Interpreter','latex','FontSize',30,'Rotation',0)
text(275,9500,'Critical Velocity Boundary','Interpreter','latex','FontSize',20,'Rotation',-75)
text(100,h_abs_6+200,'Absolute Ceiling = 16440 m','Interpreter','latex','FontSize',20,'Rotation',0)
hold off
xticks(50:50:500)
ax = gca;
ax.TickDir = 'out';
ax.TickLength = [0.005 0.005];
grid on
set(gcf, 'Position', get(0,'ScreenSize'));
set(gca,'Box','on');
ax = gca;
ax.TickDir = 'out';
ax.FontSize = 20;
ax.TickLength = [0.005 0.005];
%% 0.9 WTO and 95% Throttle
sigma_9_95 = (2*(k*CDo)^0.5)/(Tasl*0.95/(0.9*wto));
rho_9_a_1 = sigma_9_95*Rho_SL;
A = CDo.*rho.*S.*0.5;
B = (2*k*((0.9*wto*1000)^2))./(rho.*S);
h_abs_9_1 = 13540;
sigma = rho./Rho_SL;
v = [];
for i=1:1360
    v1 = sqrt(((Tasl*0.95*1000*sigma(i))+sqrt(((Tasl*0.95*1000*sigma(i))^2)-(4*A(i)*B(i))))/(2*A(i)));
    v = [v v1];
end
for i=1:1360
    v2 = sqrt(((Tasl*0.95*1000*sigma(i))-sqrt(((Tasl*0.95*1000*sigma(i))^2)-(4*A(i)*B(i))))/(2*A(i)));
    v = [v v2];
end

% Boundaries
v_stall_9 = ((2*0.9*wto*1000)./(rho(1:1150).*S.*CLmax)).^0.5;
v_crit_9 = 0.895*a(1:1300);

% Plot
hold on
title("\textbf{V-h Plot for 0.9 $W_{TO}$ and 95 \% Throttle}","Interpreter","latex",'FontSize',30)
plot(v(1:1360),height(1:1360),'Color','magenta','LineWidth',1.2)
plot(v(1361:2720),height(1:1360),'Color','magenta','LineWidth',1.2)
plot(v_stall_9,height(1:1150),'Color','blue','LineWidth',1.5)
plot(v_crit_9,height(1:1300),'Color','red','LineWidth',1.5)
plot(v_q(1:840),height(1:840),'Color','green','LineWidth',1.3)
xlabel("Velocity (m/s)",'Interpreter','latex','FontSize',25)
ylabel("Altitude (m)",'Interpreter','latex','FontSize',25)
plot([0 350],[h_abs_9_1 h_abs_9_1],'--','Color',"#FFA500",'LineWidth',1.1)
ylim([0 16000])
xlim([0 500])
% Text
text(118,4000,'Stall Boundary','Interpreter','latex','FontSize',20,'Rotation',67)
text(350,3720,'Aeroelastic Boundary ($q_{max}$)','Interpreter','latex','FontSize',20,'Rotation',40)
text(175,6200,'Flight Envelope','Interpreter','latex','FontSize',30,'Rotation',0)
text(280,8000,'Critical Velocity Boundary','Interpreter','latex','FontSize',15,'Rotation',-77)
text(100,h_abs_9_1+200,'Absolute Ceiling = 13540 m','Interpreter','latex','FontSize',20,'Rotation',0)
hold off
ax = gca;
ax.TickDir = 'out';
ax.TickLength = [0.005 0.005];
grid on
set(gcf, 'Position', get(0,'ScreenSize'));
set(gca,'Box','on');
ax = gca;
```

```
ax.TickDir = 'out';
ax.FontSize = 20;
ax.TickLength = [0.005 0.005];
%% 0.9 WTO and 82.5% Throttle
sigma_9_82 = (2*(k*CDo)^0.5)/(Tasl*0.825/(0.9*wto));
rho_9_a_2 = sigma_9_82*Rho_SL;
A = CDo.*rho.*S.*0.5;
B = (2*k*((0.9*wto*1000)^2))./(rho.*S);
h_abs_9_2 = 12650;
sigma = rho./Rho_SL;
v = [];
for i=1:1270
    v1 = sqrt(((Tasl*0.825*1000*sigma(i))+sqrt(((Tasl*0.825*1000*sigma(i))^2)-(4*A(i)*B(i))))/(2*A(i)));
    v = [v v1];
end
for i=1:1270
    v2 = sqrt(((Tasl*0.825*1000*sigma(i))-sqrt(((Tasl*0.825*1000*sigma(i))^2)-(4*A(i)*B(i))))/(2*A(i)));
    v = [v v2];
end

% Boundaries
v_stall_9 = ((2*0.9*wto*1000)./(rho(1:1060).*S.*CLmax)).^0.5;
v_crit_9 = 0.895*a(1:1230);

% Plot
hold on
title("\textbf{V-h Plot for 0.9 $W_{TO}$ and 82.5 \% Throttle}","Interpreter","latex",'FontSize',30)
plot(v(1:1270),height(1:1270),'Color','magenta','LineWidth',1.2)
plot(v(1271:2540),height(1:1270),'Color','magenta','LineWidth',1.2)
plot(v_stall_9,height(1:1060),'Color','blue','LineWidth',1.5)
plot(v_crit_9,height(1:1230),'Color','red','LineWidth',1.5)
plot(v_q(1:720),height(1:720),'Color','green','LineWidth',1.3)
plot([0 325],[h_abs_9_2 h_abs_9_2],'--','Color',"#FFA500",'LineWidth',1.1)
xlabel("Velocity (m/s)",'Interpreter','latex','FontSize',25)
ylabel("Altitude (m)",'Interpreter','latex','FontSize',25)
ylim([0 14000])
xlim([0 500])
% Text
text(117,4000,'Stall Boundary','Interpreter','latex','FontSize',20,'Rotation',69)
text(330,2500,'Aeroelastic Boundary ($q_{max}$)','Interpreter','latex','FontSize',20,'Rotation',47)
text(175,5000,'Flight Envelope','Interpreter','latex','FontSize',30,'Rotation',0)
text(280,8000,'Critical Velocity Boundary','Interpreter','latex','FontSize',20,'Rotation',-78)
text(100,h_abs_9_2+200,'Absolute Ceiling = 12650 m','Interpreter','latex','FontSize',20,'Rotation',0)
hold off
ax = gca;
ax.TickDir = 'out';
ax.TickLength = [0.005 0.005];
grid on
set(gcf, 'Position', get(0,'ScreenSize'));
set(gca,'Box','on');
ax = gca;
ax.TickDir = 'out';
ax.FontSize = 20;
ax.TickLength = [0.005 0.005];
%% 0.9 WTO and 70% Throttle
% Calculations
sigma_9_7 = (2*(k*CDo)^0.5)/(Tasl*0.7/(0.9*wto));
rho_9_a_3 = sigma_9_7*Rho_SL;
A = CDo.*rho.*S.*0.5;
B = (2*k*((0.9*wto*1000)^2))./(rho.*S);
h_abs_9_3 = 11610;
sigma = rho./Rho_SL;
v = [];
for i=1:1165
    v1 = sqrt(((Tasl*0.7*1000*sigma(i))+sqrt(((Tasl*0.7*1000*sigma(i))^2)-(4*A(i)*B(i))))/(2*A(i)));
```

```matlab
    v = [v v1];
end
for i=1:1165
    v2 = sqrt(((Tasl*0.7*1000*sigma(i))-sqrt(((Tasl*0.7*1000*sigma(i))^2)-(4*A(i)*B(i))))/(2*A(i)));
    v = [v v2];
end

% Boundaries
v_stall_9 = ((2*0.9*wto*1000)./(rho(1:925).*S.*CLmax)).^0.5;
v_crit_9 = 0.895*a(1:1150);

% Plot
hold on
title("\textbf{V-h Plot for 0.9 $W_{TO}$ and 70 \% Throttle}","Interpreter","latex",'FontSize',30)
plot(v(1:1165),height(1:1165),'Color','magenta','LineWidth',1.2)
plot(v(1166:2330),height(1:1165),'Color','magenta','LineWidth',1.2)
plot(v_stall_9,height(1:925),'Color','blue','LineWidth',1.5)
plot(v_crit_9,height(1:1150),'Color','red','LineWidth',1.5)
plot(v_q(1:575),height(1:575),'Color','green','LineWidth',1.3)
plot([0 300],[h_abs_9_3 h_abs_9_3],'--','Color',"#FFA500",'LineWidth',1.1)
xlabel("Velocity (m/s)",'Interpreter','latex','FontSize',25)
ylabel("Altitude (m)",'Interpreter','latex','FontSize',25)
ylim([0 13000])
xlim([0 500])
% Text
text(112,3300,'Stall Boundary','Interpreter','latex','FontSize',20,'Rotation',70)
text(315,1600,'Aeroelastic Boundary ($q_{max}$)','Interpreter','latex','FontSize',20,'Rotation',50)
text(180,6200,'Flight Envelope','Interpreter','latex','FontSize',30,'Rotation',0)
text(284,7000,'Critical Velocity Boundary','Interpreter','latex','FontSize',20,'Rotation',-79)
text(100,h_abs_9_3+200,'Absolute Ceiling = 11610 m','Interpreter','latex','FontSize',20,'Rotation',0)
hold off
ax = gca;
ax.TickDir = 'out';
ax.TickLength = [0.005 0.005];
grid on
set(gcf, 'Position', get(0,'ScreenSize'));
set(gca,'Box','on');
ax = gca;
ax.TickDir = 'out';
ax.FontSize = 20;
ax.TickLength = [0.005 0.005];
%% Combined V-h Plot
% 0.9 WTO and 100% Throttle
% Calculations
sigma_9_100 = (2*(k*CDo)^0.5)/(Tasl/(0.9*wto));
rho_9_a = sigma_9_100*Rho_SL;
A = CDo.*rho.*S.*0.5;
B = (2*k*((0.9*wto*1000)^2))./(rho.*S);
h_abs_9 = height(1388);
sigma = rho./Rho_SL;
v = [];
for i=1:1388
    v1 = sqrt(((Tasl*1000*sigma(i))+sqrt(((Tasl*1000*sigma(i))^2)-(4*A(i)*B(i))))/(2*A(i)));
    v = [v v1];
end
for i=1:1388
    v2 = sqrt(((Tasl*1000*sigma(i))-sqrt(((Tasl*1000*sigma(i))^2)-(4*A(i)*B(i))))/(2*A(i)));
    v = [v v2];
end

% Boundaries
v_stall_9 = ((2*0.9*wto*1000)./(rho(1:1190).*S.*CLmax)).^0.5;
v_crit_9 = 0.895*a(1:1320);

% Plot
```

```
hold on
plot(v(1:1388),height(1:1388),'Color','magenta','LineWidth',1.2)
plot(v(1389:2776),height(1:1388),'Color','magenta','LineWidth',1.2)
plot(v_stall_9,height(1:1190),'Color','blue','LineWidth',1.5)
plot(v_crit_9,height(1:1320),'Color','red','LineWidth',1.5)
plot(v_q(1:885),height(1:885),'Color','green','LineWidth',1.3)
plot([0 350],[h_abs_9 h_abs_9],'--','Color',"black",'LineWidth',1.1)

% Text
text(100,h_abs_9+200,'Absolute Ceiling = 13870 m','Interpreter','latex','FontSize',20,'Rotation',0)

% 0.9 WTO and 95% Throttle
sigma_9_95 = (2*(k*CDo)^0.5)/(Tasl*0.95/(0.9*wto));
rho_9_a_1 = sigma_9_95*Rho_SL;
A = CDo.*rho.*S.*0.5;
B = (2*k*((0.9*wto*1000)^2))./(rho.*S);
h_abs_9_1 = 13540;
sigma = rho./Rho_SL;
v = [];
for i=1:1360
    v1 = sqrt(((Tasl*0.95*1000*sigma(i))+sqrt(((Tasl*0.95*1000*sigma(i))^2)-(4*A(i)*B(i))))/(2*A(i)));
    v = [v v1];
end
for i=1:1360
    v2 = sqrt(((Tasl*0.95*1000*sigma(i))-sqrt(((Tasl*0.95*1000*sigma(i))^2)-(4*A(i)*B(i))))/(2*A(i)));
    v = [v v2];
end

% Boundaries
v_stall_9 = ((2*0.9*wto*1000)./(rho(1:1150).*S.*CLmax)).^0.5;
v_crit_9 = 0.895*a(1:1300);

% Plot

plot(v(1:1360),height(1:1360),'Color','cyan','LineWidth',1.2)
plot(v(1361:2720),height(1:1360),'Color','cyan','LineWidth',1.2)
plot(v_stall_9,height(1:1150),'Color','blue','LineWidth',1.5)
plot(v_crit_9,height(1:1300),'Color','red','LineWidth',1.5)
plot(v_q(1:840),height(1:840),'Color','green','LineWidth',1.3)
plot([0 350],[h_abs_9_1 h_abs_9_1],'--','Color',"black",'LineWidth',1.1)
% Text
text(100,h_abs_9_1-200,'Absolute Ceiling = 13540 m','Interpreter','latex','FontSize',20,'Rotation',0)

% 0.9 WTO and 82.5% Throttle
sigma_9_82 = (2*(k*CDo)^0.5)/(Tasl*0.825/(0.9*wto));
rho_9_a_2 = sigma_9_82*Rho_SL;
A = CDo.*rho.*S.*0.5;
B = (2*k*((0.9*wto*1000)^2))./(rho.*S);
h_abs_9_2 = 12650;
sigma = rho./Rho_SL;
v = [];
for i=1:1270
    v1 = sqrt(((Tasl*0.825*1000*sigma(i))+sqrt(((Tasl*0.825*1000*sigma(i))^2)-(4*A(i)*B(i))))/(2*A(i)));
    v = [v v1];
end
for i=1:1270
    v2 = sqrt(((Tasl*0.825*1000*sigma(i))-sqrt(((Tasl*0.825*1000*sigma(i))^2)-(4*A(i)*B(i))))/(2*A(i)));
    v = [v v2];
end

% Boundaries
v_stall_9 = ((2*0.9*wto*1000)./(rho(1:1060).*S.*CLmax)).^0.5;
v_crit_9 = 0.895*a(1:1230);

% Plot
```

```
plot(v(1:1270),height(1:1270),'Color','#808000','LineWidth',1.2)
plot(v(1271:2540),height(1:1270),'Color','#808000','LineWidth',1.2)
plot(v_stall_9,height(1:1060),'Color','blue','LineWidth',1.5)
plot(v_crit_9,height(1:1230),'Color','red','LineWidth',1.5)
plot(v_q(1:720),height(1:720),'Color','green','LineWidth',1.3)
plot([0 325],[h_abs_9_2 h_abs_9_2],'--','Color',"black",'LineWidth',1.1)

% Text
text(100,h_abs_9_2-200,'Absolute Ceiling = 12650 m','Interpreter','latex','FontSize',20,'Rotation',0)

% 0.9 WTO and 70% Throttle
% Calculations
sigma_9_7 = (2*(k*CDo)^0.5)/(Tasl*0.7/(0.9*wto));
rho_9_a_3 = sigma_9_7*Rho_SL;
A = CDo.*rho.*S.*0.5;
B = (2*k*((0.9*wto*1000)^2))./(rho.*S);
h_abs_9_3 = 11610;
sigma = rho./Rho_SL;
v = [];
for i=1:1165
    v1 = sqrt(((Tasl*0.7*1000*sigma(i))+sqrt(((Tasl*0.7*1000*sigma(i))^2)-(4*A(i)*B(i))))/(2*A(i)));
    v = [v v1];
end
for i=1:1165
    v2 = sqrt(((Tasl*0.7*1000*sigma(i))-sqrt(((Tasl*0.7*1000*sigma(i))^2)-(4*A(i)*B(i))))/(2*A(i)));
    v = [v v2];
end

% Boundaries
v_stall_9 = ((2*0.9*wto*1000)./(rho(1:925).*S.*CLmax)).^0.5;
v_crit_9 = 0.895*a(1:1150);

% Plot

title("\textbf{Combined V-h Plot for 0.9 $W_{TO}$ and Various Throttle Settings}", ...
    "Interpreter","latex",'FontSize',30)
plot(v(1:1165),height(1:1165),'Color','#FFA500','LineWidth',1.2)
plot(v(1166:2330),height(1:1165),'Color','#FFA500','LineWidth',1.2)
plot(v_stall_9,height(1:925),'Color','blue','LineWidth',1.5)
plot(v_crit_9,height(1:1150),'Color','red','LineWidth',1.5)
plot(v_q(1:575),height(1:575),'Color','green','LineWidth',1.3)
plot([0 300],[h_abs_9_3 h_abs_9_3],'--','Color',"black",'LineWidth',1.1)
xlabel("Velocity (m/s)",'Interpreter','latex','FontSize',25)
ylabel("Altitude (m)",'Interpreter','latex','FontSize',25)

% Text
text(112,3300,'Stall Boundary','Interpreter','latex','FontSize',20,'Rotation',70)
text(315,1600,'Aeroelastic Boundary ($q_{max}$)','Interpreter','latex','FontSize',20,'Rotation',47)
text(180,6200,'Flight Envelope','Interpreter','latex','FontSize',30,'Rotation',0)
text(284,7000,'Critical Velocity Boundary','Interpreter','latex','FontSize',20,'Rotation',-79)
text(75,h_abs_9_3+200,'Absolute Ceiling = 11610 m','Interpreter','latex','FontSize',20,'Rotation',0)
hold off
ax = gca;
ax.TickDir = 'out';
ax.TickLength = [0.005 0.005];
grid on
ylim([0 15000])
xticks(25:25:500)
yticks(0:1000:15000)
set(gcf, 'Position', get(0,'ScreenSize'));
set(gca,'Box','on');
ax = gca;
ax.TickDir = 'out';
ax.FontSize = 20;
```

