

Airbus A380-800M, Image Source - SkyBrary Aviation

# Flight Mechanics Project 2022-2023

## Aircraft #8 Airbus A380-800M

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Manipal Institute of Technology

Bachelor of Technology in Aeronautical Engineering

May 9, 2023

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# 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. L<sup>A</sup>T<sub>E</sub>X was 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)	$47.5\sqrt{\theta} \text{ kg/hrkN}$
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 $C_{L_{maxTO}}$
$C_L$ (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
$\Delta C_{D_0 \text{ Landing Gear}}$	0.0042
$\Delta C_{D_0 \text{ Flap}}$	0.0034
Rolling Coefficient $\mu$	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,

$$C_D = C_{D_0} + C_{D_i} + C_{D_{wave}} \quad (1)$$

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,

$$C_D = C_{D_0} + C_{D_i} \quad (2)$$

Substituting the value for  $C_{D_i}$  we get,

$$C_D = C_{D_0} + kC_L^2 \quad (3)$$

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

$$D = (C_{D_0} + kC_L^2) [1/2\rho V^2 S] \quad (4)$$

However, for level flight,

$$C_L = \frac{W}{1/2\rho V^2 S} \quad (5)$$

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

$$D = AV^2 + B/V^2 \quad (6)$$

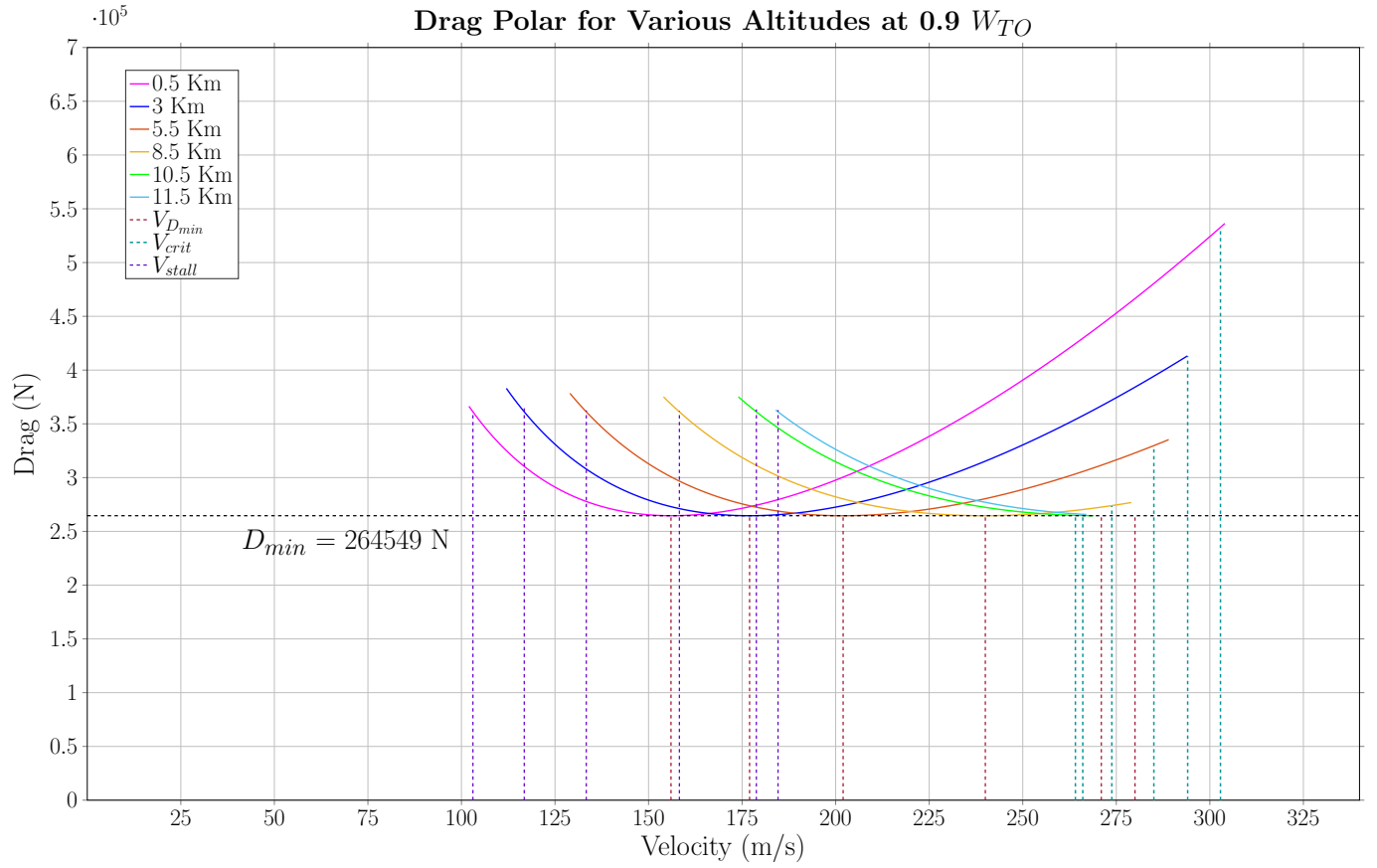
where  $A = C_{D_0}\rho S/2$  and  $B = 2kW^2/\rho S$ . The flight speed for minimum drag  $V_{D_{min}}$  was obtained from the plot. The corresponding minimum drag  $D_{min}$  was identified from the respective drag polars. The flight envelope was defined by the region of the plot between the  $V_{stall}$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

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

$$V_{stall} = \sqrt{\frac{2W_{TO}}{\rho SC_{L_{max}}}} \quad (7)$$

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 $W_{TO}$

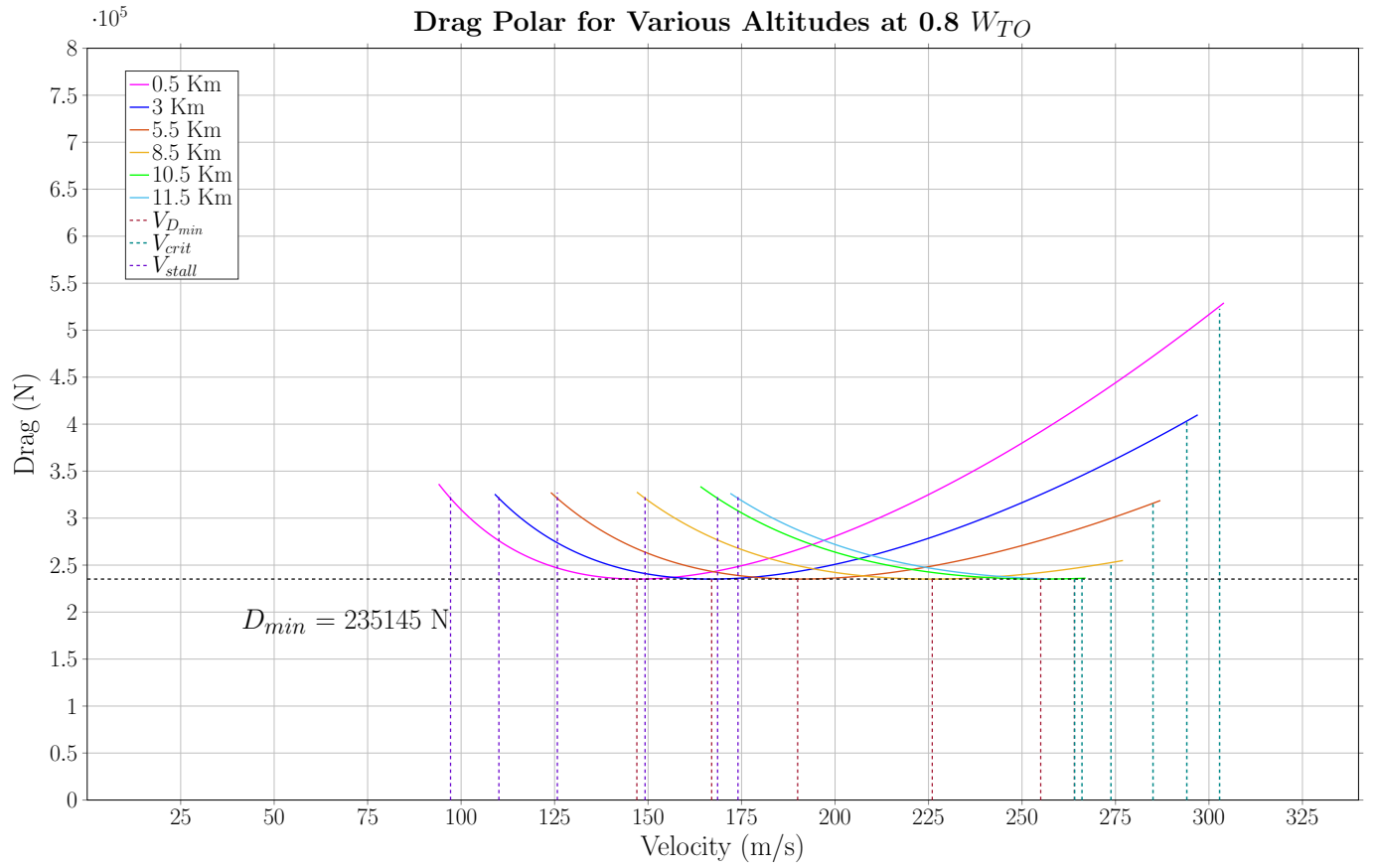


Parameter	Value
Take-off Weight ( $W_{TO}$ )	6025.5 kN
$V_{stall}$ at 0.5 km	103.06 m/s
$V_{stall}$ at 3 km	116.78 m/s
$V_{stall}$ at 5.5 km	133.36 m/s
$V_{stall}$ at 8.5 km	158.24 m/s
$V_{stall}$ at 10.5 km	178.81 m/s
$V_{stall}$ at 11.5 km	184.60 m/s
$V_{D_{min}}$ at 0.5 km	156 m/s
$V_{D_{min}}$ at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

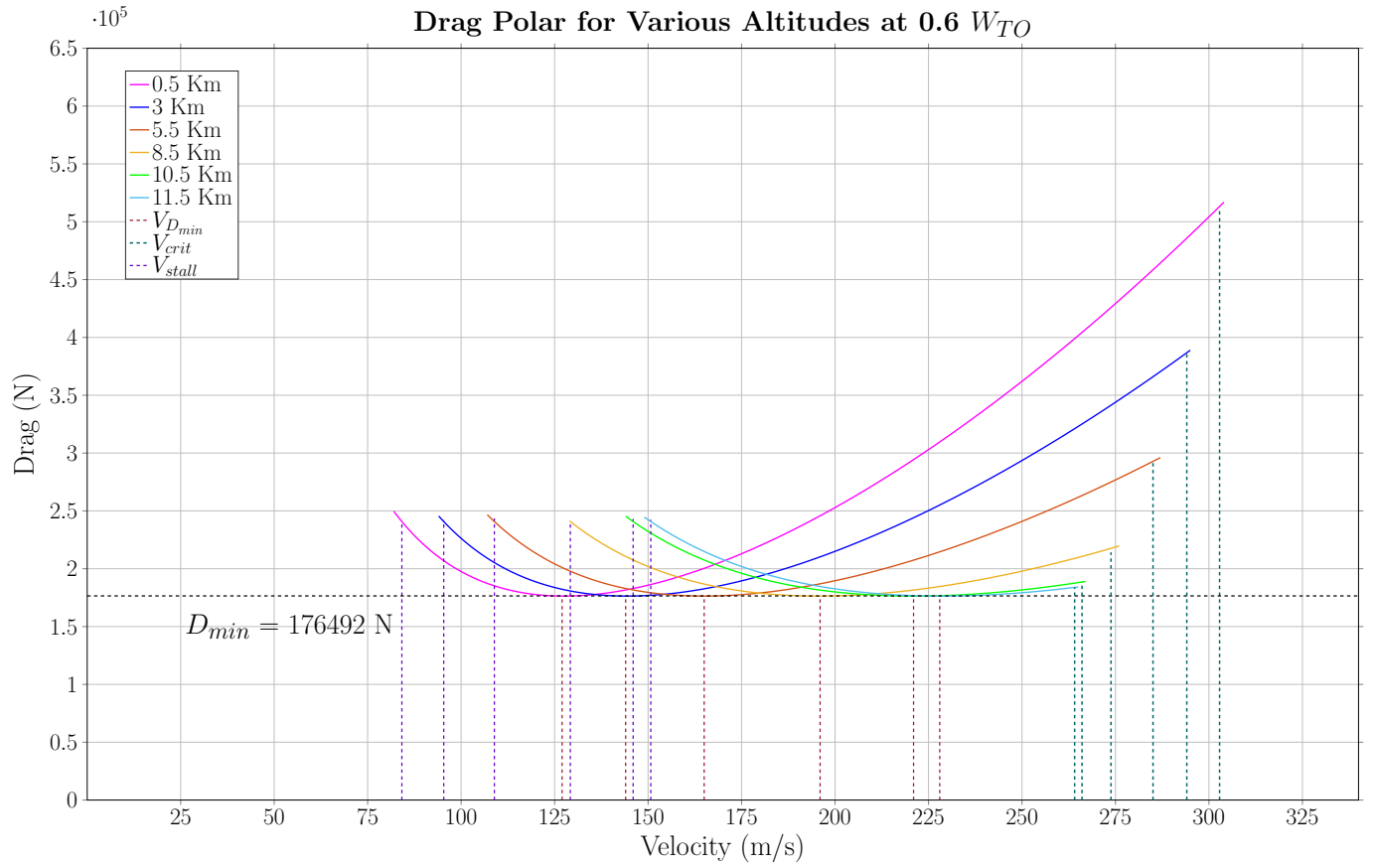


Parameter	Value
Take-off Weight ( $W_{TO}$ )	5356 kN
$V_{stall}$ at 0.5 km	97.17 m/s
$V_{stall}$ at 3 km	110.10 m/s
$V_{stall}$ at 5.5 km	125.73 m/s
$V_{stall}$ at 8.5 km	149.19 m/s
$V_{stall}$ at 10.5 km	168.58 m/s
$V_{stall}$ at 11.5 km	174.04 m/s
$V_{D_{min}}$ at 0.5 km	147 m/s
$V_{D_{min}}$ at 3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