```
ax.TickLength = [0.005 0.005];
%% PLOT 3
%% INITIALISATION
%% V_stall Calculation
% 0.9 WTO
V_stall_1_9_t = ((2*0.9*WTO)/(rho_1*S*0.9*CLmax_HLD_part))^0.5;
V_stall_2_9_t = ((2*0.9*WTO)/(rho_2*S*0.9*CLmax_HLD_part))^0.5;
V_stall_3_9_t = ((2*0.9*WTO)/(rho_3*S*0.9*CLmax_HLD_part))^0.5;
V_stall_4_9_t = ((2*0.9*WTO)/(rho_4*S*0.9*CLmax_HLD_part))^0.5;
V_stall_5_9_t = ((2*0.9*WTO)/(rho_5*S*0.9*CLmax_HLD_part))^0.5;
V_stall_6_9_t = ((2*0.9*WTO)/(rho_6*S*0.9*CLmax_HLD_part))^0.5;
% 0.8 WTO
V_stall_1_8_t = ((2*0.8*WTO)/(rho_1*S*0.9*CLmax_HLD_part))^0.5;
V_stall_2_8_t = ((2*0.8*WTO)/(rho_2*S*0.9*CLmax_HLD_part))^0.5;
V_stall_3_8_t = ((2*0.8*WTO)/(rho_3*S*0.9*CLmax_HLD_part))^0.5;
V_stall_4_8_t = ((2*0.8*WTO)/(rho_4*S*0.9*CLmax_HLD_part))^0.5;
V_stall_5_8_t = ((2*0.8*WTO)/(rho_5*S*0.9*CLmax_HLD_part))^0.5;
V_stall_6_8_t = ((2*0.8*WTO)/(rho_6*S*0.9*CLmax_HLD_part))^0.5;
%% THRUST DATA
t_1 = sigma_1*4*350*1000;
t_2 = sigma_1*4*350*1000;
t_3 = sigma_1*4*350*1000;
t_4 = sigma_1*4*350*1000;
t_5 = sigma_1*4*350*1000;
t_6 = sigma_1*4*350*1000;
t_sl = 4*350*1000;
%% Calculations
% Sea Level and 0.9 WTO
P_avb_0_9 = t_sl.*V;
P_reqd_0_9 = D_0_9.*V;
Delta_P_0_9 = P_avb_0_9 - P_reqd_0_9;
ROC_0_9 = Delta_P_0_9./(0.9*WTO);

% Sea Level and 0.8 WTO
P_avb_0_8 = t_sl.*V;
P_reqd_0_8 = D_0_8.*V;
Delta_P_0_8 = P_avb_0_8 - P_reqd_0_8;
ROC_0_8 = Delta_P_0_8./(0.8*WTO);

% Alt 1 and 0.9 WTO
P_avb_1_9 = t_1.*V;
P_reqd_1_9 = D_1_9.*V;
Delta_P_1_9 = P_avb_1_9 - P_reqd_1_9;
ROC_1_9 = Delta_P_1_9./(0.9*WTO);

% Alt 1 and 0.8 WTO
P_avb_1_8 = t_1.*V;
P_reqd_1_8 = D_1_8.*V;
Delta_P_1_8 = P_avb_1_8 - P_reqd_1_8;
ROC_1_8= Delta_P_1_8./(0.8*WTO);

% Alt 2 and 0.9 WTO
P_avb_2_9 = t_2.*V;
P_reqd_2_9 = D_2_9.*V;
Delta_P_2_9 = P_avb_2_9 - P_reqd_2_9;
ROC_2_9 = Delta_P_2_9./(0.9*WTO);

% Alt 2 and 0.8 WTO
P_avb_2_8 = t_2.*V;
P_reqd_2_8 = D_2_8.*V;
Delta_P_2_8 = P_avb_2_8 - P_reqd_2_8;
ROC_2_8= Delta_P_2_8./(0.8*WTO);

% Alt 3 and 0.9 WTO
P_avb_3_9 = t_3.*V;
```

```
P_reqd_3_9 = D_3_9.*V;
Delta_P_3_9 = P_avb_3_9 - P_reqd_3_9;
ROC_3_9 = Delta_P_3_9./(0.9*WTO);

% Alt 3 and 0.8 WTO
P_avb_3_8 = t_3.*V;
P_reqd_3_8 = D_3_8.*V;
Delta_P_3_8 = P_avb_3_8 - P_reqd_3_8;
ROC_3_8= Delta_P_3_8./(0.8*WTO);

% Alt 4 and 0.9 WTO
P_avb_4_9 = t_4.*V;
P_reqd_4_9 = D_4_9.*V;
Delta_P_4_9 = P_avb_4_9 - P_reqd_4_9;
ROC_4_9 = Delta_P_4_9./(0.9*WTO);

% Alt 4 and 0.8 WTO
P_avb_4_8 = t_4.*V;
P_reqd_4_8 = D_4_8.*V;
Delta_P_4_8 = P_avb_4_8 - P_reqd_4_8;
ROC_4_8= Delta_P_4_8./(0.8*WTO);

% Alt 5 and 0.9 WTO
P_avb_5_9 = t_5.*V;
P_reqd_5_9 = D_5_9.*V;
Delta_P_5_9 = P_avb_5_9 - P_reqd_5_9;
ROC_5_9 = Delta_P_5_9./(0.9*WTO);

% Alt 5 and 0.8 WTO
P_avb_5_8 = t_5.*V;
P_reqd_5_8 = D_5_8.*V;
Delta_P_5_8 = P_avb_5_8 - P_reqd_5_8;
ROC_5_8= Delta_P_5_8./(0.8*WTO);

% Alt 6 and 0.9 WTO
P_avb_6_9 = t_6.*V;
P_reqd_6_9 = D_6_9.*V;
Delta_P_6_9 = P_avb_6_9 - P_reqd_6_9;
ROC_6_9 = Delta_P_6_9./(0.9*WTO);

% Alt 6 and 0.8 WTO
P_avb_6_8 = t_6.*V;
P_reqd_6_8 = D_6_8.*V;
Delta_P_6_8 = P_avb_6_8 - P_reqd_6_8;
ROC_6_8= Delta_P_6_8./(0.8*WTO);

%% Plotting
%% Plot 0.9 WTO and 6 Altitudes
hold on
title("\textbf{Rate of Climb Plot for 0.9 $W_{TO}$ and Various Altitudes}", ...
    "Interpreter","latex",'FontSize',30)
plot(V,ROC_1_9,'Color','magenta','LineWidth',1.2)
plot(V,ROC_2_9,'Color','blue','LineWidth',1.2)
plot(V,ROC_3_9,'Color',"#D95319",'LineWidth',1.2)
plot(V,ROC_4_9,'Color',"#EDB120",'LineWidth',1.2)
plot(V,ROC_5_9,'Color','green','LineWidth',1.2)
plot(V,ROC_6_9,'Color',"#4DBEEE",'LineWidth',1.2)
% M_crit for legend
plot([Mcrit_1 Mcrit_1],[0 ROC_1_9(278)],'-.','Color',"#008888",'LineWidth',1.3)
% V_stall for legend
plot([V_stall_1_9 V_stall_1_9],[0 ROC_1_9(79)],'-.','Color',"#6600cc",'LineWidth',1.1)
% V_stall lines
plot([V_stall_2_9 V_stall_2_9],[0 ROC_2_9(92)],'-.','Color',"#6600cc",'LineWidth',1.1)
plot([V_stall_3_9 V_stall_3_9],[0 ROC_3_9(109)],'-.','Color',"#6600cc",'LineWidth',1.1)
plot([V_stall_4_9 V_stall_4_9],[0 ROC_4_9(134)],'-.','Color',"#6600cc",'LineWidth',1.1)
```

```
plot([V_stall_5_9 V_stall_5_9],[0 ROC_5_9(154)],'-.','Color',"#6600cc",'LineWidth',1.1)
plot([V_stall_6_9 V_stall_6_9],[0 ROC_6_9(160)],'-.','Color',"#6600cc",'LineWidth',1.1)
% M_crit line
plot([Mcrit_2 Mcrit_2],[0 ROC_2_9(270)],'-.','Color',"#008888",'LineWidth',1.3)
plot([Mcrit_3 Mcrit_3],[0 ROC_3_9(261)],'-.','Color',"#008888",'LineWidth',1.3)
plot([Mcrit_4 Mcrit_4],[0 ROC_4_9(249)],'-.','Color',"#008888",'LineWidth',1.3)
plot([Mcrit_5 Mcrit_5],[0 ROC_5_9(242)],'-.','Color',"#008888",'LineWidth',1.3)
plot([Mcrit_6 Mcrit_6],[0 ROC_6_9(240)],'-.','Color',"#008888",'LineWidth',1.3)
hold off
xlabel("Velocity (m/s)",'Interpreter','latex','FontSize',25)
ylabel("Rate of Climb (m/s)",'Interpreter','latex','FontSize',25)
leg1 = legend("0.5 Km","3 Km","5.5 Km","8.5 Km","10.5 Km","11.5 Km","$V_{crit}$", ...
    "$V_{stall}$",'Interpreter','latex','Location','northwest','FontSize',20);
title(leg1,'Legend')
ylim([5 50])
xlim([50 325])
xticks(45:15:325)
ax = gca;
ax.TickDir = 'out';
ax.TickLength = [0.005 0.005];
grid on
set(gcf, 'Position', get(0,'ScreenSize'));
set(gca,'Box','on');
ax = gca;
ax.TickDir = 'out';
ax.FontSize = 20;
ax.TickLength = [0.005 0.005];
%% Plot 0.8 WTO and 6 Altitudes
hold on
title("\textbf{Rate of Climb Plot for 0.8 $W_{TO}$ and Various Altitudes}", ...
    "Interpreter","latex",'FontSize',30)
plot(V,ROC_1_8,'Color','magenta','LineWidth',1.2)
plot(V,ROC_2_8,'Color','blue','LineWidth',1.2)
plot(V,ROC_3_8,'Color',"#D95319",'LineWidth',1.2)
plot(V,ROC_4_8,'Color',"#EDB120",'LineWidth',1.2)
plot(V,ROC_5_8,'Color','green','LineWidth',1.2)
plot(V,ROC_6_8,'Color',"#4DBEEE",'LineWidth',1.2)
% M_crit for legend
plot([Mcrit_1 Mcrit_1],[0 ROC_1_8(278)],'-.','Color',"#008888",'LineWidth',1.3)
% V_stall for legend
plot([V_stall_1_9 V_stall_1_9],[0 ROC_1_8(80)],'-.','Color',"#6600cc",'LineWidth',1.1)
% V_stall lines
plot([V_stall_2_9 V_stall_2_9],[0 ROC_2_8(93)],'-.','Color',"#6600cc",'LineWidth',1.1)
plot([V_stall_3_9 V_stall_3_9],[0 ROC_3_8(110)],'-.','Color',"#6600cc",'LineWidth',1.1)
plot([V_stall_4_9 V_stall_4_9],[0 ROC_4_8(134)],'-.','Color',"#6600cc",'LineWidth',1.1)
plot([V_stall_5_9 V_stall_5_9],[0 ROC_5_8(155)],'-.','Color',"#6600cc",'LineWidth',1.1)
plot([V_stall_6_9 V_stall_6_9],[0 ROC_6_8(161)],'-.','Color',"#6600cc",'LineWidth',1.1)
% M_crit line
plot([Mcrit_2 Mcrit_2],[0 ROC_2_8(270)],'-.','Color',"#008888",'LineWidth',1.3)
plot([Mcrit_3 Mcrit_3],[0 ROC_3_8(261)],'-.','Color',"#008888",'LineWidth',1.3)
plot([Mcrit_4 Mcrit_4],[0 ROC_4_8(248)],'-.','Color',"#008888",'LineWidth',1.3)
plot([Mcrit_5 Mcrit_5],[0 ROC_5_8(242)],'-.','Color',"#008888",'LineWidth',1.3)
plot([Mcrit_6 Mcrit_6],[0 ROC_6_8(240)],'-.','Color',"#008888",'LineWidth',1.3)
hold off
xlabel("Velocity (m/s)",'Interpreter','latex','FontSize',25)
ylabel("Rate of Climb (m/s)",'Interpreter','latex','FontSize',25)
leg1 = legend("0.5 Km","3 Km","5.5 Km","8.5 Km","10.5 Km","11.5 Km","$V_{crit}$", ...
    "$V_{stall}$",'Interpreter','latex','Location','northwest','FontSize',20);
title(leg1,'Legend')
ylim([15 50])
xlim([75 325])
xticks(45:15:325)
ax = gca;
ax.TickDir = 'out';
ax.TickLength = [0.005 0.005];
```

```
grid on
set(gcf, 'Position', get(0,'ScreenSize'));
set(gca,'Box','on');
ax = gca;
ax.TickDir = 'out';
ax.FontSize = 20;
ax.TickLength = [0.005 0.005];
%% R/C Max Calculation
[ROC_max_0_9,indexr_0_9] = max(ROC_0_9);
[ROC_max_1_9,indexr_1_9] = max(ROC_1_9);
[ROC_max_2_9,indexr_2_9] = max(ROC_2_9);
[ROC_max_3_9,indexr_3_9] = max(ROC_3_9);
[ROC_max_4_9,indexr_4_9] = max(ROC_4_9);
[ROC_max_5_9,indexr_5_9] = max(ROC_5_9);
[ROC_max_6_9,indexr_6_9] = max(ROC_6_9);

[ROC_max_0_8,indexr_0_8] = max(ROC_0_8);
[ROC_max_1_8,indexr_1_8] = max(ROC_1_8);
[ROC_max_2_8,indexr_2_8] = max(ROC_2_8);
[ROC_max_3_8,indexr_3_8] = max(ROC_3_8);
[ROC_max_4_8,indexr_4_8] = max(ROC_4_8);
[ROC_max_5_8,indexr_5_8] = max(ROC_5_8);
[ROC_max_6_8,indexr_6_8] = max(ROC_6_8);

ROC_Best_9 = (ROC_max_1_9+ROC_max_6_9)/2;
ROC_Best_8 = (ROC_max_1_8+ROC_max_6_8)/2;

V_Best_9 = (V(indexr_1_9)+V(indexr_6_9))/2;
V_Best_8 = (V(indexr_1_8)+V(indexr_6_8))/2;
%% Plot for R/C MAX 0.9 WTO

hold on
title("Rate of Climb Plot $(R/C)_{max}$ for 0.9 $W_{TO}$ and Various Altitudes", ...
    "Interpreter","latex",'FontSize',20)
plot(V,ROC_1_9,'Color','magenta','LineWidth',1.2)
plot(V,ROC_2_9,'Color','blue','LineWidth',1.2)
plot(V,ROC_3_9,'Color',"#D95319",'LineWidth',1.2)
plot(V,ROC_4_9,'Color',"#EDB120",'LineWidth',1.2)
plot(V,ROC_5_9,'Color','green','LineWidth',1.2)
plot(V,ROC_6_9,'Color',"#4DBEEE",'LineWidth',1.2)
% M_crit for legend
plot([Mcrit_1 Mcrit_1],[0 ROC_1_9(278)],'-.','Color',"#008888",'LineWidth',1.3)
% V_stall for legend
plot([V_stall_1_9 V_stall_1_9],[0 ROC_1_9(79)],'-.','Color',"#6600cc",'LineWidth',1.1)
% R/C Max line
plot([V(indexr_1_9) V(indexr_2_9) V(indexr_3_9) V(indexr_4_9) V(indexr_5_9) V(indexr_6_9)], ...
    [ROC_max_1_9 ROC_max_2_9 ROC_max_3_9 ROC_max_4_9 ROC_max_5_9 ROC_max_6_9],'Color',"black", ...
    'LineWidth',1.5,'LineStyle','-.','Marker','o','MarkerSize',3.5,'MarkerFaceColor','r')
% V_best
plot([V_Best_9 V_Best_9],[ROC_max_6_9 ROC_max_1_9],'Color',"blue",'LineWidth',1.5)
% ROC_Best
plot([0 V_Best_9],[ROC_Best_9 ROC_Best_9],'--','Color',"#A020F0",'LineWidth',1.3)
% V_stall lines
plot([V_stall_2_9 V_stall_2_9],[0 ROC_2_9(92)],'-.','Color',"#6600cc",'LineWidth',1.1)
plot([V_stall_3_9 V_stall_3_9],[0 ROC_3_9(109)],'-.','Color',"#6600cc",'LineWidth',1.1)
plot([V_stall_4_9 V_stall_4_9],[0 ROC_4_9(134)],'-.','Color',"#6600cc",'LineWidth',1.1)
plot([V_stall_5_9 V_stall_5_9],[0 ROC_5_9(154)],'-.','Color',"#6600cc",'LineWidth',1.1)
plot([V_stall_6_9 V_stall_6_9],[0 ROC_6_9(160)],'-.','Color',"#6600cc",'LineWidth',1.1)
% M_crit line
plot([Mcrit_2 Mcrit_2],[0 ROC_2_9(270)],'-.','Color',"#008888",'LineWidth',1.3)
plot([Mcrit_3 Mcrit_3],[0 ROC_3_9(261)],'-.','Color',"#008888",'LineWidth',1.3)
plot([Mcrit_4 Mcrit_4],[0 ROC_4_9(249)],'-.','Color',"#008888",'LineWidth',1.3)
plot([Mcrit_5 Mcrit_5],[0 ROC_5_9(242)],'-.','Color',"#008888",'LineWidth',1.3)
plot([Mcrit_6 Mcrit_6],[0 ROC_6_9(240)],'-.','Color',"#008888",'LineWidth',1.3)
text(260,41.5,'Best Speed for Climb = 294 m/s','Interpreter','latex','FontSize',15)
```

```
text(195,39.5,'Best (R/C) = 38.4 m/s','Interpreter','latex','FontSize',15)
hold off
xlabel("Velocity (m/s)",'Interpreter','latex','FontSize',17)
ylabel("Rate of Climb (m/s)",'Interpreter','latex','FontSize',17)
leg1 = legend("0.5 Km","3 Km","5.5 Km","8.5 Km","10.5 Km","11.5 Km","$V_{crit}$","$V_{stall}$", ...
    "$(R/C)_{max}$","Best Speed For Climb","Best (R/C)",'Interpreter','latex','Location','west', ...
    'FontSize',16);
title(leg1,'Legend')
ylim([5 50])
xlim([50 325])
xticks(45:15:325)
ax = gca;
ax.TickDir = 'out';
ax.TickLength = [0.005 0.005];
grid on
set(gcf, 'Position', get(0,'ScreenSize'));
set(gca,'Box','on');
ax = gca;
ax.TickDir = 'out';
ax.FontSize = 20;
ax.TickLength = [0.005 0.005];
%% Plot R/C Max at 0.8 WTO
hold on
title("\textbf{Rate of Climb Plot $(R/C)_{max}$ for 0.8 $W_{TO}$ and Various Altitudes}", ...
    "Interpreter","latex",'FontSize',30)
plot(V,ROC_1_8,'Color','magenta','LineWidth',1.2)
plot(V,ROC_2_8,'Color','blue','LineWidth',1.2)
plot(V,ROC_3_8,'Color',"#D95319",'LineWidth',1.2)
plot(V,ROC_4_8,'Color',"#EDB120",'LineWidth',1.2)
plot(V,ROC_5_8,'Color','green','LineWidth',1.2)
plot(V,ROC_6_8,'Color',"#4DBEEE",'LineWidth',1.2)
% M_crit for legend
plot([Mcrit_1 Mcrit_1],[0 ROC_1_8(278)],'-.','Color',"#008888",'LineWidth',1.3)
% V_stall for legend
plot([V_stall_1_9 V_stall_1_9],[0 ROC_1_8(80)],'-.','Color',"#6600cc",'LineWidth',1.1)
% R/C Max line
plot([V(indexr_1_8) V(indexr_2_8) V(indexr_3_8) V(indexr_4_8) V(indexr_5_8) V(indexr_6_8)], ...
    [ROC_max_1_8 ROC_max_2_8 ROC_max_3_8 ROC_max_4_8 ROC_max_5_8 ROC_max_6_8],'Color',"black", ...
    'LineWidth',1.5,'LineStyle','-.','Marker','o','MarkerSize',3.5,'MarkerFaceColor','r')
% V_best
plot([V_Best_8 V_Best_8],[ROC_max_6_8 ROC_max_1_8],'Color',"blue",'LineWidth',1.5)
% ROC_Best
plot([0 V_Best_8],[ROC_Best_8 ROC_Best_8],'--','Color',"#A020F0",'LineWidth',1.3)
% V_stall lines
plot([V_stall_2_9 V_stall_2_9],[0 ROC_2_8(93)],'-.','Color',"#6600cc",'LineWidth',1.1)
plot([V_stall_3_9 V_stall_3_9],[0 ROC_3_8(110)],'-.','Color',"#6600cc",'LineWidth',1.1)
plot([V_stall_4_9 V_stall_4_9],[0 ROC_4_8(134)],'-.','Color',"#6600cc",'LineWidth',1.1)
plot([V_stall_5_9 V_stall_5_9],[0 ROC_5_8(155)],'-.','Color',"#6600cc",'LineWidth',1.1)
plot([V_stall_6_9 V_stall_6_9],[0 ROC_6_8(161)],'-.','Color',"#6600cc",'LineWidth',1.1)
% M_crit line
plot([Mcrit_2 Mcrit_2],[0 ROC_2_8(270)],'-.','Color',"#008888",'LineWidth',1.3)
plot([Mcrit_3 Mcrit_3],[0 ROC_3_8(261)],'-.','Color',"#008888",'LineWidth',1.3)
plot([Mcrit_4 Mcrit_4],[0 ROC_4_8(248)],'-.','Color',"#008888",'LineWidth',1.3)
plot([Mcrit_5 Mcrit_5],[0 ROC_5_8(242)],'-.','Color',"#008888",'LineWidth',1.3)
plot([Mcrit_6 Mcrit_6],[0 ROC_6_8(240)],'-.','Color',"#008888",'LineWidth',1.3)
text(260,47,'Best Speed for Climb = 293 m/s','Interpreter','latex','FontSize',20)
text(195,45,'Best (R/C) = 44.1 m/s','Interpreter','latex','FontSize',15)
hold off
xlabel("Velocity (m/s)",'Interpreter','latex','FontSize',25)
ylabel("Rate of Climb (m/s)",'Interpreter','latex','FontSize',25)
leg1 = legend("0.5 Km","3 Km","5.5 Km","8.5 Km","10.5 Km","11.5 Km","$V_{crit}$","$V_{stall}$", ...
    "$(R/C)_{max}$","Best Speed For Climb","Best (R/C)",'Interpreter','latex','Location','west', ...
    'FontSize',20);
title(leg1,'Legend')
ylim([15 50])
```

```
xlim([75 325])
xticks(45:15:325)
ax = gca;
ax.TickDir = 'out';
ax.TickLength = [0.005 0.005];
grid on
set(gcf, 'Position', get(0,'ScreenSize'));
set(gca,'Box','on');
ax = gca;
ax.TickDir = 'out';
ax.FontSize = 20;
ax.TickLength = [0.005 0.005];
%% %% h v/s R/C Max Calculation
alt = [500 3000 5500 8500 10500 11500];
ROC_max_9 = [ROC_max_1_9 ROC_max_2_9 ROC_max_3_9 ROC_max_4_9 ROC_max_5_9 ROC_max_6_9];
ROC_max_8 = [ROC_max_1_8 ROC_max_2_8 ROC_max_3_8 ROC_max_4_8 ROC_max_5_8 ROC_max_6_8];
x = 0:0.5:50;
m1 = -1*h_abs_9/ROC_max_0_9;
y1 = m1*x + h_abs_9;
m2 = -1*h_abs_8/ROC_max_0_8;
y2 = m2*x + h_abs_8;
%% Service Ceiling 0.9 WTO
rho1 = ((-0.5 +((V_Best_9*t_sl)/(0.9*WTO))) + sqrt(((0.5-(V_Best_9*t_sl)/(0.9*WTO)))^2 - ...
    (4*k*V_Best_9^2*CDo)))/(((V_Best_9^3)*S*CDo)/(0.9*WTO));
rho2 = ((-0.5 + ((V_Best_9*t_sl)/(0.9*WTO))) - sqrt(((0.5-(V_Best_9*t_sl)/(0.9*WTO)))^2 - ...
    (4*k*V_Best_9^2*CDo)))/(((V_Best_9^3)*S*CDo)/(0.9*WTO));
%% Service Ceiling 0.8 WTO
rho1 = ((-0.5 +((V_Best_9*t_sl)/(0.8*WTO))) + sqrt(((0.5-(V_Best_9*t_sl)/(0.8*WTO)))^2 - ...
    (4*k*V_Best_9^2*CDo)))/(((V_Best_9^3)*S*CDo)/(0.8*WTO));
rho2 = ((-0.5 + ((V_Best_9*t_sl)/(0.8*WTO))) - sqrt(((0.5-(V_Best_9*t_sl)/(0.8*WTO)))^2 - ...
    (4*k*V_Best_9^2*CDo)))/(((V_Best_9^3)*S*CDo)/(0.8*WTO));
%% h v/s R/C Max Plot 0.9 WTO
hold on
title("\textbf{Rate of Climb Plot $(R/C)_{max}$ for 0.9 $W_{TO}$ and Various Altitudes}", ...
    "Interpreter","latex",'FontSize',30)
plot(x,y1,'Color',"red",'LineWidth',1.3)
plot([2.5 0],[h_abs_9 h_abs_9],'-.','Color',"#FFA500",'LineWidth',1.3)
plot([0.5 0.5],[0 13707.1],'-.','Color',"blue",'LineWidth',1.3)
plot([42.5 42.5],[0 1000],'-.','Color',"magenta",'LineWidth',1.3)
plot([2.5 0],[13707.1 13707.1],'-.','Color',"blue",'LineWidth',1.3)
text(3,h_abs_9+200,'Absolute Ceiling = 13870 m (Rate of Climb at Absolute Ceiling = 0 m/s)', ...
    'Interpreter','latex','FontSize',20)
text(3,13700,'Service Ceiling = 13707.1 m','Interpreter','latex','FontSize',20)
text(42.5,1200,'Rate of Climb at SL = 42.58 m/s','Interpreter','latex','FontSize',20,'Rotation',90)
text(1.5,3000,'Rate of Climb at Service Ceiling = 0.5 m/s','Interpreter','latex', ...
    'FontSize',20,'Rotation',90)
hold off
ylabel("Altitude (m)",'Interpreter','latex','FontSize',25)
xlabel("Rate of Climb (m/s)",'Interpreter','latex','FontSize',25)
xlim([0 45])
ylim([0 15000])
yticks(0:1000:15000)
xticks(2.5:2.5:45)
ax = gca;
ax.TickDir = 'out';
ax.TickLength = [0.005 0.005];
grid on
set(gcf, 'Position', get(0,'ScreenSize'));
set(gca,'Box','on');
ax = gca;
ax.TickDir = 'out';
ax.FontSize = 20;
ax.TickLength = [0.005 0.005];
%% h v/s R/C Max Plot 0.8 WTO
hold on
```

```matlab
title("\textbf{Rate of Climb Plot $(R/C)_{max}$ for 0.8 $W_{TO}$ and Various Altitudes}", ...
    "Interpreter","latex",'FontSize',30)
plot(x,y2,'Color',"red",'LineWidth',1.3)
plot([2.5 0],[h_abs_8 h_abs_8],'-.','Color',"#FFA500",'LineWidth',1.3)
plot([0.5 0.5],[0 14468.7],'-.','Color',"blue",'LineWidth',1.3)
plot([48.3 48.3],[0 1000],'-.','Color',"magenta",'LineWidth',1.3)
plot([2.5 0],[14468.7 14468.7],'-.','Color',"blue",'LineWidth',1.3)
text(4,h_abs_8+200,'Absolute Ceiling = 13870 m (Rate of Climb at Absolute Ceiling = 0 m/s)', ...
    'Interpreter','latex','FontSize',20)
text(4,14300,'Service Ceiling = 14468.7 m','Interpreter','latex','FontSize',20)
text(48.3,1200,'Rate of Climb at SL = 48.32 m/s','Interpreter','latex', ...
    'FontSize',20,'Rotation',90)
text(1.5,3000,'Rate of Climb at Service Ceiling = 0.5 m/s','Interpreter','latex', ...
    'FontSize',20,'Rotation',90)
hold off
ylabel("Altitude (m)",'Interpreter','latex','FontSize',25)
xlabel("Rate of Climb (m/s)",'Interpreter','latex','FontSize',25)
xlim([0 50])
ylim([0 16000])
yticks(0:1000:16000)
xticks(2.5:2.5:50)
ax = gca;
ax.TickDir = 'out';
ax.TickLength = [0.005 0.005];
grid on
set(gcf, 'Position', get(0,'ScreenSize'));
set(gca,'Box','on');
ax = gca;
ax.TickDir = 'out';
ax.FontSize = 20;
ax.TickLength = [0.005 0.005];
%% Variation of Thrust with Altitude for 0.9 WTO
sigma = rho(1:1501)./Rho_SL;
Thrust = Tasl*1000.*sigma;
hold on
title("\textbf{Variation of Thrust with Altitude for 0.9 $W_{TO}$}", ...
    "Interpreter","latex",'FontSize',30)
plot(height(1:1501),Thrust,'Color',"blue",'LineWidth',1.5)
xlabel("Altitude (m)",'Interpreter','latex','FontSize',20)
ylabel("Thrust (N)",'Interpreter','latex','FontSize',20)
hold off
xlim([0 15000])
xticks(0:1500:15000)
ax = gca;
ax.TickDir = 'out';
ax.TickLength = [0.005 0.005];
grid on
set(gcf, 'Position', get(0,'ScreenSize'));
set(gca,'Box','on');
ax = gca;
ax.TickDir = 'out';
ax.FontSize = 20;
ax.TickLength = [0.005 0.005];
%% Variation of TSFC with Altitude for 0.9 WTO
Theta = T./T_SL;
TSFC = 47.5*sqrt(Theta);
hold on
title("\textbf{Variation of Thrust Specific Fuel Consumption (TSFC) with Altitude for 0.9 $W_{TO}$}", ...
    "Interpreter","latex",'FontSize',30)
plot(height,TSFC,'Color',"blue",'LineWidth',1.5)
xlabel("Altitude (m)",'Interpreter','latex','FontSize',25)
ylabel("Thrust Specific Fuel Consumption (TSFC) ($\frac{kg}{hr kN}$)", ...
    'Interpreter','latex','FontSize',25)
hold off
xlim([0 15000])
```

```
xticks(0:1500:15000)
ax = gca;
ax.TickDir = 'out';
ax.TickLength = [0.005 0.005];
grid on
set(gcf, 'Position', get(0,'ScreenSize'));
set(gca,'Box','on');
ax = gca;
ax.TickDir = 'out';
ax.FontSize = 20;
ax.TickLength = [0.005 0.005];
%% Time to Climb and Fuel to Climb using for loop
h = 11500;
H = 0:10:11500;
del_h = 10;
W = [];
V_crit_9 = 0.895*a(1:1150);
W(1) = 0.9*WTO;
tc=0;
TC = [];
TC(1) = 0;
DEL_W = [];
Del_W = 0;
DEL_W(1) = 0;
Sing =[];
roc =[];
for i = 1:1150
    if V_Best_9 ≥ V_crit_9(i)
        q_SL = 0.5*1.225*(V_crit_9(i)^2);
    else
        q_SL = 0.5*1.225*(V_Best_9^2);
    end
    hi = (i)*del_h;
    sigma = (1-(hi/44300))^(1/0.235);
    q = sigma*q_SL;
    theta = (288.16 - (0.0065*hi))/288.16;
    TSFC = TSFC_SL*9.81*sqrt(theta)/(3600*1000);
    Cl = W(i)/(q*S);
    Cd = CDo + (k*(Cl^2));
    D = q*S*Cd;
    sing = ((t_sl*sigma)-D)/(W(i));
    if V_Best_9 ≥ V_crit_9(i)
        ROC = V_crit_9(i)*sing;
    else
        ROC = V_Best_9*sing;
    end
    del_t = del_h/ROC;
    del_W = (t_sl*sigma)*TSFC*del_t;
    W(i+1) = W(i) - del_W;
    tc = tc + del_t;
    TC = [TC tc];
    Del_W = Del_W+del_W;
    DEL_W = [DEL_W Del_W];
    Sing = [Sing sing];
    roc = [roc ROC];
end
tc = tc/60;
TC = TC./60;
%% Time to climb PLOTS
%% SUBPLOT 1
hold on
title("\textbf{Variation of Altitude with Time ($\Sigma\Delta t_i$) for 0.9 $W_{TO}$}", ...
    "Interpreter","latex",'FontSize',30)
plot(TC,H,'Color',"blue",'LineWidth',1.5)
ylabel("Altitude (m)",'Interpreter','latex','FontSize',25)
```

```
xlabel("Time ($\Sigma\Delta t_i$)   (in minutes)",'Interpreter','latex','FontSize',25)
yticks(0:1000:12000)
xticks(1:12)
hold off
ax = gca;
ax.TickDir = 'out';
ax.TickLength = [0.005 0.005];
grid on
set(gcf, 'Position', get(0,'ScreenSize'));
set(gca,'Box','on');
ax = gca;
ax.TickDir = 'out';
ax.FontSize = 20;
ax.TickLength = [0.005 0.005];
%% SUBPLOT 2
hold on
title("\textbf{Variation of Weight ($W_i$ ) with Altitude for 0.9 $W_{TO}$}", ...
    "Interpreter","latex",'FontSize',30)
plot(H,W,'Color',"blue",'LineWidth',1.5)
xlabel("Altitude (m)",'Interpreter','latex','FontSize',25)
ylabel("Weight ($W_i$ ) (N)",'Interpreter','latex','FontSize',25)
xticks(0:1000:12000)
hold off
ax = gca;
ax.TickDir = 'out';
ax.TickLength = [0.005 0.005];
grid on
set(gcf, 'Position', get(0,'ScreenSize'));
set(gca,'Box','on');
ax = gca;
ax.TickDir = 'out';
ax.FontSize = 20;
ax.TickLength = [0.005 0.005];
%% SUBPLOT 3
hold on
title("\textbf{Variation of Change in Weight ( $\Sigma\Delta W_{fi}$ ) with Altitude for 0.9 $W_{TO}$}", ...
    "Interpreter","latex",'FontSize',30)
plot(H,DEL_W,'Color',"blue",'LineWidth',1.5)
xlabel("Altitude (m)",'Interpreter','latex','FontSize',25)
ylabel("Change in Weight ( $\Sigma\Delta W_{fi}$ ) (N)",'Interpreter','latex','FontSize',25)
hold off
ax = gca;
ax.TickDir = 'out';
ax.TickLength = [0.005 0.005];
grid on
set(gcf, 'Position', get(0,'ScreenSize'));
set(gca,'Box','on');
ax = gca;
ax.TickDir = 'out';
ax.FontSize = 20;
ax.TickLength = [0.005 0.005];
%% SUBPLOT 4
hold on
title("\textbf{Variation of sin $\gamma_i$ with Altitude for 0.9 $W_{TO}$}", ...
    "Interpreter","latex",'FontSize',30)
plot(H(1:end-1),Sing,'Color',"blue",'LineWidth',1.5)
xlabel("Altitude (m)",'Interpreter','latex','FontSize',25)
ylabel("sin $\gamma_i$",'Interpreter','latex','FontSize',25)
hold off
ax = gca;
ax.TickDir = 'out';
ax.TickLength = [0.005 0.005];
grid on
set(gcf, 'Position', get(0,'ScreenSize'));
set(gca,'Box','on');
```