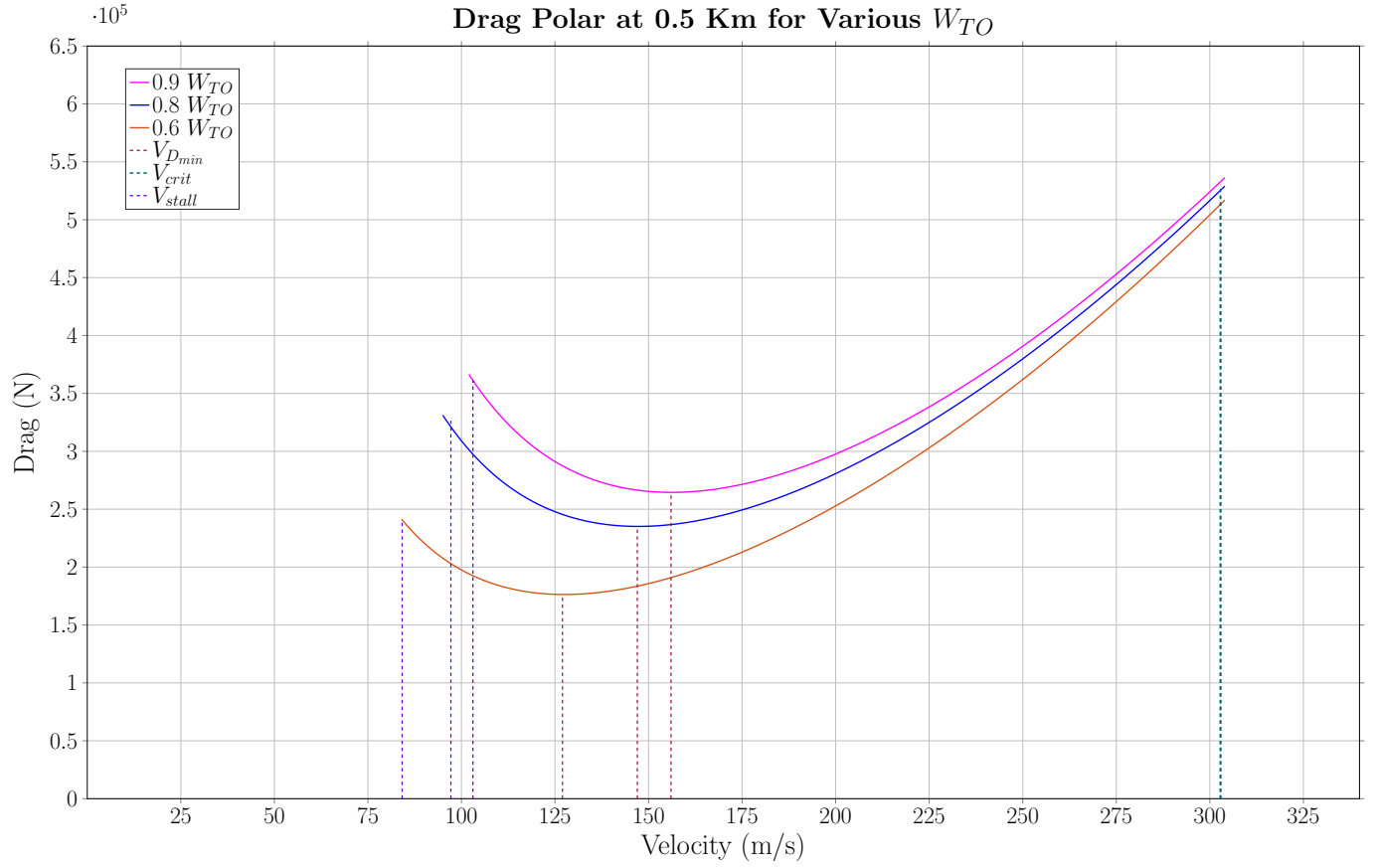
Parameter	Value
Take-off Weight ( $W_{TO}$ )	4017 kN
$V_{stall}$ at 0.5 km	84.15 m/s
$V_{stall}$ at 3 km	95.35 m/s
$V_{stall}$ at 5.5 km	108.88 m/s
$V_{stall}$ at 8.5 km	129.20 m/s
$V_{stall}$ at 10.5 km	145.99 m/s
$V_{stall}$ at 11.5 km	150.72 m/s
$V_{Dmin}$ at 0.5 km	127 m/s
$V_{Dmin}$ at 3 km	144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

Parameter	Value
Take-off Weight ( $W_{TO}$ )	4017 kN
$V_{Dmin}$ at 8.5 km	196 m/s
$V_{Dmin}$ at 10.5 km	221 m/s
$V_{Dmin}$ 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  $W_{TO}$