```
ax = gca;
ax.TickDir = 'out';
ax.FontSize = 20;
ax.TickLength = [0.005 0.005];
%% SUBPLOT 5
hold on
title("\textbf{Variation of R/C with Altitude for 0.9 $W_{TO}$}","Interpreter","latex",'FontSize',30)
plot(H(1:end-1),roc,'Color',"blue",'LineWidth',1.5)
xlabel("Altitude (m)",'Interpreter','latex','FontSize',25)
ylabel("Rate of Climb (R/C)  (m/s)",'Interpreter','latex','FontSize',25)
hold off
ax = gca;
ax.TickDir = 'out';
ax.TickLength = [0.005 0.005];
grid on
set(gcf, 'Position', get(0,'ScreenSize'));
set(gca,'Box','on');
ax = gca;
ax.TickDir = 'out';
ax.FontSize = 20;
ax.TickLength = [0.005 0.005];
%% PLOT 4
sigma_5km = rho(501)/1.225;
%% Omega - V PLOT
% Calculations subplot 1
V = 0:10:700;
n = 0:0.25:2.5;
V_stall_1_9_turn = sqrt(n)*sqrt(0.9*WTO/(0.5*1.225*sigma_1*S*CLmax));
omega_1_9 = [];
Omega_stall_1_9 =[];
R = 0:2.5:100;
vr = [];
for i =1:11
    Omega = ((9.81.*sqrt((n(i).^2)-1))./V)*180/pi;
    omegastall = ((9.81.*sqrt((n(i).^2)-1))./V_stall_1_9_turn(i))*180/pi;
    omega_1_9 = [omega_1_9 Omega];
    Omega_stall_1_9 = [Omega_stall_1_9 omegastall];
end
Omega_R_1_9 = [];
for i = 1:40
    for j = 1:10
    Omega = ((9.81.*sqrt((n(j).^2)-1))./V)*180/pi;
    Omega_R_1_9 =[Omega_R_1_9 Omega];
    v = Omega*R(i);
    vr =[vr v];
    end
end
v1 = sqrt(((t_sl*sigma_1)+sqrt(((t_sl*sigma_1)^2)-(4*A_1*B_1_9*n.^2)))./(2*A_1));
v2 = sqrt(((t_sl*sigma_1)-sqrt(((t_sl*sigma_1)^2)-(4*A_1*B_1_9*n.^2)))./(2*A_1));
om1 = ((9.81*sqrt((n.^2)-1))./v1)*180/pi;
om2 = ((9.81*sqrt((n.^2)-1))./v2)*180/pi;
%% Plot 0.5 Km and 0.9 WTO
title("\textbf{Turn Performance for 0.9 $W_{TO}$ and Altitude 0.5 Km}", ...
    "Interpreter","latex",'FontSize',30)
xlabel("Mach Number (M)",'Interpreter','latex','FontSize',25)
ylabel("Turn Rate ($\omega$)  ($^\circ/s$)",'Interpreter','latex','FontSize',25)
hold on
grid on
% radius of turn lines
plot(vr(711:1420)./a(500),Omega_R_1_9(711:1420),'Color',"cyan",'LineWidth',0.0001)
plot(vr(1421:2130)./a(500),Omega_R_1_9(1421:2130),'Color',"cyan",'LineWidth',0.0001)
plot(vr(2131:2840)./a(500),Omega_R_1_9(2131:2840),'Color',"cyan",'LineWidth',0.0001)
plot(vr(2841:3550)./a(500),Omega_R_1_9(2841:3550),'Color',"cyan",'LineWidth',0.0001)
plot(vr(3551:4260)./a(500),Omega_R_1_9(3551:4260),'Color',"cyan",'LineWidth',0.0001)
plot(vr(4261:4970)./a(500),Omega_R_1_9(4261:4970),'Color',"cyan",'LineWidth',0.0001)
```

```
plot(vr(4971:5680)./a(500),Omega_R_1_9(4971:5680),'Color',"cyan",'LineWidth',0.0001)
plot(vr(5681:6390)./a(500),Omega_R_1_9(5681:6390),'Color',"cyan",'LineWidth',0.0001)
plot(vr(6391:7100)./a(500),Omega_R_1_9(6391:7100),'Color',"cyan",'LineWidth',0.0001)
plot(vr(7101:7810)./a(500),Omega_R_1_9(7101:7810),'Color',"cyan",'LineWidth',0.0001)
plot(vr(7811:8522)./a(500),Omega_R_1_9(7811:8522),'Color',"cyan",'LineWidth',0.0001)
% load factor lines
plot(V./a(500),omega_1_9(356:426),'Color',"red",'LineWidth',0.0001)
plot(V./a(500),omega_1_9(427:497),'Color',"red",'LineWidth',0.0001)
plot(V./a(500),omega_1_9(498:568),'Color',"red",'LineWidth',0.0001)
plot(V./a(500),omega_1_9(569:639),'Color',"red",'LineWidth',0.0001)
plot(V./a(500),omega_1_9(640:710),'Color',"red",'LineWidth',0.0001)
plot(V./a(500),omega_1_9(711:781),'Color',"red",'LineWidth',3)
% Stall Boundary
plot(V_stall_1_9_turn(5:end)./a(500),Omega_stall_1_9(5:end),'Color',"blue",'LineWidth',1.3)
% Propulsive Boundary
plot(v1(5:11)./a(500),om1(5:11),'Color',"magenta",'LineWidth',1.3)
plot(v2(5:11)./a(500),om2(5:11),'Color',"magenta",'LineWidth',1.3)
% Text and Markers
plot(0.50839,7.9029,'Color',"black",'LineWidth',1.5,'LineStyle','-.','Marker','o', ...
    'MarkerSize',3.5,'MarkerFaceColor','r')
text(0.51,8.5,'Corner Speed','Interpreter','latex','FontSize',20,'Rotation',15)
text(0.075,80,'Maximum Load Factor ($n_{max}$) = 2.5','Interpreter','latex', ...
    'Color',"red",'FontSize',20,'Rotation',-73)
text(0.4,12,'Sustained Turn Rate (STR)','Interpreter','latex','Color',"magenta", ...
    'FontSize',20,'Rotation',13)
text(0.38,2,'$C_{L_{max}}$ Limit','Interpreter','latex','Color',"blue", ...
    'FontSize',20,'Rotation',0)
% Radius of Turn
text(0.48,65,'Radius of Turn = 2.5 m','Interpreter','latex','Color',"#8282ff", ...
    'FontSize',20,'Rotation',45)
text(0.78,52,'Radius of Turn = 5 m','Interpreter','latex','Color',"#8282ff", ...
    'FontSize',20,'Rotation',28)
text(0.9,40,'Radius of Turn = 7.5 m','Interpreter','latex','Color',"#8282ff", ...
    'FontSize',20,'Rotation',20)
text(0.9,30,'Radius of Turn = 10 m','Interpreter','latex','Color',"#8282ff", ...
    'FontSize',20,'Rotation',15)
xlim([0 1.4])
ylim([0 100])
xticks(0.1:0.1:1.4)
hold off
set(gcf, 'Position', get(0,'ScreenSize'));
set(gca,'Box','on');
ax = gca;
ax.TickDir = 'out';
ax.FontSize = 20;
ax.TickLength = [0.005 0.005];
%% Plot 5 Km and 0.9 WTO
% Calculations subplot 2
V = 0:10:700;
n = 0:0.25:2.5;
V_stall_2_9_turn = sqrt(n)*sqrt(0.9*WTO/(0.5*1.225*sigma_5km*S*CLmax));
omega_2_9 = [];
Omega_stall_2_9 =[];
R = 0:2.5:100;
vr = [];
for i =1:11
    Omega = ((9.81.*sqrt((n(i).^2)-1))./V)*180/pi;
    omegastall = ((9.81.*sqrt((n(i).^2)-1))./V_stall_2_9_turn(i))*180/pi;
    omega_2_9 = [omega_2_9 Omega];
    Omega_stall_2_9 = [Omega_stall_2_9 omegastall];
end
Omega_R_2_9 = [];
for i = 1:40
    for j = 1:10
    Omega = ((9.81.*sqrt((n(j).^2)-1))./V)*180/pi;
```

```
        Omega_R_2_9 =[Omega_R_2_9 Omega];
        v = Omega*R(i);
        vr =[vr v];
        end
    end
    v1 = sqrt(((t_sl*sigma_5km)+sqrt(((t_sl*sigma_5km)^2)-(4*A_2*B_2_9*n.^2)))./(2*A_2));
    v2 = sqrt(((t_sl*sigma_5km)-sqrt(((t_sl*sigma_5km)^2)-(4*A_2*B_2_9*n.^2)))./(2*A_2));
    om1 = ((9.81*sqrt((n.^2)-1))./v1)*180/pi;
    om2 = ((9.81*sqrt((n.^2)-1))./v2)*180/pi;
    %% Plot 5 Km and 0.9 WTO
    title("\textbf{Turn Performance for 0.9 $W_{TO}$ and Altitude 5 Km}", ...
        "Interpreter","latex",'FontSize',30)
    xlabel("Mach Number (M)",'Interpreter','latex','FontSize',25)
    ylabel("Turn Rate ($\omega$)  ($^\circ/s$)",'Interpreter','latex','FontSize',25)
    hold on
    grid on
    % radius of turn lines
    plot(vr(711:1420)./a(500),Omega_R_2_9(711:1420),'Color',"cyan",'LineWidth',0.0001)
    plot(vr(1421:2130)./a(500),Omega_R_2_9(1421:2130),'Color',"cyan",'LineWidth',0.0001)
    plot(vr(2131:2840)./a(500),Omega_R_2_9(2131:2840),'Color',"cyan",'LineWidth',0.0001)
    plot(vr(2841:3550)./a(500),Omega_R_2_9(2841:3550),'Color',"cyan",'LineWidth',0.0001)
    plot(vr(3551:4260)./a(500),Omega_R_2_9(3551:4260),'Color',"cyan",'LineWidth',0.0001)
    plot(vr(4261:4970)./a(500),Omega_R_2_9(4261:4970),'Color',"cyan",'LineWidth',0.0001)
    plot(vr(4971:5680)./a(500),Omega_R_2_9(4971:5680),'Color',"cyan",'LineWidth',0.0001)
    plot(vr(5681:6390)./a(500),Omega_R_2_9(5681:6390),'Color',"cyan",'LineWidth',0.0001)
    plot(vr(6391:7100)./a(500),Omega_R_2_9(6391:7100),'Color',"cyan",'LineWidth',0.0001)
    plot(vr(7101:7810)./a(500),Omega_R_2_9(7101:7810),'Color',"cyan",'LineWidth',0.0001)
    plot(vr(7811:8522)./a(500),Omega_R_2_9(7811:8522),'Color',"cyan",'LineWidth',0.0001)
    plot(vr(8523:9230)./a(500),Omega_R_2_9(8523:9230),'Color',"cyan",'LineWidth',0.0001)
    plot(vr(9231:9940)./a(500),Omega_R_2_9(9231:9940),'Color',"cyan",'LineWidth',0.0001)
    % load factor lines
    plot(V./a(500),omega_2_9(356:426),'Color',"red",'LineWidth',0.0001)
    plot(V./a(500),omega_2_9(427:497),'Color',"red",'LineWidth',0.0001)
    plot(V./a(500),omega_2_9(498:568),'Color',"red",'LineWidth',0.0001)
    plot(V./a(500),omega_2_9(569:639),'Color',"red",'LineWidth',0.0001)
    plot(V./a(500),omega_2_9(640:710),'Color',"red",'LineWidth',0.0001)
    plot(V./a(500),omega_2_9(711:781),'Color',"red",'LineWidth',3)
    % Stall Boundary
    plot(V_stall_2_9_turn(5:end)./a(500),Omega_stall_2_9(5:end),'Color',"blue",'LineWidth',1.3)
    % Propulsive Boundary
    plot(v1(5:11)./a(500),om1(5:11),'Color',"magenta",'LineWidth',1.3)
    plot(v2(5:11)./a(500),om2(5:11),'Color',"magenta",'LineWidth',1.3)
    % Text and Markers
    plot(0.640189,6.27538,'Color',"black",'LineWidth',1.5,'LineStyle','-.', ...
        'Marker','o','MarkerSize',3.5,'MarkerFaceColor','r')
    text(0.65,7.5,'Corner Speed','Interpreter','latex','FontSize',20,'Rotation',5)
    text(0.075,80,'Maximum Load Factor ($n_{max}$) = 2.5','Interpreter','latex', ...
        'Color',"red",'FontSize',20,'Rotation',-78)
    text(0.48,10,'Sustained Turn Rate (STR)','Interpreter','latex','Color', ...
        "magenta",'FontSize',20,'Rotation',7)
    text(0.28,2,'$C_{L_{max}}$ Limit','Interpreter','latex','Color',"blue", ...
        'FontSize',20,'Rotation',0)
    % Radius of Turn
    text(0.48,65,'Radius of Turn = 2.5 m','Interpreter','latex','Color',"#8282ff", ...
        'FontSize',20,'Rotation',45)
    text(0.78,52,'Radius of Turn = 5 m','Interpreter','latex','Color',"#8282ff", ...
        'FontSize',20,'Rotation',28)
    text(0.9,40,'Radius of Turn = 7.5 m','Interpreter','latex','Color',"#8282ff", ...
        'FontSize',20,'Rotation',20)
    text(0.9,30,'Radius of Turn = 10 m','Interpreter','latex','Color',"#8282ff", ...
        'FontSize',20,'Rotation',15)
    xlim([0 1.4])
    ylim([0 100])
    xticks(0.1:0.1:1.4)
    hold off
```

```
set(gcf, 'Position', get(0,'ScreenSize'));
set(gca,'Box','on');
ax = gca;
ax.TickDir = 'out';
ax.FontSize = 20;
ax.TickLength = [0.005 0.005];
%% Plot 0.5 Km and O.8 WTO
% Calculations subplot 3
V = 0:10:700;
n = 0:0.25:2.5;
V_stall_1_8_turn = sqrt(n)*sqrt(0.8*WTO/(0.5*1.225*sigma_1*S*CLmax));
omega_1_8 = [];
Omega_stall_1_8 =[];
R = 0:2.5:100;
vr = [];
for i =1:11
    Omega = ((9.81.*sqrt((n(i).^2)-1))./V)*180/pi;
    omegastall = ((9.81.*sqrt((n(i).^2)-1))./V_stall_1_8_turn(i))*180/pi;
    omega_1_8 = [omega_1_8 Omega];
    Omega_stall_1_8 = [Omega_stall_1_8 omegastall];
end
Omega_R_1_8 = [];
for i = 1:40
    for j = 1:10
    Omega = ((9.81.*sqrt((n(j).^2)-1))./V)*180/pi;
    Omega_R_1_8 =[Omega_R_1_8 Omega];
    v = Omega*R(i);
    vr =[vr v];
    end
end
v1 = sqrt(((t_sl*sigma_1)+sqrt(((t_sl*sigma_1)^2)-(4*A_1*B_1_8*n.^2)))./(2*A_1));
v2 = sqrt(((t_sl*sigma_1)-sqrt(((t_sl*sigma_1)^2)-(4*A_1*B_1_8*n.^2)))./(2*A_1));
om1 = ((9.81*sqrt((n.^2)-1))./v1)*180/pi;
om2 = ((9.81*sqrt((n.^2)-1))./v2)*180/pi;
%% Plot 0.5 Km and O.8 WTO
title("\textbf{Turn Performance for 0.8 $W_{TO}$ and Altitude 0.5 Km}", ...
    "Interpreter","latex",'FontSize',30)
xlabel("Mach Number (M)",'Interpreter','latex','FontSize',25)
ylabel("Turn Rate ($\omega$)  ($^\circ/s$)",'Interpreter','latex','FontSize',25)
hold on
grid on
% radius of turn lines
plot(vr(711:1420)./a(500),Omega_R_1_8(711:1420),'Color',"cyan",'LineWidth',0.0001)
plot(vr(1421:2130)./a(500),Omega_R_1_8(1421:2130),'Color',"cyan",'LineWidth',0.0001)
plot(vr(2131:2840)./a(500),Omega_R_1_8(2131:2840),'Color',"cyan",'LineWidth',0.0001)
plot(vr(2841:3550)./a(500),Omega_R_1_8(2841:3550),'Color',"cyan",'LineWidth',0.0001)
plot(vr(3551:4260)./a(500),Omega_R_1_8(3551:4260),'Color',"cyan",'LineWidth',0.0001)
plot(vr(4261:4970)./a(500),Omega_R_1_8(4261:4970),'Color',"cyan",'LineWidth',0.0001)
plot(vr(4971:5680)./a(500),Omega_R_1_8(4971:5680),'Color',"cyan",'LineWidth',0.0001)
plot(vr(5681:6390)./a(500),Omega_R_1_8(5681:6390),'Color',"cyan",'LineWidth',0.0001)
plot(vr(6391:7100)./a(500),Omega_R_1_8(6391:7100),'Color',"cyan",'LineWidth',0.0001)
plot(vr(7101:7810)./a(500),Omega_R_1_8(7101:7810),'Color',"cyan",'LineWidth',0.0001)
plot(vr(7811:8522)./a(500),Omega_R_1_8(7811:8522),'Color',"cyan",'LineWidth',0.0001)
% load factor lines
plot(V./a(500),omega_1_8(356:426),'Color',"red",'LineWidth',0.0001)
plot(V./a(500),omega_1_8(427:497),'Color',"red",'LineWidth',0.0001)
plot(V./a(500),omega_1_8(498:568),'Color',"red",'LineWidth',0.0001)
plot(V./a(500),omega_1_8(569:639),'Color',"red",'LineWidth',0.0001)
plot(V./a(500),omega_1_8(640:710),'Color',"red",'LineWidth',0.0001)
plot(V./a(500),omega_1_8(711:781),'Color',"red",'LineWidth',3)
% Stall Boundary
plot(V_stall_1_8_turn(5:end)./a(500),Omega_stall_1_8(5:end),'Color',"blue",'LineWidth',1.3)
% Propulsive Boundary
plot(v1(5:11)./a(500),om1(5:11),'Color',"magenta",'LineWidth',1.3)
plot(v2(5:11)./a(500),om2(5:11),'Color',"magenta",'LineWidth',1.3)
```

```
% Text and Markers
plot(0.47926,8.38229,'Color',"black",'LineWidth',1.5,'LineStyle','-.', ...
    'Marker','o','MarkerSize',3.5,'MarkerFaceColor','r')
text(0.48,10,'Corner Speed','Interpreter','latex','FontSize',20,'Rotation',5)
text(0.075,80,'Maximum Load Factor ($n_{max}$) = 2.5','Interpreter','latex', ...
    'Color',"red",'FontSize',20,'Rotation',-78)
text(0.35,13,'Sustained Turn Rate (STR)','Interpreter','latex','Color',"magenta", ...
    'FontSize',20,'Rotation',15)
text(0.35,2,'$C_{L_{max}}$ Limit','Interpreter','latex','Color',"blue", ...
    'FontSize',20,'Rotation',0)
% Radius of Turn
text(0.48,65,'Radius of Turn = 2.5 m','Interpreter','latex','Color',"#8282ff", ...
    'FontSize',20,'Rotation',45)
text(0.78,52,'Radius of Turn = 5 m','Interpreter','latex','Color',"#8282ff", ...
    'FontSize',20,'Rotation',28)
text(0.9,40,'Radius of Turn = 7.5 m','Interpreter','latex','Color',"#8282ff", ...
    'FontSize',20,'Rotation',20)
text(0.9,30,'Radius of Turn = 10 m','Interpreter','latex','Color',"#8282ff", ...
    'FontSize',20,'Rotation',15)
xlim([0 1.4])
ylim([0 100])
xticks(0.1:0.1:1.4)
hold off
set(gcf, 'Position', get(0,'ScreenSize'));
set(gca,'Box','on');
ax = gca;
ax.FontSize = 20;
ax.TickDir = 'out';
ax.TickLength = [0.005 0.005];
%% Plot 5 Km and 0.8 WTO
% Calculations subplot 2
V = 0:10:700;
n = 0:0.25:2.5;
V_stall_2_8_turn = sqrt(n)*sqrt(0.8*WTO/(0.5*1.225*sigma_5km*S*CLmax));
omega_2_8 = [];
Omega_stall_2_8 =[];
R = 0:2.5:100;
vr = [];
for i =1:11
    Omega = ((9.81.*sqrt((n(i).^2)-1))./V)*180/pi;
    omegastall = ((9.81.*sqrt((n(i).^2)-1))./V_stall_2_8_turn(i))*180/pi;
    omega_2_8 = [omega_2_8 Omega];
    Omega_stall_2_8 = [Omega_stall_2_8 omegastall];
end
Omega_R_2_8 = [];
for i = 1:40
    for j = 1:10
    Omega = ((9.81.*sqrt((n(j).^2)-1))./V)*180/pi;
    Omega_R_2_8 =[Omega_R_2_8 Omega];
    v = Omega*R(i);
    vr =[vr v];
    end
end
v1 = sqrt(((t_sl*sigma_5km)+sqrt(((t_sl*sigma_5km)^2)-(4*A_2*B_2_8*n.^2)))./(2*A_2));
v2 = sqrt(((t_sl*sigma_5km)-sqrt(((t_sl*sigma_5km)^2)-(4*A_2*B_2_8*n.^2)))./(2*A_2));
om1 = ((9.81*sqrt((n.^2)-1))./v1)*180/pi;
om2 = ((9.81*sqrt((n.^2)-1))./v2)*180/pi;
%% Plot 5 Km and 0.8 WTO
title("\textbf{Turn Performance for 0.8 $W_{TO}$ and Altitude 5 Km}", ...
    "Interpreter","latex",'FontSize',30)
xlabel("Mach Number (M)",'Interpreter','latex','FontSize',25)
ylabel("Turn Rate ($\omega$)  ($^\circ/s$)",'Interpreter','latex','FontSize',25)
hold on
grid on
% radius of turn lines
```

```
plot(vr(711:1420)./a(500),Omega_R_2_8(711:1420),'Color',"cyan",'LineWidth',0.0001)
plot(vr(1421:2130)./a(500),Omega_R_2_8(1421:2130),'Color',"cyan",'LineWidth',0.0001)
plot(vr(2131:2840)./a(500),Omega_R_2_8(2131:2840),'Color',"cyan",'LineWidth',0.0001)
plot(vr(2841:3550)./a(500),Omega_R_2_8(2841:3550),'Color',"cyan",'LineWidth',0.0001)
plot(vr(3551:4260)./a(500),Omega_R_2_8(3551:4260),'Color',"cyan",'LineWidth',0.0001)
plot(vr(4261:4970)./a(500),Omega_R_2_8(4261:4970),'Color',"cyan",'LineWidth',0.0001)
plot(vr(4971:5680)./a(500),Omega_R_2_8(4971:5680),'Color',"cyan",'LineWidth',0.0001)
plot(vr(5681:6390)./a(500),Omega_R_2_8(5681:6390),'Color',"cyan",'LineWidth',0.0001)
plot(vr(6391:7100)./a(500),Omega_R_2_8(6391:7100),'Color',"cyan",'LineWidth',0.0001)
plot(vr(7101:7810)./a(500),Omega_R_2_8(7101:7810),'Color',"cyan",'LineWidth',0.0001)
plot(vr(7811:8522)./a(500),Omega_R_2_8(7811:8522),'Color',"cyan",'LineWidth',0.0001)
plot(vr(8523:9230)./a(500),Omega_R_2_9(8523:9230),'Color',"cyan",'LineWidth',0.0001)
plot(vr(9231:9940)./a(500),Omega_R_2_9(9231:9940),'Color',"cyan",'LineWidth',0.0001)
% load factor lines
plot(V./a(500),omega_2_8(356:426),'Color',"red",'LineWidth',0.0001)
plot(V./a(500),omega_2_8(427:497),'Color',"red",'LineWidth',0.0001)
plot(V./a(500),omega_2_8(498:568),'Color',"red",'LineWidth',0.0001)
plot(V./a(500),omega_2_8(569:639),'Color',"red",'LineWidth',0.0001)
plot(V./a(500),omega_2_8(640:710),'Color',"red",'LineWidth',0.0001)
plot(V./a(500),omega_2_8(711:781),'Color',"red",'LineWidth',3)
% Stall Boundary
plot(V_stall_2_8_turn(5:end)./a(500),Omega_stall_2_8(5:end),'Color',"blue",'LineWidth',1.3)
% Propulsive Boundary
plot(v1(5:11)./a(500),om1(5:11),'Color',"magenta",'LineWidth',1.3)
plot(v2(5:11)./a(500),om2(5:11),'Color',"magenta",'LineWidth',1.3)
% Text and Markers
plot(0.603576,6.6505,'Color',"black",'LineWidth',1.5,'LineStyle','-.', ...
    'Marker','o','MarkerSize',3.5,'MarkerFaceColor','r')
text(0.6,8,'Corner Speed','Interpreter','latex','FontSize',20,'Rotation',5)
text(0.075,83,'Maximum Load Factor ($n_{max}$) = 2.5','Interpreter','latex', ...
    'Color',"red",'FontSize',20,'Rotation',-81)
text(0.48,10,'Sustained Turn Rate (STR)','Interpreter','latex','Color', ...
    "magenta",'FontSize',20,'Rotation',7)
text(0.27,2,'$C_{L_{max}}$ Limit','Interpreter','latex','Color',"blue", ...
    'FontSize',20,'Rotation',0)
% Radius of Turn
text(0.48,65,'Radius of Turn = 2.5 m','Interpreter','latex','Color',"#8282ff", ...
    'FontSize',20,'Rotation',45)
text(0.78,52,'Radius of Turn = 5 m','Interpreter','latex','Color',"#8282ff", ...
    'FontSize',20,'Rotation',28)
text(0.9,40,'Radius of Turn = 7.5 m','Interpreter','latex','Color',"#8282ff", ...
    'FontSize',20,'Rotation',20)
text(0.9,30,'Radius of Turn = 10 m','Interpreter','latex','Color',"#8282ff", ...
    'FontSize',20,'Rotation',15)
xlim([0 1.4])
ylim([0 100])
xticks(0.1:0.1:1.4)
hold off
set(gcf, 'Position', get(0,'ScreenSize'));
set(gca,'Box','on');
ax = gca;
ax.FontSize = 20;
ax.TickDir = 'out';
ax.TickLength = [0.005 0.005];
%% n - V PLOT
%% Plot 0.5 Km and 0.9 WTO
% Calculations
n_stall =0:0.05:5;
V = 0:10:508;
n = sqrt((0.5*1.225*sigma_1*S.*(V.^2)/(k*(0.9*WTO))).*(((t_sl*sigma_1)/ ...
    (0.9*WTO))-((0.5*S*1.225*sigma_1.*(V.^2).*CDo)./(0.9*WTO))));
V_stall_1_9_turn = sqrt(n_stall)*sqrt(0.9*WTO/(0.5*1.225*sigma_1*S*CLmax));
n_max = 0.5*1.225*sigma_1*S.*(V.^2).*CLmax./(0.9*WTO);
phi = atand(sqrt(n.^2-1));
[¬,index] = max(n);
```

```
title("\textbf{Turn Performance for 0.9 $W_{TO}$ and Altitude 0.5 Km}", ...
    "Interpreter","latex",'FontSize',30)
xlabel("Velocity ($V_{\infty}$)  (m/s)",'Interpreter','latex','FontSize',25)
yyaxis left
yticks(0:0.5:6)
ylabel("Load Factor (n)",'Interpreter','latex','FontSize',25)
grid on
hold on
plot(V,n,'Color',"blue",'LineWidth',1.3)
plot(V_stall_1_9_turn(1:75),n_stall(1:75),'Color',"red",'LineWidth',1.3,'LineStyle','-')
plot([0 550],[2.5 2.5],'Color',"#FFA500",'LineWidth',1.3,'LineStyle','-')
plot(162.961,2.5,'Color',"black",'LineWidth',1.5,'LineStyle','-.', ...
    'Marker','o','MarkerSize',3.5,'MarkerFaceColor','r')
plot(V(index),max(n),'Color',"black",'LineWidth',1.5,'LineStyle','-.', ...
    'Marker','o','MarkerSize',3.5,'MarkerFaceColor','r')
text(168,2.58,'Corner Speed','Interpreter','latex','FontSize',20,'Rotation',0)
text(250,5.15,'Maximum load factor (from propulsive boundary) = 5.04', ...
    'Interpreter','latex','FontSize',20,'Rotation',0,'Color',"blue")
text(20,2.6,'Structural limit n = 2.5','Interpreter','latex','FontSize',20, ...
    'Rotation',0,'Color',"#FFA500")
text(290,4.6,'Bank Angle Boundary ($\phi_{max}$)','Interpreter','latex', ...
    'FontSize',20,'Rotation',0,'Color',"green")
text(85,0.8,'Stall Boundary ($C_{L_{max}}$)','Interpreter','latex', ...
    'FontSize',20,'Rotation',51,'Color',"red")
yyaxis right
plot(V(32:end),phi(32:end),'Color',"green",'LineWidth',1.3)
ylabel("Bank Angle ($^\circ$)",'Interpreter','latex','FontSize',25)
ylim([0 100])
hold off
xlim([0 550])
xticks(50:50:550)
yticks(10:10:100)
ax = gca;
ax.YAxis(1).Color = 'k';
ax.YAxis(2).Color = 'k';
set(gcf, 'Position', get(0,'ScreenSize'));
ax.FontSize = 20;
set(gca,'Box','on');
ax = gca;
ax.TickDir = 'out';
ax.TickLength = [0.005 0.005];
%% Plot 5 Km and 0.9 WTO
% Calculations
n_stall =0:0.05:5;
V = 0:10:508;
n = sqrt((0.5*1.225*sigma_5km*S.*(V.^2)/(k*(0.9*WTO))).*(((t_sl*sigma_5km)/ ...
    (0.9*WTO))-((0.5*S*1.225*sigma_5km.*(V.^2).*CDo)./(0.9*WTO))));
V_stall_2_9_turn = sqrt(n_stall)*sqrt(0.9*WTO/(0.5*1.225*sigma_5km*S*CLmax));
n_max = 0.5*1.225*sigma_5km*S.*(V.^2).*CLmax./(0.9*WTO);
phi = atand(sqrt(n.^2-1));
[¬,index] = max(n);
title("\textbf{Turn Performance for 0.9 $W_{TO}$ and Altitude 5 Km}", ...
    "Interpreter","latex",'FontSize',30)
xlabel("Velocity ($V_{\infty}$)  (m/s)",'Interpreter','latex','FontSize',25)
yyaxis left
yticks(0:0.5:6)
ylabel("Load Factor (n)",'Interpreter','latex','FontSize',25)
grid on
hold on
plot(V,n,'Color',"blue",'LineWidth',1.3)
plot(V_stall_2_9_turn(1:51),n_stall(1:51),'Color',"red",'LineWidth',1.3,'LineStyle','-')
plot([0 550],[2.5 2.5],'Color',"#FFA500",'LineWidth',1.3,'LineStyle','-')
plot(205.225,2.5,'Color',"black",'LineWidth',1.5,'LineStyle','-.','Marker','o', ...
    'MarkerSize',3.5,'MarkerFaceColor','r')
plot(V(index),max(n),'Color',"black",'LineWidth',1.5,'LineStyle','-.','Marker','o', ...
```

```
    'MarkerSize',3.5,'MarkerFaceColor','r')
text(160,2.59,'Corner Speed','Interpreter','latex','FontSize',20,'Rotation',0)
text(250,3.25,'Maximum load factor (from propulsive boundary) = 3.18', ...
    'Interpreter','latex','FontSize',20,'Rotation',0,'Color',"blue")
text(40,2.6,'Structural limit n = 2.5','Interpreter','latex','FontSize',20, ...
    'Rotation',0,'Color',"#FFA500")
text(300,2.4,'Bank Angle Boundary ($\phi_{max}$)','Interpreter','latex', ...
    'FontSize',20,'Rotation',0,'Color',"green")
text(100,0.8,'Stall Boundary ($C_{L_{max}}$)','Interpreter','latex', ...
    'FontSize',20,'Rotation',55,'Color',"red")
yyaxis right
plot(V(32:end),phi(32:end),'Color',"green",'LineWidth',1.3)
ylabel("Bank Angle ($^\circ$)",'Interpreter','latex','FontSize',25)
ylim([0 100])
hold off
xlim([0 550])
xticks(50:50:550)
yticks(10:10:100)
ax = gca;
ax.YAxis(1).Color = 'k';
ax.YAxis(2).Color = 'k';
set(gcf, 'Position', get(0,'ScreenSize'))
ax.FontSize = 20;
set(gca,'Box','on');
ax = gca;
ax.TickDir = 'out';
ax.TickLength = [0.005 0.005];
%% Plot 0.5 Km and 0.8 WTO
% Calculations
n_stall =0:0.05:5;
V = 0:10:508;
n = sqrt((0.5*1.225*sigma_1*S.*(V.^2)/(k*(0.8*WTO))).*(((t_sl*sigma_1)/ ...
    (0.8*WTO))-((0.5*S*1.225*sigma_1.*(V.^2).*CDo)./(0.8*WTO))));
V_stall_1_8_turn = sqrt(n_stall)*sqrt(0.8*WTO/(0.5*1.225*sigma_1*S*CLmax));
n_max = 0.5*1.225*sigma_1*S.*(V.^2).*CLmax./(0.8*WTO);
phi = atand(sqrt(n.^2-1));
[¬,index] = max(n);
title("\textbf{Turn Performance for 0.8 $W_{TO}$ and Altitude 0.5 Km}","Interpreter","latex",'FontSize',30)
xlabel("Velocity ($V_{\infty}$)  (m/s)",'Interpreter','latex','FontSize',25)
yyaxis left
yticks(0:0.5:6)
ylabel("Load Factor (n)",'Interpreter','latex','FontSize',25)
grid on
hold on
plot(V,n,'Color',"blue",'LineWidth',1.3)
plot(V_stall_1_8_turn(1:85),n_stall(1:85),'Color',"red",'LineWidth',1.3,'LineStyle','-')
plot([0 550],[2.5 2.5],'Color',"#FFA500",'LineWidth',1.3,'LineStyle','-')
plot(153.642,2.5,'Color',"black",'LineWidth',1.5,'LineStyle','-.','Marker','o', ...
    'MarkerSize',3.5,'MarkerFaceColor','r')
plot(V(index),max(n),'Color',"black",'LineWidth',1.5,'LineStyle','-.', ...
    'Marker','o','MarkerSize',3.5,'MarkerFaceColor','r')
text(158,2.58,'Corner Speed','Interpreter','latex','FontSize',20,'Rotation',0)
text(250,5.8,'Maximum load factor (from propulsive boundary) = 5.67', ...
    'Interpreter','latex','FontSize',20,'Rotation',0,'Color',"blue")
text(7,2.6,'Structural limit n = 2.5','Interpreter','latex','FontSize',20, ...
    'Rotation',0,'Color',"#FFA500")
text(300,4.6,'Bank Angle Boundary ($\phi_{max}$)','Interpreter','latex', ...
    'FontSize',20,'Rotation',0,'Color',"green")
text(80,0.8,'Stall Boundary ($C_{L_{max}}$)','Interpreter','latex', ...
    'FontSize',20,'Rotation',52,'Color',"red")
yyaxis right
plot(V(32:end),phi(32:end),'Color',"green",'LineWidth',1.3)
ylabel("Bank Angle ($^\circ$)",'Interpreter','latex','FontSize',25)
ylim([0 100])
hold off
```

```
xlim([0 550])
xticks(50:50:550)
yticks(10:10:100)
ax = gca;
ax.YAxis(1).Color = 'k';
ax.YAxis(2).Color = 'k';
set(gcf, 'Position', get(0,'ScreenSize'));
ax.FontSize = 20;
set(gca,'Box','on');
ax = gca;
ax.TickDir = 'out';
ax.TickLength = [0.005 0.005];
%% Plot 5 Km and 0.8 WTO
% Calculations
n_stall =0:0.05:5;
V = 0:10:508;
n = sqrt((0.5*1.225*sigma_5km*S.*(V.^2)/(k*(0.8*WTO))).*(((t_sl*sigma_5km)/ ...
    (0.8*WTO))-((0.5*S*1.225*sigma_5km.*(V.^2).*CDo)./(0.8*WTO))));
V_stall_2_8_turn = sqrt(n_stall)*sqrt(0.8*WTO/(0.5*1.225*sigma_5km*S*CLmax));
n_max = 0.5*1.225*sigma_5km*S.*(V.^2).*CLmax./(0.9*WTO);
phi = atand(sqrt(n.^2-1));
[¬,index] = max(n);
title("\textbf{Turn Performance for 0.8 $W_{TO}$ and Altitude 5 Km}", ...
    "Interpreter","latex",'FontSize',30)
xlabel("Velocity ($V_{\infty}$)  (m/s)",'Interpreter','latex','FontSize',25)
yyaxis left
yticks(0:0.5:6)
ylabel("Load Factor (n)",'Interpreter','latex','FontSize',25)
grid on
hold on
plot(V,n,'Color',"blue",'LineWidth',1.3)
plot(V_stall_2_8_turn(1:54),n_stall(1:54),'Color',"red",'LineWidth',1.3,'LineStyle','-')
plot([0 550],[2.5 2.5],'Color',"#FFA500",'LineWidth',1.3,'LineStyle','-')
plot(193.488,2.5,'Color',"black",'LineWidth',1.5,'LineStyle','-.','Marker','o', ...
    'MarkerSize',3.5,'MarkerFaceColor','r')
plot(V(index),max(n),'Color',"black",'LineWidth',1.5,'LineStyle','-.', ...
    'Marker','o','MarkerSize',3.5,'MarkerFaceColor','r')
text(200,2.55,'Corner Speed','Interpreter','latex','FontSize',20,'Rotation',0)
text(275,3.7,'Maximum load factor (from propulsive boundary) = 3.57', ...
    'Interpreter','latex','FontSize',20,'Rotation',0,'Color',"blue")
text(40,2.6,'Structural limit n = 2.5','Interpreter','latex','FontSize',20, ...
    'Rotation',0,'Color',"#FFA500")
text(300,2.8,'Bank Angle Boundary ($\phi_{max}$)','Interpreter','latex', ...
    'FontSize',20,'Rotation',0,'Color',"green")
text(105,0.8,'Stall Boundary ($C_{L_{max}}$)','Interpreter','latex', ...
    'FontSize',20,'Rotation',57,'Color',"red")
yyaxis right
plot(V(32:end),phi(32:end),'Color',"green",'LineWidth',1.3)
ylabel("Bank Angle ($^\circ$)",'Interpreter','latex','FontSize',25)
ylim([0 100])
hold off
xlim([0 550])
xticks(50:50:550)
yticks(10:10:100)
ax = gca;
ax.YAxis(1).Color = 'k';
ax.YAxis(2).Color = 'k';
set(gcf, 'Position', get(0,'ScreenSize'));
ax.FontSize = 20;
set(gca,'Box','on');
ax = gca;
ax.TickDir = 'out';
ax.TickLength = [0.005 0.005];
%% Combined Plot for 0.9 WTO
% Calculations
```