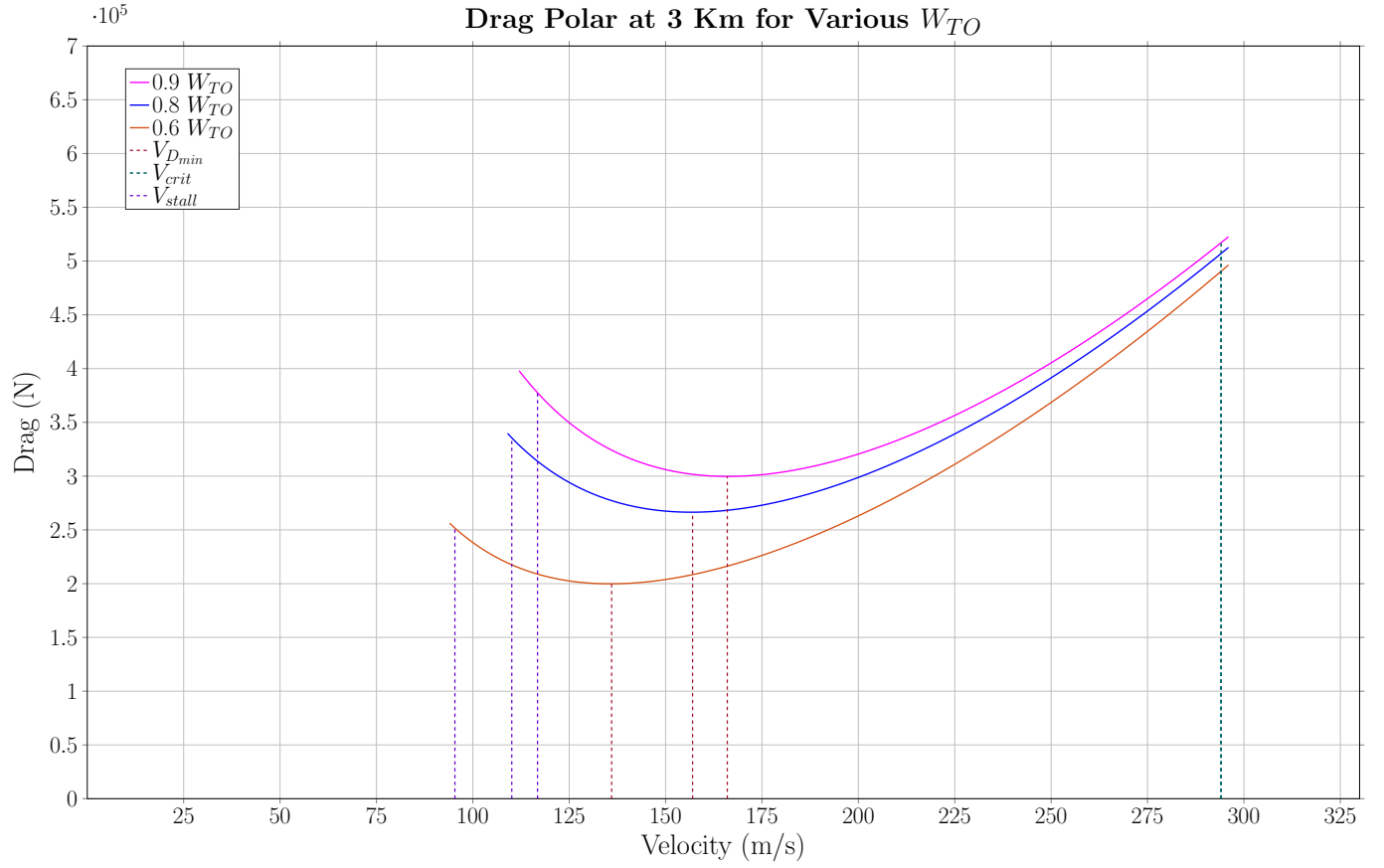
## 2.5 Drag Polar for 0.5 km



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

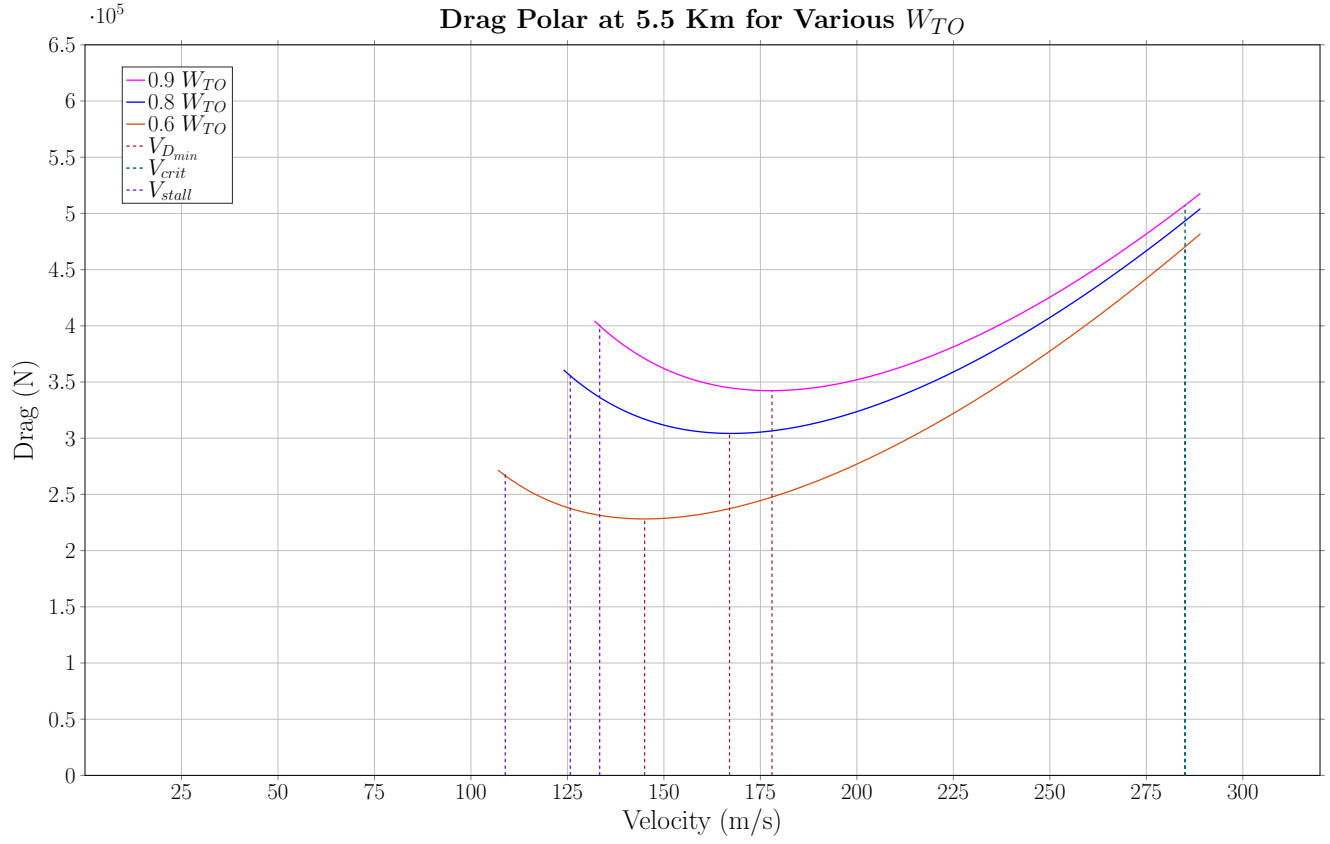
## 2.6 Drag Polar for 3 km



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

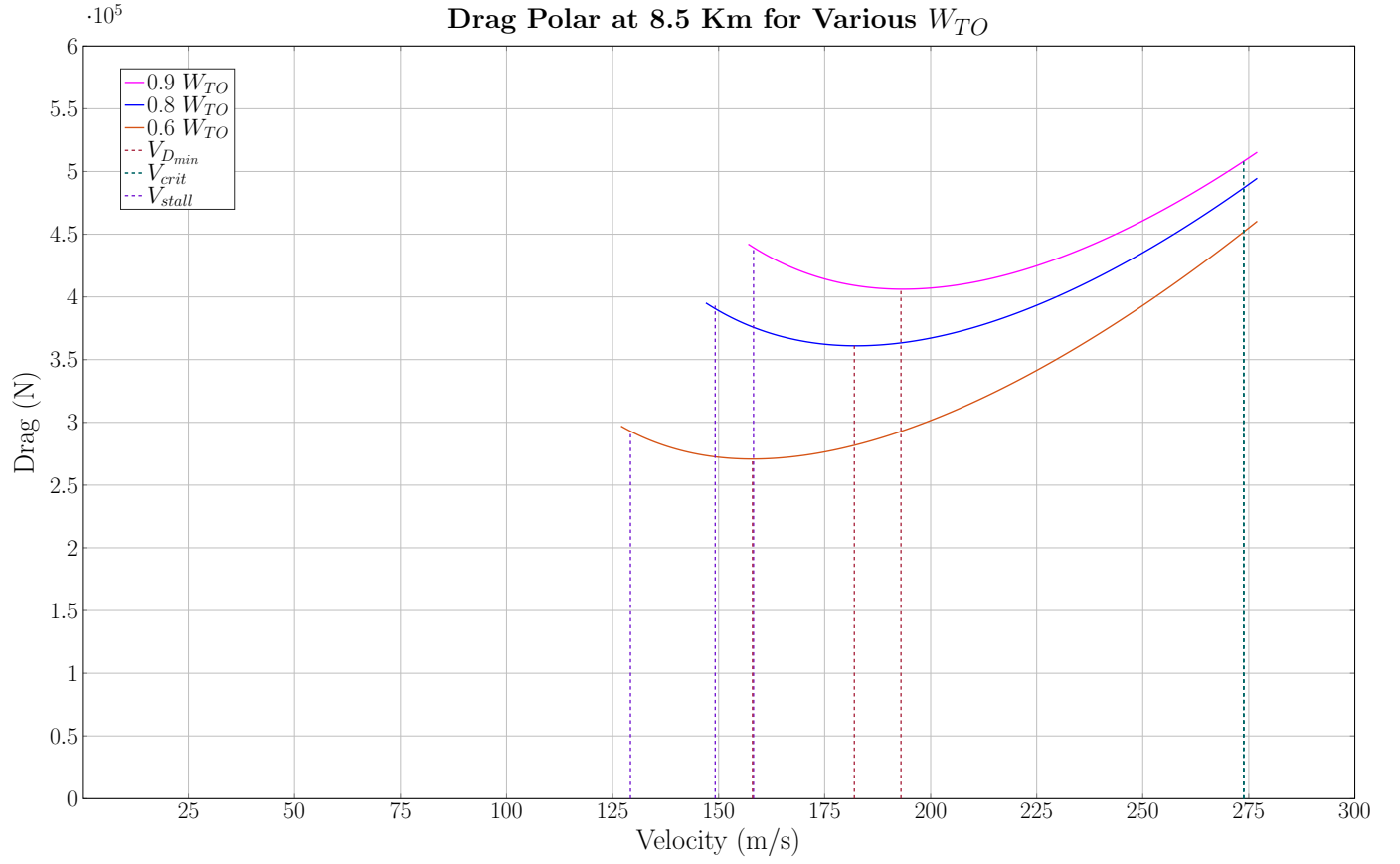
## 2.7 Drag Polar for 5.5 km



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

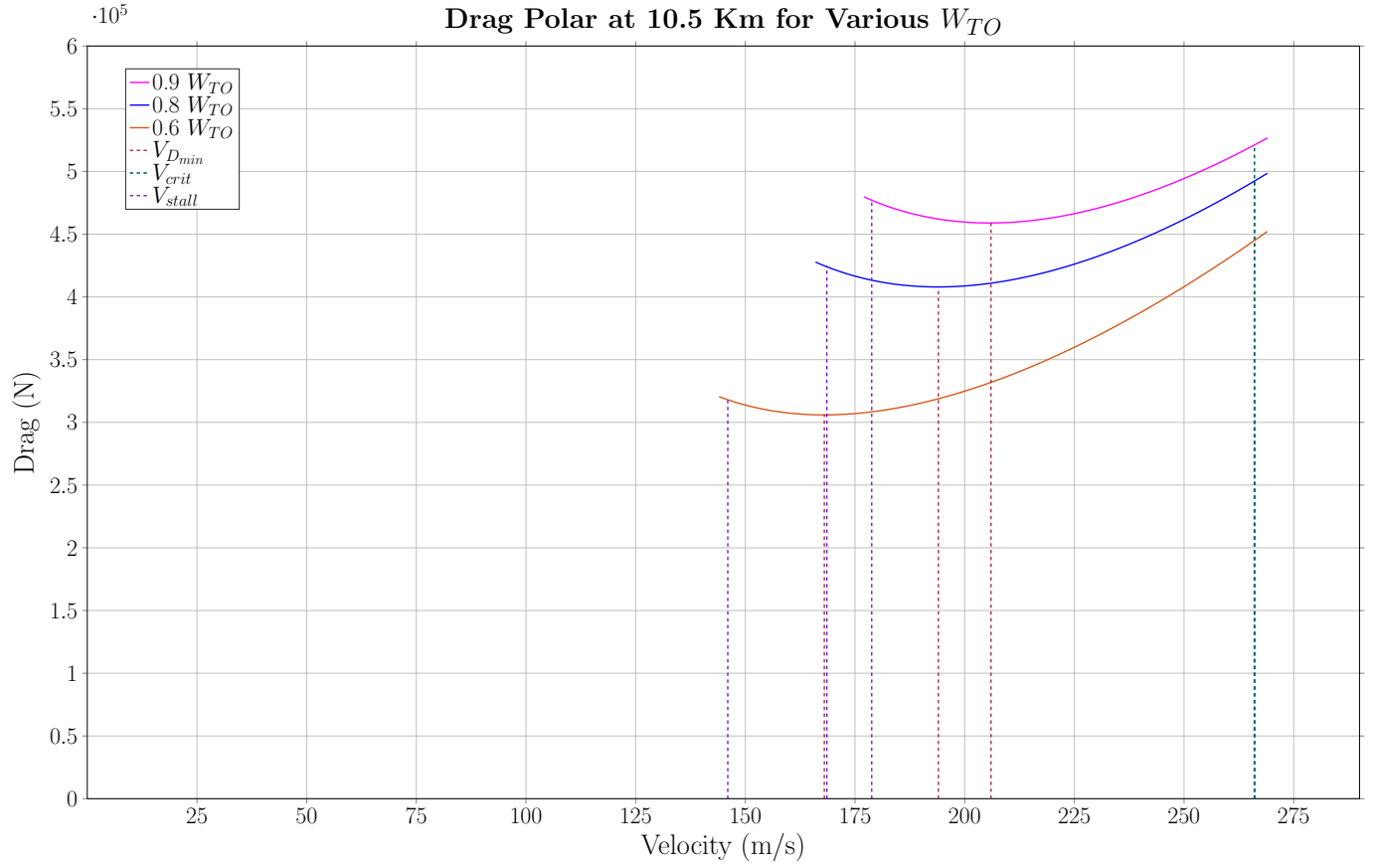