```
n_stall =0:0.05:5;
V = 0:10:508;
n = sqrt((0.5*1.225*sigma_1*S.*(V.^2)/(k*(0.9*WTO))).*(((t_sl*sigma_1)/ ...
    (0.9*WTO))-((0.5*S*1.225*sigma_1.*(V.^2).*CDo)./(0.9*WTO))));
V_stall_1_9_turn = sqrt(n_stall)*sqrt(0.9*WTO/(0.5*1.225*sigma_1*S*CLmax));
n_max = 0.5*1.225*sigma_1*S.*(V.^2).*CLmax./(0.9*WTO);
phi = atand(sqrt(n.^2-1));
[¬,index] = max(n);
hold on
plot(V,n,'Color',"blue",'LineWidth',1.3)
plot(V_stall_1_9_turn(1:75),n_stall(1:75),'Color',"red",'LineWidth',1.3,'LineStyle','-')
plot([0 550],[2.5 2.5],'Color',"#FFA500",'LineWidth',1.3,'LineStyle','-')
plot(V(index),max(n),'Color',"black",'LineWidth',1.5,'LineStyle','-.', ...
    'Marker','o','MarkerSize',3.5,'MarkerFaceColor','r')
text(168,2.58,'Corner Speed','Interpreter','latex','FontSize',20,'Rotation',0)
text(200,5.15,['Maximum load factor (from propulsive boundary of Altitude 0.5 Km) ' ...
    '= 5.04'],'Interpreter','latex','FontSize',20,'Rotation',0,'Color',"blue")

% Calculations
n_stall =0:0.05:5;
V = 0:10:508;
n = sqrt((0.5*1.225*sigma_5km*S.*(V.^2)/(k*(0.9*WTO))).*(((t_sl*sigma_5km)/ ...
    (0.9*WTO))-((0.5*S*1.225*sigma_2.*(V.^2).*CDo)./(0.9*WTO))));
V_stall_2_9_turn = sqrt(n_stall)*sqrt(0.9*WTO/(0.5*1.225*sigma_5km*S*CLmax));
n_max = 0.5*1.225*sigma_5km*S.*(V.^2).*CLmax./(0.9*WTO);
phi = atand(sqrt(n.^2-1));
[¬,index] = max(n);
title("\textbf{Turn Performance for 0.9 $W_{TO}$ and Altitudes 0.5 and 5 Km}", ...
    "Interpreter","latex",'FontSize',30)
xlabel("Velocity ($V_{\infty}$)  (m/s)",'Interpreter','latex','FontSize',25)
yticks(0:0.5:6)
ylabel("Load Factor (n)",'Interpreter','latex','FontSize',25)
grid on
plot(V,n,'Color',"blue",'LineWidth',1.3)
plot(V_stall_2_9_turn(1:51),n_stall(1:51),'Color',"red",'LineWidth',1.3,'LineStyle','-')
plot([0 550],[2.5 2.5],'Color',"#FFA500",'LineWidth',1.3,'LineStyle','-')
plot(205.225,2.5,'Color',"black",'LineWidth',1.5,'LineStyle','-.','Marker','o', ...
    'MarkerSize',3.5,'MarkerFaceColor','r')
plot(162.961,2.5,'Color',"black",'LineWidth',1.5,'LineStyle','-.','Marker','o', ...
    'MarkerSize',3.5,'MarkerFaceColor','r')
plot(V(index),max(n),'Color',"black",'LineWidth',1.5,'LineStyle','-.','Marker','o', ...
    'MarkerSize',3.5,'MarkerFaceColor','r')
text(195,3.3,'Maximum load factor (from propulsive boundary of Altitude 5 Km) = 3.18', ...
    'Interpreter','latex','FontSize',20,'Rotation',0,'Color',"blue")
text(10,2.6,'Structural limit n = 2.5','Interpreter','latex','FontSize',20, ...
    'Rotation',0,'Color',"#FFA500")
text(105,0.8,'Stall Boundary ($C_{L_{max}}$)','Interpreter','latex','FontSize',20, ...
    'Rotation',40,'Color',"red")
hold off
xlim([0 530])
xticks(50:50:550)
set(gcf, 'Position', get(0,'ScreenSize'));
set(gca,'Box','on');
ax = gca;
ax.FontSize = 20;
ax.TickDir = 'out';
ax.TickLength = [0.005 0.005];
%% Combined Plot for 0.8 WTO
% Calculations
n_stall =0:0.05:5;
V = 0:10:508;
n = sqrt((0.5*1.225*sigma_1*S.*(V.^2)/(k*(0.8*WTO))).*(((t_sl*sigma_1)/ ...
    (0.8*WTO))-((0.5*S*1.225*sigma_1.*(V.^2).*CDo)./(0.8*WTO))));
V_stall_1_8_turn = sqrt(n_stall)*sqrt(0.8*WTO/(0.5*1.225*sigma_1*S*CLmax));
n_max = 0.5*1.225*sigma_1*S.*(V.^2).*CLmax./(0.8*WTO);
```

```
phi = atand(sqrt(n.^2-1));
[¬,index] = max(n);
hold on
plot(V,n,'Color',"blue",'LineWidth',1.3)
plot(V_stall_1_8_turn(1:85),n_stall(1:85),'Color',"red",'LineWidth',1.3,'LineStyle','-')
plot([0 550],[2.5 2.5],'Color',"#FFA500",'LineWidth',1.3,'LineStyle','-')
plot(V(index),max(n),'Color',"black",'LineWidth',1.5,'LineStyle','-.','Marker','o', ...
    'MarkerSize',3.5,'MarkerFaceColor','r')
text(275,5.8,'Maximum load factor (from propulsive boundary) = 5.67','Interpreter','latex', ...
    'FontSize',20,'Rotation',0,'Color',"blue")
% Calculations
n_stall =0:0.05:5;
V = 0:10:508;
n = sqrt((0.5*1.225*sigma_5km*S.*(V.^2)/(k*(0.8*WTO))).*(((t_sl*sigma_5km)/ ...
    (0.8*WTO))-((0.5*S*1.225*sigma_5km.*(V.^2).*CDo)./(0.8*WTO))));
V_stall_2_8_turn = sqrt(n_stall)*sqrt(0.8*WTO/(0.5*1.225*sigma_5km*S*CLmax));
n_max = 0.5*1.225*sigma_5km*S.*(V.^2).*CLmax./(0.9*WTO);
phi = atand(sqrt(n.^2-1));
[¬,index] = max(n);
title("\textbf{Turn Performance for 0.8 $W_{TO}$ and Altitudes 0.5 and 5 Km}", ...
    "Interpreter","latex",'FontSize',30)
xlabel("Velocity ($V_{\infty}$)  (m/s)",'Interpreter','latex','FontSize',25)
yticks(0:0.5:6)
ylabel("Load Factor (n)",'Interpreter','latex','FontSize',25)
grid on
plot(V,n,'Color',"blue",'LineWidth',1.3)
plot(V_stall_2_8_turn(1:54),n_stall(1:54),'Color',"red",'LineWidth',1.3,'LineStyle','-')
plot([0 550],[2.5 2.5],'Color',"#FFA500",'LineWidth',1.3,'LineStyle','-')
plot(193.488,2.5,'Color',"black",'LineWidth',1.5,'LineStyle','-.','Marker','o', ...
    'MarkerSize',3.5,'MarkerFaceColor','r')
plot(153.642,2.5,'Color',"black",'LineWidth',1.5,'LineStyle','-.','Marker','o', ...
    'MarkerSize',3.5,'MarkerFaceColor','r')
plot(V(index),max(n),'Color',"black",'LineWidth',1.5,'LineStyle','-.','Marker','o', ...
    'MarkerSize',3.5,'MarkerFaceColor','r')
text(200,2.6,'Corner Speed','Interpreter','latex','FontSize',20,'Rotation',0)
text(210,3.7,'Maximum load factor (from propulsive boundary) = 3.57', ...
    'Interpreter','latex','FontSize',20,'Rotation',0,'Color',"blue")
text(10,2.6,'Structural limit n = 2.5','Interpreter','latex','FontSize',20, ...
    'Rotation',0,'Color',"#FFA500")
text(105,0.8,'Stall Boundary ($C_{L_{max}}$)','Interpreter','latex','FontSize',20, ...
    'Rotation',45,'Color',"red")
hold off
xlim([0 530])
xticks(50:50:550)
set(gcf, 'Position', get(0,'ScreenSize'));
set(gca,'Box','on');
ax = gca;
ax.FontSize = 20;
ax.TickDir = 'out';
ax.TickLength = [0.005 0.005];
%% PLOT 5
% Calculation
T = t_sl*sigma_1;
V_stall_1_9 = ((2*0.9*WTO)/(1.225*sigma_1*S*(1.15+1.15)))^0.5;
V_stall_1_8 = ((2*0.8*WTO)/(1.225*sigma_1*S*(1.15+1.15)))^0.5;
V_lo_9 = 1.2*V_stall_1_9;
V_lo_8 = 1.2*V_stall_1_8;
CDp = CDo+CDo_Flap + CDo_Land_Gear;
Cl_gr = CLmax + CLmax_HLD_part;
Cl_climb = 0.9*Cl_gr;
Cl_ge = 0.12;
Cdi = k*Cl_ge^2;
Cdi_c = k*Cl_ge^2;
CD_TO = CDp+Cdi;
CD_climb = CDp+Cdi_c;
```

```
D_9 = 0.5*1.225*sigma_1*V_lo_9^2*S*CD_TO;
D_9_c = 0.5*1.225*sigma_1*(V_lo_9^2)*S*CD_climb;
D_8 = 0.5*1.225*sigma_1*V_lo_8^2*S*CD_TO;
D_8_c = 0.5*1.225*sigma_1*V_lo_8^2*S*CD_climb;
% Distance for Rotation
sr_9 = 3*V_lo_9;
sr_8 = 3*V_lo_8;
% Calculation
sing_9 = (T-D_9_c)/(0.9*WTO);
g_9 = asind(sing_9);
sing_8 = (T-D_8_c)/(0.8*WTO);
g_8 = asind(sing_8);
% Distance to Climb
s_c_9 = 10.7/tand(g_9);
s_c_8 = 10.7/tand(g_8);
% Time for Rotation
t_r = 3;
% Time to Climb
t_c_9 = 10.7/(V_lo_9*tand(g_9));
t_c_8 = 10.7/(V_lo_8*tand(g_8));
%% AEO for 0.9 WTO
T = t_sl*sigma_1;
Vstall = ((2*0.9*WTO)/(1.225*sigma_1*S*(1.15+1.15)))^0.5;
Vr = 1.2*Vstall;
v = zeros([500 1]);
a = zeros([500 1]);
s = zeros([500 1]);
t = zeros([500 1]);
del_v = zeros([500 1]);
del_s = zeros([500 1]);
q = zeros([500 1]);
D = zeros([500 1]);
L = zeros([500 1]);
i = 1;
while v(i) ≤ Vr                    % loop to find T/O parameters
    q(i) = 0.5*1.225*v(i)^2;
    L(i) = q(i)*S*0.12;
    D(i) = q(i)*S*CD_TO;
    a(i) = ((T - D(i) - mu*((0.9*WTO)-L(i)))*g)/(0.9*WTO);
    del_v(i) = a(i)*0.25;
    del_s(i) = v(i)*0.25 + 0.5*a(i)*0.25^2;
    v(i+1) = v(i) +  del_v(i);
    s(i+1) = s(i) + del_s(i);
    t(i+1) = t(i) + 0.25;
    i = i+1;
end
S_9 = s(182)+sr_9+s_c_9;
T_9 = t_r + t_c_9 + t(182);
%% AEO for 0.8 WTO
T = t_sl*sigma_1;
Vstall = ((2*0.8*WTO)/(1.225*sigma_1*S*(1.15+1.15)))^0.5;
Vr = 1.2*Vstall;
v = zeros([500 1]);
a = zeros([500 1]);
s = zeros([500 1]);
t = zeros([500 1]);
del_v = zeros([500 1]);
del_s = zeros([500 1]);
q = zeros([500 1]);
D = zeros([500 1]);
L = zeros([500 1]);
i = 1;
while v(i) ≤ Vr                    % loop to find T/O parameters
    q(i) = 0.5*1.225*v(i)^2;
    L(i) = q(i)*S*0.12;
```

```
    D(i) = q(i)*S*CD_TO;
    a(i) = ((T - D(i) - mu*((0.8*WTO)-L(i)))*g)/(0.8*WTO);
    del_v(i) = a(i)*0.25;
    del_s(i) = v(i)*0.25 + 0.5*a(i)*0.25^2;
    v(i+1) = v(i) +  del_v(i);
    s(i+1) = s(i) + del_s(i);
    t(i+1) = t(i) + 0.25;
    i = i+1;
end
S_8 = s(151)+sr_8+s_c_8;
T_8 = t_r + t_c_8 + t(151);
%% OEI for 0.9 WTO
%% ASDR for 0.9 WTO and 0.5 km
T = t_sl*sigma_1;
Vstall = ((2*0.9*WTO)/(1.225*sigma_1*S*(1.15+1.15)))^0.5;
Vr = 1.2*Vstall;
v_asdr_9 = zeros([400 8]);
a = zeros([400 8]);
s_asdr_9 = zeros([400 8]);
t_asdr_9 = zeros([400 8]);
del_v = zeros([400 8]);
del_s = zeros([400 8]);
q = zeros([400 8]);
D = zeros([400 8]);
L = zeros([400 8]);
x = 0.65;
z = 1;
condition = true;
% loop
while condition == true
    i = 1;
    while v_asdr_9(i,z) <= x*Vr           % loop to find T/O parameters till failure
        q(i,z) = 0.5*1.225*sigma_1*v_asdr_9(i,z)^2;
        L(i,z) = q(i,z)*S*0.12;
        D(i,z) = q(i,z)*S*CD_TO;
        a(i,z) = ((T - D(i,z) - mu*((0.9*WTO)-L(i,z)))*g)/(0.9*WTO);
        del_v(i,z) = a(i,z)*0.25;
        del_s(i,z) = v_asdr_9(i,z)*0.25 + 0.5*a(i,z)*0.25^2;
        v_asdr_9(i+1,z) = v_asdr_9(i,z) +  del_v(i,z);
        s_asdr_9(i+1,z) = s_asdr_9(i,z) + del_s(i,z);
        t_asdr_9(i+1,z) = t_asdr_9(i,z) + 0.25;
        i = i+1;
    end
    j = i;
    v_asdr_9(j) = x*Vr;
    s_asdr_9(j) = s_asdr_9(i);
    q(j) = q(i);
    L(j) = L(i);
    D(j) = D(i);
    t_asdr_9(j) = t_asdr_9(i);
    while j < i + 12                   % loop to find T/O paramters during decision phase
        q(j,z) = 0.5*1.225*v_asdr_9(j,z)^2;
        L(j,z) = q(j,z)*S*0.12;
        D(j,z) = q(j,z)*S*CD_TO;
        a(j,z) = ((0.75*T - D(i,z) - mu*((0.9*WTO)-L(i,z)))*g)/(0.9*WTO);
        del_v(j,z) = a(j,z)*0.25;
        del_s(j,z) = v_asdr_9(j,z)*0.25 + 0.5*a(j,z)*0.25^2;
        v_asdr_9(j+1,z) = v_asdr_9(j,z) + del_v(j,z);
        s_asdr_9(j+1,z) = s_asdr_9(j) + del_s(j,z);
        t_asdr_9(j+1,z) = t_asdr_9(j,z) + 0.25;
        j = j+1;
    end
    k = j;
    v_asdr_9(k) = x*Vr;
    s_asdr_9(k) = s_asdr_9(j);
```

```
    q(k) = q(j);
    L(k) = L(j);
    D(k) = D(j);
    t_asdr_9(k) = t_asdr_9(j);
    while v_asdr_9(k,z) ≥ 0              % loop to find T/O parameters during deceleration phase
        q(k,z) = 0.5*1.225*sigma_1*v_asdr_9(k,z)^2;
        L(k,z) = q(k,z)*S*0.12;
        D(k,z) = q(k,z)*S*CD_TO;
        a(k,z) = -2.4525;
        del_v(k,z) = a(k,z)*0.25;
        del_s(k,z) = v_asdr_9(k,z)*0.25 + 0.5*a(k,z)*0.25^2;
        v_asdr_9(k+1,z) = v_asdr_9(k,z) + del_v(k,z);
        s_asdr_9(k+1,z) = s_asdr_9(k,z) + del_s(k,z);
        t_asdr_9(k+1,z) = t_asdr_9(k,z) + 0.25;
        k = k+1;
    end
    if x<1
        x = x + 0.05;
    else
        condition = false;
    end
    z = z + 1;
end
%% TODR for 0.9 WTO and 0.5 km
% Initialisation
T = t_sl*sigma_1;
Vstall = ((2*WTO*0.9)/(1.225*sigma_1*S*(1.15+1.15)))^0.5;
Vr = 1.2*Vstall;
a = zeros([400 8]);
s_todr_9 = zeros([400 8]);
v_todr_9 = zeros([400 8]);
t_todr_9 = zeros([400 8]);
del_v = zeros([400 8]);
del_s = zeros([400 8]);
q = zeros([400 8]);
D = zeros([400 8]);
L = zeros([400 8]);
x = 0.65;
z = 1;
condition = true;
% Loop
while condition == true
    i = 1;
    while v_todr_9(i,z) ≤ x*Vr            % loop to find T/O parameters till failure
        q(i,z) = 0.5*1.225*sigma_1*v_todr_9(i,z)^2;
        L(i,z) = q(i,z)*S*0.12;
        D(i,z) = q(i,z)*S*CD_TO;
        a(i,z) = ((T - D(i,z) - mu*((0.9*WTO)-L(i,z)))*g)/(0.9*WTO);
        del_v(i,z) = a(i,z)*0.25;
        del_s(i,z) = v_todr_9(i,z)*0.25 + 0.5*a(i,z)*0.25^2;
        v_todr_9(i+1,z) = v_todr_9(i,z) +  del_v(i,z);
        s_todr_9(i+1,z) = s_todr_9(i,z) + del_s(i,z);
        t_todr_9(i+1,z) = t_todr_9(i,z) + 0.25;
        i = i+1;
    end
    j = i;
    v_todr_9(j,z) = x*Vr;
    s_todr_9(j,z) = s_todr_9(i,z);
    q(j,z) = q(i,z);
    L(j,z) = L(i,z);
    D(j,z) = D(i,z);
    t_todr_9(j,z) = t_todr_9(i,z);
    while v_todr_9(j,z) ≤ Vr              % loop to find T/O parameters after failure
        q(j,z) = 0.5*1.225*sigma_1*v_todr_9(j,z)^2;
        L(j,z) = q(j,z)*S*0.12;
```

```
        D(j,z) = q(j,z)*S*CD_TO;
        a(j,z) = ((0.75*T - D(j,z) - mu*((0.9*WTO)-L(j,z)))*g)/(0.9*WTO);
        del_v(j,z) = a(j,z)*0.25;
        del_s(j,z) = v_todr_9(j,z)*0.25 + 0.5*a(j,z)*0.25^2;
        v_todr_9(j+1,z) = v_todr_9(j,z) +  del_v(j,z);
        s_todr_9(j+1,z) = s_todr_9(j,z) + del_s(j,z);
        t_todr_9(j+1,z) = t_todr_9(j,z) + 0.25;
        j = j+1;
    end
    if x < 1
        x = x + 0.05;
    else
        condition = false;
    end
    z = z + 1;
end
%% BFL for 0.5 Km
V_f = [0.65*Vr 0.70*Vr 0.75*Vr 0.80*Vr 0.85*Vr 0.90*Vr 0.95*Vr Vr];
S_TODR_9 = [2.4541e03 2.4143e03 2.3654e03 2.2973e03 2.2472e03 2.1709e03 2.0903e03 2.0050e03];
S_ASDR_9 = [1.6634e+03 2.0008e03 2.2562e03 2.4803e03 2.6988e03 2.9116e03 3.1185e03 3.3414e03];
hold on
title("\textbf{Balanced Field Length for a Take-Off Altitude of 0.5 km and 0.9 $W_{TO}$}", ...
    "Interpreter","latex",'FontSize',30)
P = InterX([V_f;S_ASDR_9],[V_f;S_TODR_9]);
plot(V_f,S_ASDR_9,'Color',"blue",'LineWidth',1.3,'LineStyle','-')
plot(V_f,S_TODR_9,'Color',"magenta",'LineWidth',1.3,'LineStyle','-')
plot([P(1) P(1)],[1400 P(2)],'Color',"green",'LineWidth',1.3,'LineStyle','--')
plot([0 P(1)],[P(2) P(2)],'Color',"green",'LineWidth',1.3,'LineStyle','--')
plot(P(1),P(2),'Color',"black",'LineWidth',1.5,'LineStyle','-.','Marker','o', ...
    'MarkerSize',3.5,'MarkerFaceColor','r')
text(P(1)+0.5,1500,'Decision Speed = 67.23 m/s','Interpreter','latex', ...
    'FontSize',20,'Rotation',90)
text(56,P(2)-50,'BFL = 2339.95 m','Interpreter','latex','FontSize',20,'Rotation',0)
hold off
grid on
set(gcf, 'Position', get(0,'ScreenSize'));
leg1 = legend("ASDR","TODR",'Interpreter','latex','Location','northwest','FontSize',20);
xlabel("Velocity (m/s)",'Interpreter','latex','FontSize',25)
ylabel("Distance (m)",'Interpreter','latex','FontSize',25)
title(leg1,'Legend')
set(gca,'Box','on');
ax = gca;
xticks(55:2.5:95)
ylim([1400 3400])
xlim([55 95])
ax.FontSize = 20;
ax.TickDir = 'out';
ax.TickLength = [0.005 0.005];
%% ASDR for 1.5 km
sigma_15 = sigma(151);
T = t_sl*sigma_15;
Vstall = ((2*0.9*WTO)/(1.225*sigma_15*S*(1.15+1.15)))^0.5;
Vr = 1.2*Vstall;
v_asdr_9 = zeros([400 8]);
a = zeros([400 8]);
s_asdr_9 = zeros([400 8]);
t_asdr_9 = zeros([400 8]);
del_v = zeros([400 8]);
del_s = zeros([400 8]);
q = zeros([400 8]);
D = zeros([400 8]);
L = zeros([400 8]);
x = 0.65;
z = 1;
condition = true;
```

```
% loop
while condition == true
    i = 1;
    while v_asdr_9(i,z) ≤ x*Vr           % loop to find T/O parameters till failure
        q(i,z) = 0.5*1.225*sigma_15*v_asdr_9(i,z)^2;
        L(i,z) = q(i,z)*S*0.12;
        D(i,z) = q(i,z)*S*CD_TO;
        a(i,z) = ((T - D(i,z) - mu*((0.9*WTO)-L(i,z)))*g)/(0.9*WTO);
        del_v(i,z) = a(i,z)*0.25;
        del_s(i,z) = v_asdr_9(i,z)*0.25 + 0.5*a(i,z)*0.25^2;
        v_asdr_9(i+1,z) = v_asdr_9(i,z) +  del_v(i,z);
        s_asdr_9(i+1,z) = s_asdr_9(i,z) + del_s(i,z);
        t_asdr_9(i+1,z) = t_asdr_9(i,z) + 0.25;
        i = i+1;
    end
    j = i;
    v_asdr_9(j) = x*Vr;
    s_asdr_9(j) = s_asdr_9(i);
    q(j) = q(i);
    L(j) = L(i);
    D(j) = D(i);
    t_asdr_9(j) = t_asdr_9(i);
    while j < i + 12                  % loop to find T/O paramters during decision phase
        q(j,z) = 0.5*1.225*sigma_15*v_asdr_9(j,z)^2;
        L(j,z) = q(j,z)*S*0.12;
        D(j,z) = q(j,z)*S*CD_TO;
        a(j,z) = ((0.75*T - D(i,z) - mu*((0.9*WTO)-L(i,z)))*g)/(0.9*WTO);
        del_v(j,z) = a(j,z)*0.25;
        del_s(j,z) = v_asdr_9(j,z)*0.25 + 0.5*a(j,z)*0.25^2;
        v_asdr_9(j+1,z) = v_asdr_9(j,z) + del_v(j,z);
        s_asdr_9(j+1,z) = s_asdr_9(j) + del_s(j,z);
        t_asdr_9(j+1,z) = t_asdr_9(j,z) + 0.25;
        j = j+1;
    end
    k = j;
    v_asdr_9(k) = x*Vr;
    s_asdr_9(k) = s_asdr_9(j);
    q(k) = q(j);
    L(k) = L(j);
    D(k) = D(j);
    t_asdr_9(k) = t_asdr_9(j);
    while v_asdr_9(k,z) ≥ 0              % loop to find T/O parameters during deceleration phase
        q(k,z) = 0.5*1.225*sigma_15*v_asdr_9(k,z)^2;
        L(k,z) = q(k,z)*S*0.12;
        D(k,z) = q(k,z)*S*CD_TO;
        a(k,z) = -2.4525;
        del_v(k,z) = a(k,z)*0.25;
        del_s(k,z) = v_asdr_9(k,z)*0.25 + 0.5*a(k,z)*0.25^2;
        v_asdr_9(k+1,z) = v_asdr_9(k,z) + del_v(k,z);
        s_asdr_9(k+1,z) = s_asdr_9(k,z) + del_s(k,z);
        t_asdr_9(k+1,z) = t_asdr_9(k,z) + 0.25;
        k = k+1;
    end
    if x<1
        x = x + 0.05;
    else
        condition = false;
    end
    z = z + 1;
end
%% TODR for 0.9 WTO and 1.5 km
% Initialisation
% Initialisation
T = t_sl*sigma_15;
Vstall = ((2*WTO*0.9)/(1.225*sigma_15*S*(1.15+1.15)))^0.5;
```

```
Vr = 1.2*Vstall;
a = zeros([400 8]);
s_todr_9 = zeros([400 8]);
v_todr_9 = zeros([400 8]);
t_todr_9 = zeros([400 8]);
del_v = zeros([400 8]);
del_s = zeros([400 8]);
q = zeros([400 8]);
D = zeros([400 8]);
L = zeros([400 8]);
x = 0.65;
z = 1;
condition = true;
% Loop
while condition == true
    i = 1;
    while v_todr_9(i,z) <= x*Vr           % loop to find T/O parameters till failure
        q(i,z) = 0.5*1.225*sigma_15*v_todr_9(i,z)^2;
        L(i,z) = q(i,z)*S*0.12;
        D(i,z) = q(i,z)*S*CD_TO;
        a(i,z) = ((T - D(i,z) - mu*((0.9*WTO)-L(i,z)))*g)/(0.9*WTO);
        del_v(i,z) = a(i,z)*0.25;
        del_s(i,z) = v_todr_9(i,z)*0.25 + 0.5*a(i,z)*0.25^2;
        v_todr_9(i+1,z) = v_todr_9(i,z) +  del_v(i,z);
        s_todr_9(i+1,z) = s_todr_9(i,z) + del_s(i,z);
        t_todr_9(i+1,z) = t_todr_9(i,z) + 0.25;
        i = i+1;
    end
    j = i;
    v_todr_9(j,z) = x*Vr;
    s_todr_9(j,z) = s_todr_9(i,z);
    q(j,z) = q(i,z);
    L(j,z) = L(i,z);
    D(j,z) = D(i,z);
    t_todr_9(j,z) = t_todr_9(i,z);
    while v_todr_9(j,z) <= Vr             % loop to find T/O parameters after failure
        q(j,z) = 0.5*1.225*sigma_15*v_todr_9(j,z)^2;
        L(j,z) = q(j,z)*S*0.12;
        D(j,z) = q(j,z)*S*CD_TO;
        a(j,z) = ((0.75*T - D(j,z) - mu*((0.9*WTO)-L(j,z)))*g)/(0.9*WTO);
        del_v(j,z) = a(j,z)*0.25;
        del_s(j,z) = v_todr_9(j,z)*0.25 + 0.5*a(j,z)*0.25^2;
        v_todr_9(j+1,z) = v_todr_9(j,z) +  del_v(j,z);
        s_todr_9(j+1,z) = s_todr_9(j,z) + del_s(j,z);
        t_todr_9(j+1,z) = t_todr_9(j,z) + 0.25;
        j = j+1;
    end
    if x < 1
        x = x + 0.05;
    else
        condition = false;
    end
    z = z + 1;
end
%% AEO for 0.9 WTO and 1.5 km
% Initialisation
T = t_sl*sigma_15;
Vstall = ((2*0.9*WTO)/(1.225*sigma_15*S*(1.15+1.15)))^0.5;
Vr = 1.2*Vstall;
D_9 = 0.5*1.225*sigma_15*Vr^2*S*CD_TO;
D_9_c = 0.5*1.225*sigma_15*(Vr^2)*S*CD_climb;
% Distance for Rotation
sr_9_15 = 3*Vr;
% Calculation
sing_9_15 = (T-D_9_c)/(0.9*WTO);
```

```
g_9_15 = asind(sing_9_15);
% Distance to Climb
s_c_9_15 = 10.7/tand(g_9_15);
% Time for Rotation
t_r = 3;
% Time to Climb
t_c_9_15 = 10.7/(Vr*tand(g_9));
T = t_sl*sigma_1;
v = zeros([500 1]);
a = zeros([500 1]);
s = zeros([500 1]);
t = zeros([500 1]);
del_v = zeros([500 1]);
del_s = zeros([500 1]);
q = zeros([500 1]);
D = zeros([500 1]);
L = zeros([500 1]);
i = 1;
while v(i) <= Vr                    % loop to find T/O parameters
    q(i) = 0.5*1.225*v(i)^2;
    L(i) = q(i)*S*0.12;
    D(i) = q(i)*S*CD_TO;
    a(i) = ((T - D(i) - mu*((0.8*WTO)-L(i)))*g)/(0.8*WTO);
    del_v(i) = a(i)*0.25;
    del_s(i) = v(i)*0.25 + 0.5*a(i)*0.25^2;
    v(i+1) = v(i) +  del_v(i);
    s(i+1) = s(i) + del_s(i);
    t(i+1) = t(i) + 0.25;
    i = i+1;
end
S_9_15 = s(151)+sr_9_15+s_c_9_15;
T_9_15 = t(151)+t_r+t_c_9_15;
%% BFL for 1.5 Km
V_f = [0.65*Vr 0.70*Vr 0.75*Vr 0.80*Vr 0.85*Vr 0.90*Vr 0.95*Vr Vr];
S_TODR_9 = [3.0536e03 2.9912e03 2.9253e03 2.8372e03 2.7623e03 2.6602e03 2.5674e03 2.4648e03];
S_ASDR_9 = [1.9319e+03 2.3120e03 2.5865e03 2.8272e03 3.0819e03 3.3260e03 3.5592e03 3.7814e03];
hold on
title("\textbf{Balanced Field Length for a Take-Off Altitude of 1.5 km and 0.9 $W_{TO}$}", ...
    "Interpreter","latex",'FontSize',30)
P = InterX([V_f;S_ASDR_9],[V_f;S_TODR_9]);
plot(V_f,S_ASDR_9,'Color',"blue",'LineWidth',1.3,'LineStyle','-')
plot(V_f,S_TODR_9,'Color',"magenta",'LineWidth',1.3,'LineStyle','-')
plot([P(1) P(1)],[1400 P(2)],'Color',"green",'LineWidth',1.3,'LineStyle','--')
plot([0 P(1)],[P(2) P(2)],'Color',"green",'LineWidth',1.3,'LineStyle','--')
plot(P(1),P(2),'Color',"black",'LineWidth',1.5,'LineStyle','-.', ...
    'Marker','o','MarkerSize',3.5,'MarkerFaceColor','r')
text(P(1)+0.5,1900,'Decision Speed = 73.63 m/s','Interpreter', ...
    'latex','FontSize',20,'Rotation',90)
text(56,P(2)-50,'BFL = 2834.93 m','Interpreter','latex','FontSize',20,'Rotation',0)
hold off
grid on
set(gcf, 'Position', get(0,'ScreenSize'));
leg1 = legend("ASDR","TODR",'Interpreter','latex','Location','northwest','FontSize',20);
xlabel("Velocity (m/s)",'Interpreter','latex','FontSize',25)
ylabel("Distance (m)",'Interpreter','latex','FontSize',25)
title(leg1,'Legend')
set(gca,'Box','on');
ax = gca;
xticks(57.5:2.5:95)
ylim([1800 4000])
xlim([55 95])
ax.FontSize = 20;
ax.TickDir = 'out';
ax.TickLength = [0.005 0.005];
%% Landing Distance
```

```
V_stall_8 = sqrt(2*0.8*WTO/((CLmax+CLmax_HLD_full)*S*rho_1));
V_stall_6 = sqrt(2*0.6*WTO/((CLmax+CLmax_HLD_full)*S*rho_1));
V_a_8 = 1.3*V_stall_8;
V_a_6 = 1.3*V_stall_6;
gamma = 3*pi/180;
s_1_8 = 15.2/tan(gamma);
s_1_6 = 15.2/tan(gamma);
s_2_8 = 0.1248*(V_stall_8^2)*gamma;
s_2_6 = 0.1248*(V_stall_6^2)*gamma;
s_3_8 = 3*V_a_8;
s_3_6 = 3*V_a_6;
s_4_8 = V_a_8^2/(2*2.5);
s_4_6 = V_a_6^2/(2*2.5);
s_8 = s_1_8 + s_2_8 + s_3_8 + s_4_8;
s_6 = s_1_6 + s_2_6 + s_3_6 + s_4_6;
%% PLOT 6 Payload v/s Range
MTOW = (WEmpty*1000)+(0.95*WFuel*1000)+(0.95*WPayLoad*1000);
TSFC = (47.5*9.81*(Theta(1201)^0.5))/(3600*1000);
% Weights
WA = MTOW - (0.05*WFuel*1000);
WB = MTOW - (0.93*WFuel*1000);
MTOW = (WEmpty*1000)+(1.3*0.95*WFuel*1000)+(0.95*WPayLoad*1000);
WE = MTOW - (0.05*WFuel*1000);
WC = MTOW - (1.23*WFuel*1000);
WF = (MTOW - ((1/3)*(0.95*WPayLoad*1000))) - (0.05*WFuel*1000);
WG= (MTOW - ((1/3)*(0.95*WPayLoad*1000))) - (1.23*WFuel*1000);
WH= (MTOW - ((2/3)*(0.95*WPayLoad*1000))) - (0.05*WFuel*1000);
WI= (MTOW - ((2/3)*(0.95*WPayLoad*1000))) - (1.23*WFuel*1000);
WO = (MTOW - ((0.95*WPayLoad*1000))) - (0.05*WFuel*1000);
WD = (MTOW - ((0.95*WPayLoad*1000))) - (1.23*WFuel*1000);