## 2.8 Drag Polar for 8.5 km



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

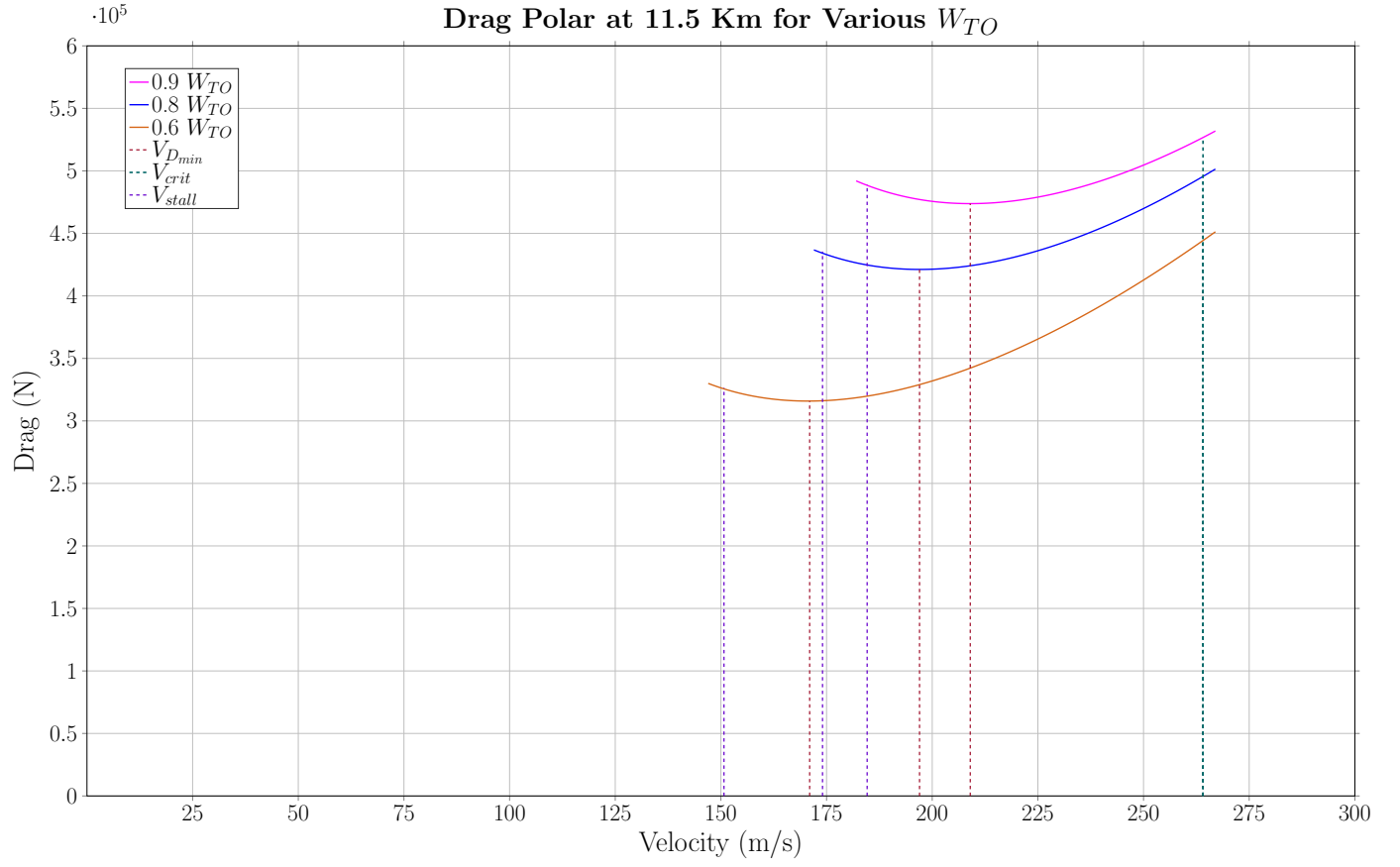
## 2.9 Drag Polar for 10.5 km



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,

$$D = AV^2 + B/V^2 = T_{ASL}\sigma^m \quad (8)$$

where  $A = C_{D0}\rho S/2$  and  $B = 2kW^2/\rho S$ .  $T_{ASL}$  is the thrust at sea level,  $\sigma$  is the density ratio and  $m \leq 1$ . A quadratic equation in  $V^2$  is obtained,