WPLA = 0.95*WPayLoad*1000;
WPLE = (0.95*WPayLoad*1000) - (0.3*0.95*WFuel*1000);
WPLF = (2/3)*WPLE;
WPLH = (1/3)*WPLE;
WPLO = 0;
% Cruise Calculation
CL_Cruise = sqrt(CDo/k);
% V_Cruise = sqrt(((2*MTOW)/(rho(1201)*S))*(1/CL_Cruise));
CD_Cruise = 2*CDo;
V_crit = a(1201)*Mcrit_orig;
V_Cruise = V_crit;
% Ranges
R_1 = ((2/TSFC)*sqrt(2/(rho(1201)*S))*(3/4)*(1/(3*k*(CDo^3)))^(1/4)* ...
    (sqrt(WA) - sqrt(WB)))/1000;
R_2 = ((2/TSFC)*sqrt(2/(rho(1201)*S))*(3/4)*(1/(3*k*(CDo^3)))^(1/4)* ...
    (sqrt(WE) - sqrt(WC)))/1000;
R_3 = ((2/TSFC)*sqrt(2/(rho(1201)*S))*(3/4)*(1/(3*k*(CDo^3)))^(1/4)* ...
    (sqrt(WF) - sqrt(WG)))/1000;
R_4 = ((2/TSFC)*sqrt(2/(rho(1201)*S))*(3/4)*(1/(3*k*(CDo^3)))^(1/4)* ...
    (sqrt(WH) - sqrt(WI)))/1000;
R_5 = ((2/TSFC)*sqrt(2/(rho(1201)*S))*(3/4)*(1/(3*k*(CDo^3)))^(1/4)* ...
    (sqrt(WO) - sqrt(WD)))/1000;
% Breguet Ranges
R_1_B = ((V_Cruise/TSFC)*(CL_Cruise/CD_Cruise)*log(WA/WB))/1000;
R_2_B = ((V_Cruise/TSFC)*(CL_Cruise/CD_Cruise)*log(WE/WC))/1000;
R_3_B = ((V_Cruise/TSFC)*(CL_Cruise/CD_Cruise)*log(WF/WG))/1000;
R_4_B = ((V_Cruise/TSFC)*(CL_Cruise/CD_Cruise)*log(WH/WI))/1000;
R_5_B = ((V_Cruise/TSFC)*(CL_Cruise/CD_Cruise)*log(WO/WD))/1000;

%% Plotting Payload v/s Range
hold on
title("\textbf{Payload v/s Range Diagram for a Cruise Altitude of 12 km}", ...
    "Interpreter","latex",'FontSize',30)
xlim([0 4.5e4])
```

```
ylim([0 16e5])
xlabel("Range (km)",'Interpreter','latex','FontSize',25)
ylabel("Payload (N)",'Interpreter','latex','FontSize',25)
% Lines
plot([0 R_1],[WPLA WPLA],'Color',"blue",'LineWidth',1.3,'LineStyle','-')
plot([0 R_2],[WPLE WPLE],'Color',"magenta",'LineWidth',1.3,'LineStyle','--')
plot([0 R_3],[WPLF WPLF],'Color',"magenta",'LineWidth',1.3,'LineStyle','--')
plot([0 R_4],[WPLH WPLH],'Color',"magenta",'LineWidth',1.3,'LineStyle','--')
plot([0 R_5],[WPLO WPLO],'Color',"magenta",'LineWidth',1.3,'LineStyle','--')
plot([R_1 R_2],[WPLA WPLE],'Color',"blue",'LineWidth',1.3,'LineStyle','-')
plot([R_2 R_3],[WPLE WPLF],'Color',"blue",'LineWidth',1.3,'LineStyle','-')
plot([R_3 R_4],[WPLF WPLH],'Color',"blue",'LineWidth',1.3,'LineStyle','-')
plot([R_4 R_5],[WPLH WPLO],'Color',"blue",'LineWidth',1.3,'LineStyle','-')
% Text
text(R_1+1000,WPLA+100,'B','Interpreter','latex','FontSize',20)
text(R_2+1000,WPLE+100,'C','Interpreter','latex','FontSize',20)
text(R_3+1000,WPLF+100,'G','Interpreter','latex','FontSize',20)
text(R_4+1000,WPLH+100,'I','Interpreter','latex','FontSize',20)
text(R_5+100,WPLO+50000,'D','Interpreter','latex','FontSize',20)
text(1000,WPLA+50000,'A','Interpreter','latex','FontSize',20)
text(1000,WPLE+50000,'E','Interpreter','latex','FontSize',20)
text(1000,WPLF+50000,'F','Interpreter','latex','FontSize',20)
text(1000,WPLH+50000,'H','Interpreter','latex','FontSize',20)
text(1000,WPLO+50000,'O','Interpreter','latex','FontSize',20)
xticks(0.5e4:0.5e4:6e4)
% Markers
plot(R_1,WPLA,'Color',"black",'LineWidth',1.5,'LineStyle','-.', ...
    'Marker','o','MarkerSize',3.5,'MarkerFaceColor','r')
plot(R_2,WPLE,'Color',"black",'LineWidth',1.5,'LineStyle','-.', ...
    'Marker','o','MarkerSize',3.5,'MarkerFaceColor','r')
plot(R_3,WPLF,'Color',"black",'LineWidth',1.5,'LineStyle','-.', ...
    'Marker','o','MarkerSize',3.5,'MarkerFaceColor','r')
plot(R_4,WPLH,'Color',"black",'LineWidth',1.5,'LineStyle','-.', ...
    'Marker','o','MarkerSize',3.5,'MarkerFaceColor','r')
plot(R_5,WPLO,'Color',"black",'LineWidth',1.5,'LineStyle','-.', ...
    'Marker','o','MarkerSize',3.5,'MarkerFaceColor','r')
plot(0,WPLA,'Color',"black",'LineWidth',1.5,'LineStyle','-.', ...
    'Marker','o','MarkerSize',3.5,'MarkerFaceColor','r')
plot(0,WPLE,'Color',"black",'LineWidth',1.5,'LineStyle','-.', ...
    'Marker','o','MarkerSize',3.5,'MarkerFaceColor','r')
plot(0,WPLF,'Color',"black",'LineWidth',1.5,'LineStyle','-.', ...
    'Marker','o','MarkerSize',3.5,'MarkerFaceColor','r')
plot(0,WPLH,'Color',"black",'LineWidth',1.5,'LineStyle','-.', ...
    'Marker','o','MarkerSize',3.5,'MarkerFaceColor','r')
plot(0,WPLO,'Color',"black",'LineWidth',1.5,'LineStyle','-.', ...
    'Marker','o','MarkerSize',3.5,'MarkerFaceColor','r')
grid on
hold off
set(gcf, 'Position', get(0,'ScreenSize'));
set(gca,'Box','on');
ax = gca;
ax.FontSize = 20;
ax.TickDir = 'out';
%% Plotting Payload v/s Breguet Range
hold on
title("\textbf{Payload v/s Breguet Range Diagram for a Cruise Altitude" + ...
    " of 12 km}","Interpreter","latex",'FontSize',30)
xlim([0 4.5e4])
ylim([0 16e5])
xlabel("Range (km)",'Interpreter','latex','FontSize',25)
ylabel("Payload (N)",'Interpreter','latex','FontSize',25)
% Lines
plot([0 R_1_B],[WPLA WPLA],'Color',"blue",'LineWidth',1.3,'LineStyle','-')
plot([0 R_2_B],[WPLE WPLE],'Color',"magenta",'LineWidth',1.3,'LineStyle','--')
plot([0 R_3_B],[WPLF WPLF],'Color',"magenta",'LineWidth',1.3,'LineStyle','--')
```

```
plot([0 R_4_B],[WPLH WPLH],'Color',"magenta",'LineWidth',1.3,'LineStyle','--')
plot([0 R_5_B],[WPLO WPLO],'Color',"magenta",'LineWidth',1.3,'LineStyle','--')
plot([R_1_B R_2_B],[WPLA WPLE],'Color',"blue",'LineWidth',1.3,'LineStyle','-')
plot([R_2_B R_3_B],[WPLE WPLF],'Color',"blue",'LineWidth',1.3,'LineStyle','-')
plot([R_3_B R_4_B],[WPLF WPLH],'Color',"blue",'LineWidth',1.3,'LineStyle','-')
plot([R_4_B R_5_B],[WPLH WPLO],'Color',"blue",'LineWidth',1.3,'LineStyle','-')
% Text
text(R_1_B+1000,WPLA+100,'B','Interpreter','latex','FontSize',20)
text(R_2_B+1000,WPLE+100,'C','Interpreter','latex','FontSize',20)
text(R_3_B+1000,WPLF+100,'G','Interpreter','latex','FontSize',20)
text(R_4_B+1000,WPLH+100,'I','Interpreter','latex','FontSize',20)
text(R_5_B+100,WPLO+50000,'D','Interpreter','latex','FontSize',20)
text(1000,WPLA+50000,'A','Interpreter','latex','FontSize',20)
text(1000,WPLE+50000,'E','Interpreter','latex','FontSize',20)
text(1000,WPLF+50000,'F','Interpreter','latex','FontSize',20)
text(1000,WPLH+50000,'H','Interpreter','latex','FontSize',20)
text(1000,WPLO+50000,'O','Interpreter','latex','FontSize',20)
xticks(0.5e4:0.5e4:8e4)
% Markers
plot(R_1_B,WPLA,'Color',"black",'LineWidth',1.5,'LineStyle','-.', ...
    'Marker','o','MarkerSize',3.5,'MarkerFaceColor','r')
plot(R_2_B,WPLE,'Color',"black",'LineWidth',1.5,'LineStyle','-.', ...
    'Marker','o','MarkerSize',3.5,'MarkerFaceColor','r')
plot(R_3_B,WPLF,'Color',"black",'LineWidth',1.5,'LineStyle','-.', ...
    'Marker','o','MarkerSize',3.5,'MarkerFaceColor','r')
plot(R_4_B,WPLH,'Color',"black",'LineWidth',1.5,'LineStyle','-.', ...
    'Marker','o','MarkerSize',3.5,'MarkerFaceColor','r')
plot(R_5_B,WPLO,'Color',"black",'LineWidth',1.5,'LineStyle','-.', ...
    'Marker','o','MarkerSize',3.5,'MarkerFaceColor','r')
plot(0,WPLA,'Color',"black",'LineWidth',1.5,'LineStyle','-.', ...
    'Marker','o','MarkerSize',3.5,'MarkerFaceColor','r')
plot(0,WPLE,'Color',"black",'LineWidth',1.5,'LineStyle','-.', ...
    'Marker','o','MarkerSize',3.5,'MarkerFaceColor','r')
plot(0,WPLF,'Color',"black",'LineWidth',1.5,'LineStyle','-.', ...
    'Marker','o','MarkerSize',3.5,'MarkerFaceColor','r')
plot(0,WPLH,'Color',"black",'LineWidth',1.5,'LineStyle','-.', ...
    'Marker','o','MarkerSize',3.5,'MarkerFaceColor','r')
plot(0,WPLO,'Color',"black",'LineWidth',1.5,'LineStyle','-.', ...
    'Marker','o','MarkerSize',3.5,'MarkerFaceColor','r')
grid on
hold off
set(gcf, 'Position', get(0,'ScreenSize'));
set(gca,'Box','on');
ax = gca;
ax.FontSize = 20;
ax.TickDir = 'out';
%% Combined Plot
hold on
title("\textbf{Combined Payload v/s Range Diagram for a Cruise " + ...
    "Altitude of 12 km}","Interpreter","latex",'FontSize',30)
xlim([0 4.5e4])
ylim([0 16e5])
xlabel("Range (km)",'Interpreter','latex','FontSize',25)
ylabel("Payload (N)",'Interpreter','latex','FontSize',25)
% Lines
plot([0 R_1],[WPLA WPLA],'Color',"blue",'LineWidth',1.3,'LineStyle','-')
plot([R_1_B R_2_B],[WPLA WPLE],'Color',"magenta",'LineWidth',1.3,'LineStyle','-')
plot([R_1 R_2],[WPLA WPLE],'Color',"blue",'LineWidth',1.3,'LineStyle','-')
plot([R_2 R_3],[WPLE WPLF],'Color',"blue",'LineWidth',1.3,'LineStyle','-')
plot([R_3 R_4],[WPLF WPLH],'Color',"blue",'LineWidth',1.3,'LineStyle','-')
plot([R_4 R_5],[WPLH WPLO],'Color',"blue",'LineWidth',1.3,'LineStyle','-')
plot([0 R_2],[WPLE WPLE],'Color',"green",'LineWidth',1.3,'LineStyle','--')
plot([0 R_3],[WPLF WPLF],'Color',"green",'LineWidth',1.3,'LineStyle','--')
plot([0 R_4],[WPLH WPLH],'Color',"green",'LineWidth',1.3,'LineStyle','--')
plot([0 R_5],[WPLO WPLO],'Color',"green",'LineWidth',1.3,'LineStyle','--')
```

```
% Markers
plot(R_1,WPLA,'Color',"black",'LineWidth',1.5,'LineStyle','-.', ...
    'Marker','o','MarkerSize',3.5,'MarkerFaceColor','r')
plot(R_2,WPLE,'Color',"black",'LineWidth',1.5,'LineStyle','-.', ...
    'Marker','o','MarkerSize',3.5,'MarkerFaceColor','r')
plot(R_3,WPLF,'Color',"black",'LineWidth',1.5,'LineStyle','-.', ...
    'Marker','o','MarkerSize',3.5,'MarkerFaceColor','r')
plot(R_4,WPLH,'Color',"black",'LineWidth',1.5,'LineStyle','-.', ...
    'Marker','o','MarkerSize',3.5,'MarkerFaceColor','r')
plot(R_5,WPLO,'Color',"black",'LineWidth',1.5,'LineStyle','-.', ...
    'Marker','o','MarkerSize',3.5,'MarkerFaceColor','r')
plot(0,WPLA,'Color',"black",'LineWidth',1.5,'LineStyle','-.', ...
    'Marker','o','MarkerSize',3.5,'MarkerFaceColor','r')
plot(0,WPLE,'Color',"black",'LineWidth',1.5,'LineStyle','-.', ...
    'Marker','o','MarkerSize',3.5,'MarkerFaceColor','r')
plot(0,WPLF,'Color',"black",'LineWidth',1.5,'LineStyle','-.', ...
    'Marker','o','MarkerSize',3.5,'MarkerFaceColor','r')
plot(0,WPLH,'Color',"black",'LineWidth',1.5,'LineStyle','-.', ...
    'Marker','o','MarkerSize',3.5,'MarkerFaceColor','r')
plot(0,WPLO,'Color',"black",'LineWidth',1.5,'LineStyle','-.', ...
    'Marker','o','MarkerSize',3.5,'MarkerFaceColor','r')
grid on
% Text
text(R_1+1000,WPLA+50000,'$B_1$','Interpreter','latex','FontSize',20)
text(R_2+1000,WPLE+50000,'$C_1$','Interpreter','latex','FontSize',20)
text(R_3+1000,WPLF+50000,'$G_1$','Interpreter','latex','FontSize',20)
text(R_4+1000,WPLH+50000,'$I_1$','Interpreter','latex','FontSize',20)
text(R_5+100,WPLO+50000,'$D_1$','Interpreter','latex','FontSize',20)

text(1000,WPLA+50000,'A','Interpreter','latex','FontSize',20)
text(1000,WPLE+50000,'E','Interpreter','latex','FontSize',20)
text(1000,WPLF+50000,'F','Interpreter','latex','FontSize',20)
text(1000,WPLH+50000,'H','Interpreter','latex','FontSize',20)
text(1000,WPLO+50000,'O','Interpreter','latex','FontSize',20)

text(R_1_B+1000,WPLA+50000,'$B_2$','Interpreter','latex','FontSize',20)
text(R_2_B+1000,WPLE+50000,'$C_2$','Interpreter','latex','FontSize',20)
text(R_3_B+1000,WPLF+50000,'$G_2$','Interpreter','latex','FontSize',20)
text(R_4_B+1000,WPLH+50000,'$I_2$','Interpreter','latex','FontSize',20)
text(R_5_B+100,WPLO+50000,'$D_2$','Interpreter','latex','FontSize',20)
% Plotting Payload v/s Breguet Range
hold on
% Lines
plot([0 R_1_B],[WPLA WPLA],'Color',"magenta",'LineWidth',1.3,'LineStyle','-')
plot([R_2_B R_3_B],[WPLE WPLF],'Color',"magenta",'LineWidth',1.3,'LineStyle','-')
plot([R_3_B R_4_B],[WPLF WPLH],'Color',"magenta",'LineWidth',1.3,'LineStyle','-')
plot([R_4_B R_5_B],[WPLH WPLO],'Color',"magenta",'LineWidth',1.3,'LineStyle','-')
% Markers
plot(R_1_B,WPLA,'Color',"black",'LineWidth',1.5,'LineStyle','-.', ...
    'Marker','o','MarkerSize',3.5,'MarkerFaceColor','r')
plot(R_2_B,WPLE,'Color',"black",'LineWidth',1.5,'LineStyle','-.', ...
    'Marker','o','MarkerSize',3.5,'MarkerFaceColor','r')
plot(R_3_B,WPLF,'Color',"black",'LineWidth',1.5,'LineStyle','-.', ...
    'Marker','o','MarkerSize',3.5,'MarkerFaceColor','r')
plot(R_4_B,WPLH,'Color',"black",'LineWidth',1.5,'LineStyle','-.', ...
    'Marker','o','MarkerSize',3.5,'MarkerFaceColor','r')
plot(R_5_B,WPLO,'Color',"black",'LineWidth',1.5,'LineStyle','-.', ...
    'Marker','o','MarkerSize',3.5,'MarkerFaceColor','r')
plot(0,WPLA,'Color',"black",'LineWidth',1.5,'LineStyle','-.', ...
    'Marker','o','MarkerSize',3.5,'MarkerFaceColor','r')
plot(0,WPLE,'Color',"black",'LineWidth',1.5,'LineStyle','-.', ...
    'Marker','o','MarkerSize',3.5,'MarkerFaceColor','r')
plot(0,WPLF,'Color',"black",'LineWidth',1.5,'LineStyle','-.', ...
    'Marker','o','MarkerSize',3.5,'MarkerFaceColor','r')
plot(0,WPLH,'Color',"black",'LineWidth',1.5,'LineStyle','-.', ...
```

```
    'Marker','o','MarkerSize',3.5,'MarkerFaceColor','r')
plot(0,WPLO,'Color',"black",'LineWidth',1.5,'LineStyle','-.', ...
    'Marker','o','MarkerSize',3.5,'MarkerFaceColor','r')
grid on
hold off
xticks(0.5e4:0.5e4:8e4)
set(gcf, 'Position', get(0,'ScreenSize'));
set(gca,'Box','on');
ax = gca;
ax.FontSize = 20;
ax.TickDir = 'out';
ax.TickLength = [0.005 0.005];
leg1 = legend("Range","Breguet Range",'Interpreter','latex','Location', ...
    'northeast','FontSize',20);
title(leg1,'Legend')
```