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

Solving this, two values of V are obtained,

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

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

$$(T_{ASL}\sigma_{abs}^m)^2 = 4AB = 4kC_{D0}W^2 \quad (11)$$

From equation 11 we get  $\sigma_{abs}$  as,

$$\sigma_{abs} = \frac{2\sqrt{kC_{D0}}}{(T_{ASL}/W)^m} \quad (12)$$

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

$$\sigma = \frac{\rho_h}{\rho_{SL}} \quad (13)$$

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

$$q = \frac{1}{2}\rho V^2 \quad (14)$$

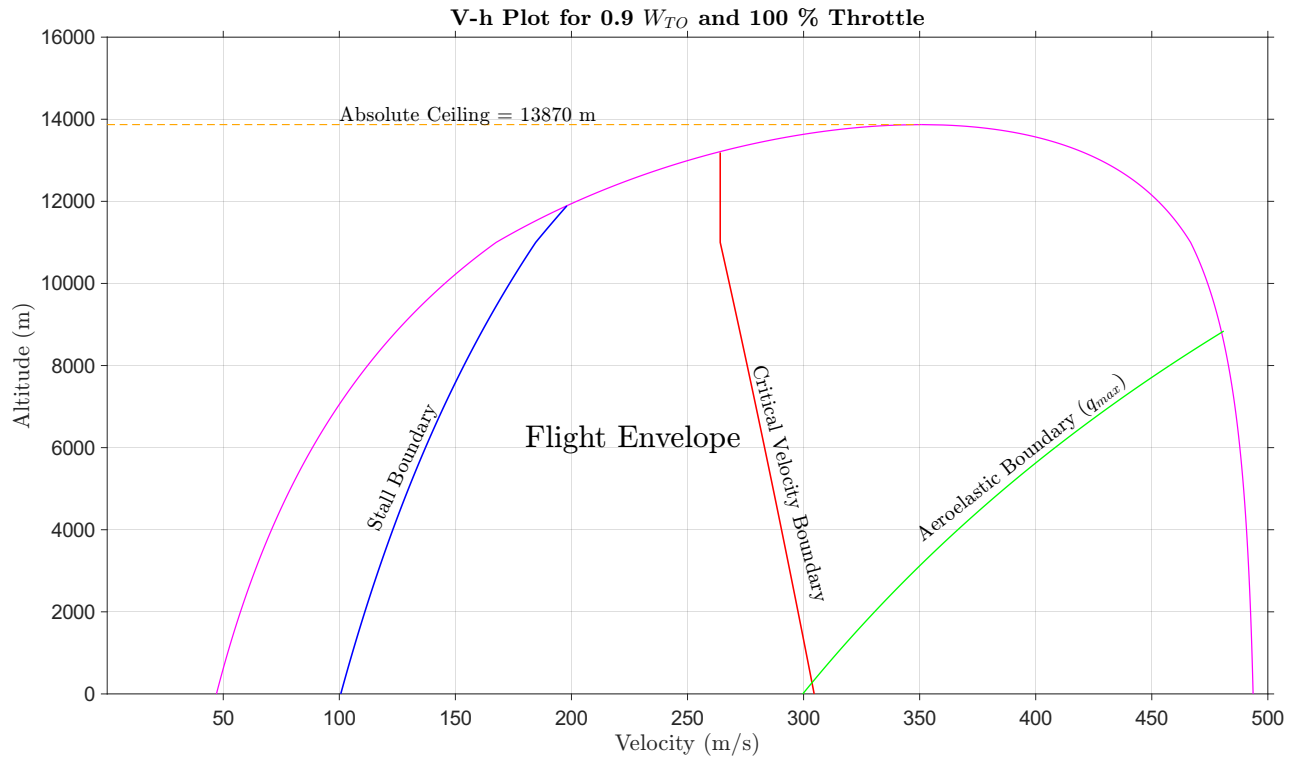
To plot the aeroelastic or the  $q_{max}$  boundary, the density is varied based on altitude, and the velocity can be obtained since  $q = q_{max}$  is constant.

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

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

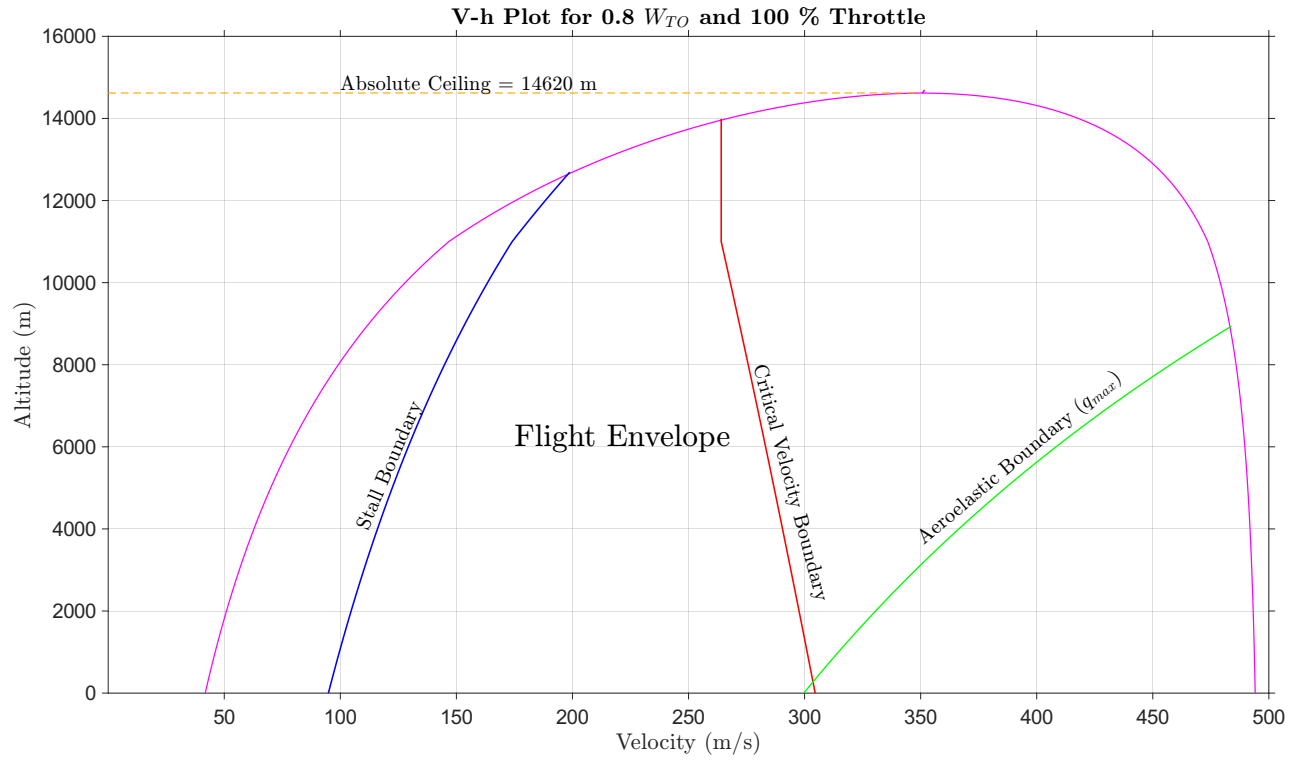
The critical velocity ( $V_{crit}$ ) was calculated from the initial value at sea level by varying the speed of sound according to the altitude.

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

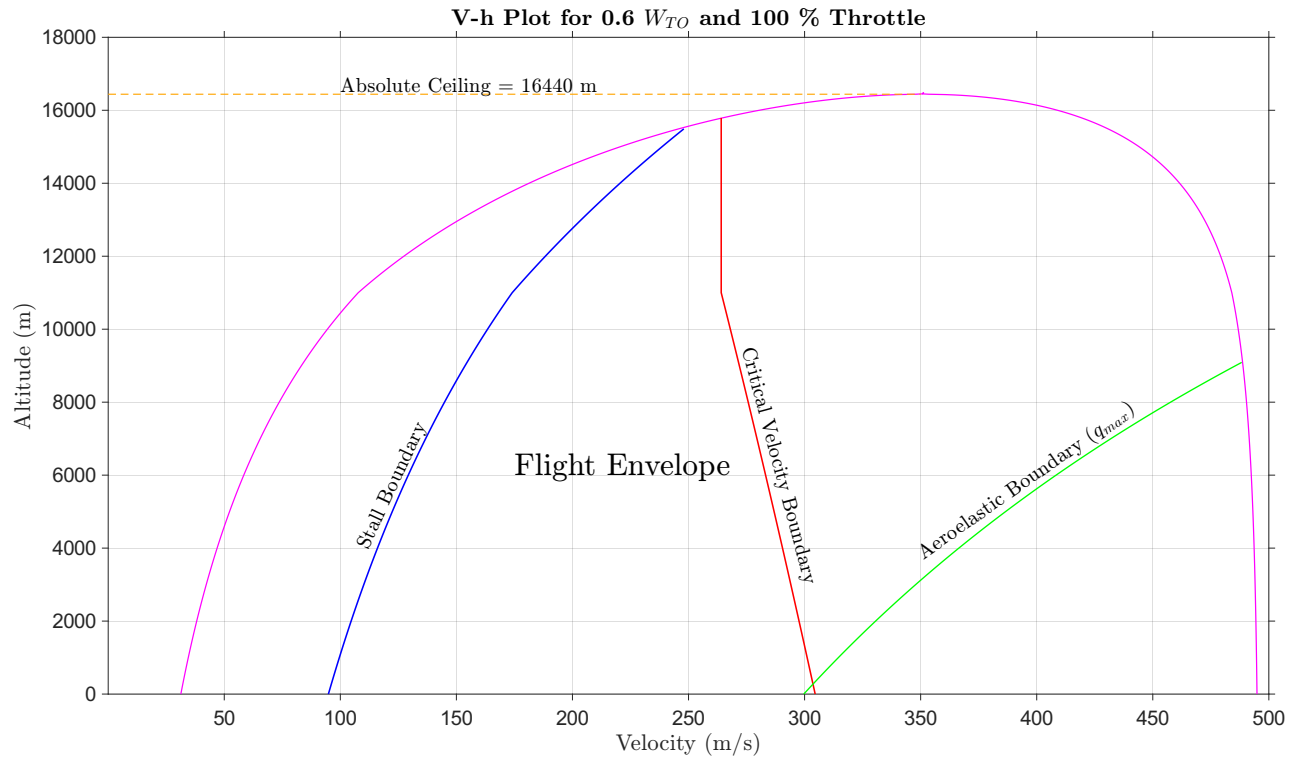




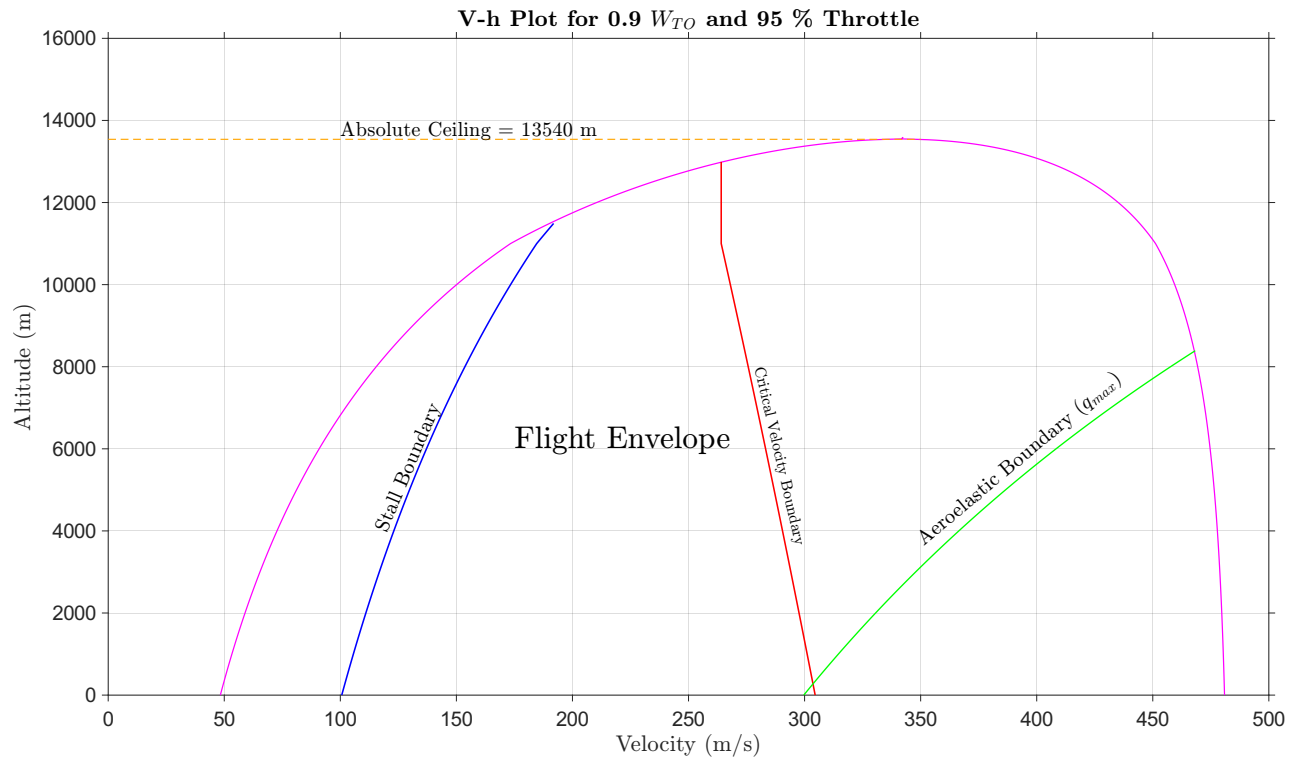
### 3.3 V-h Plot for 0.8 $W_{TO}$ and 100% Throttle



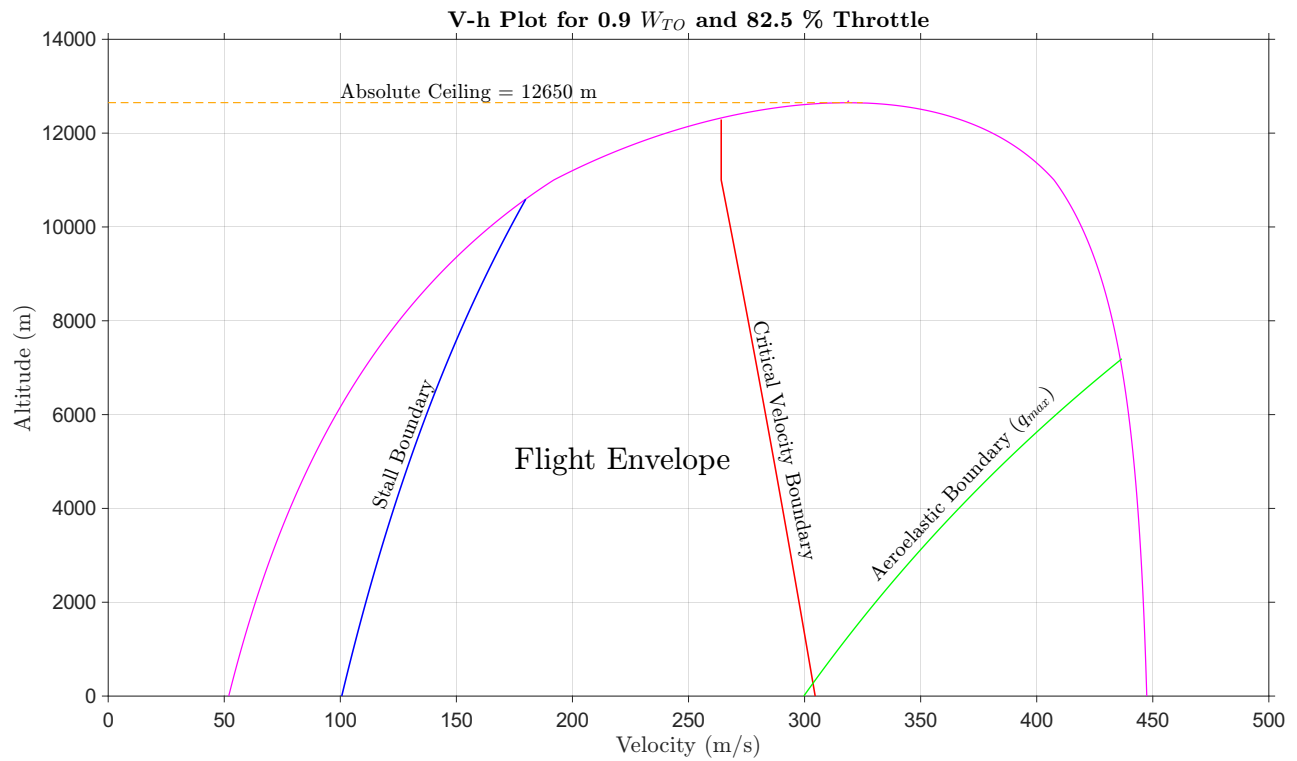
### 3.4 V-h Plot for 0.6 $W_{TO}$ and 100% Throttle



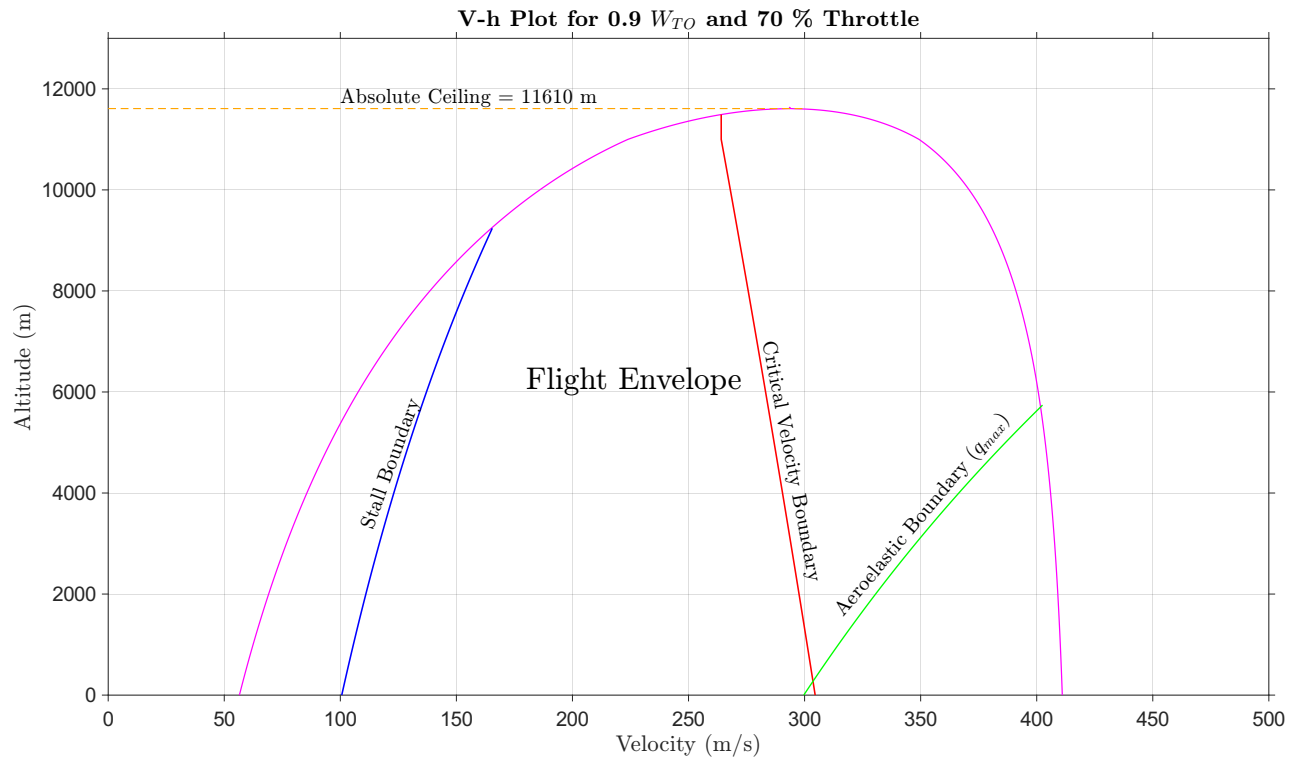
### 3.5 V-h Plot for 0.9 $W_{TO}$ and 95% Throttle



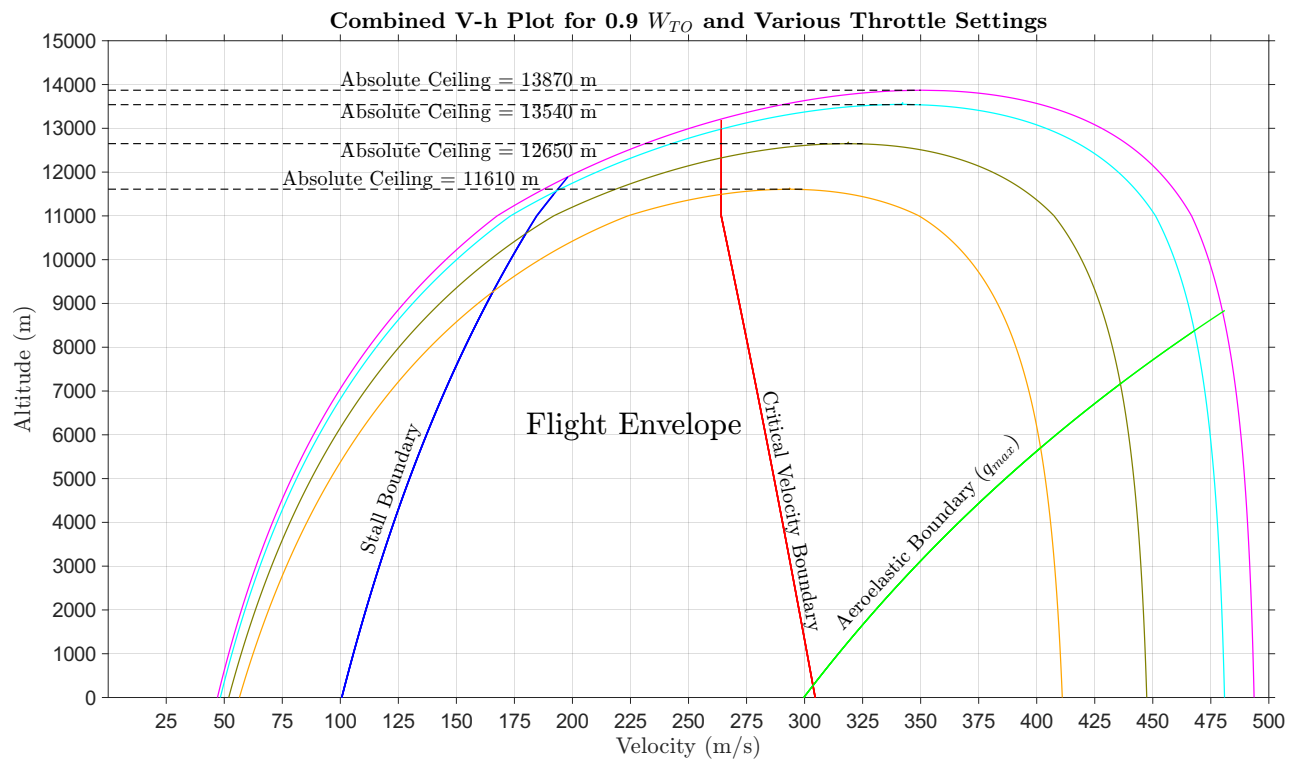
### 3.6 V-h Plot for 0.9 $W_{TO}$ and 82.5% Throttle



### 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,

$$P_{avb} = Thrust \times V \quad (16)$$

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

$$P_{reqd} = Drag \times V \quad (17)$$

The power difference for flight ( $\Delta P$ ) is given by,

$$\Delta P = P_{avb} - P_{reqd} \quad (18)$$

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

$$R/C = \frac{\Delta P}{W} \quad (19)$$

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,

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

The density ratio at the absolute altitude  $\sigma_{abs}$  can be written as,

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

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

$$\sigma = \frac{\rho_h}{\rho_0} \quad (22)$$

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,

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

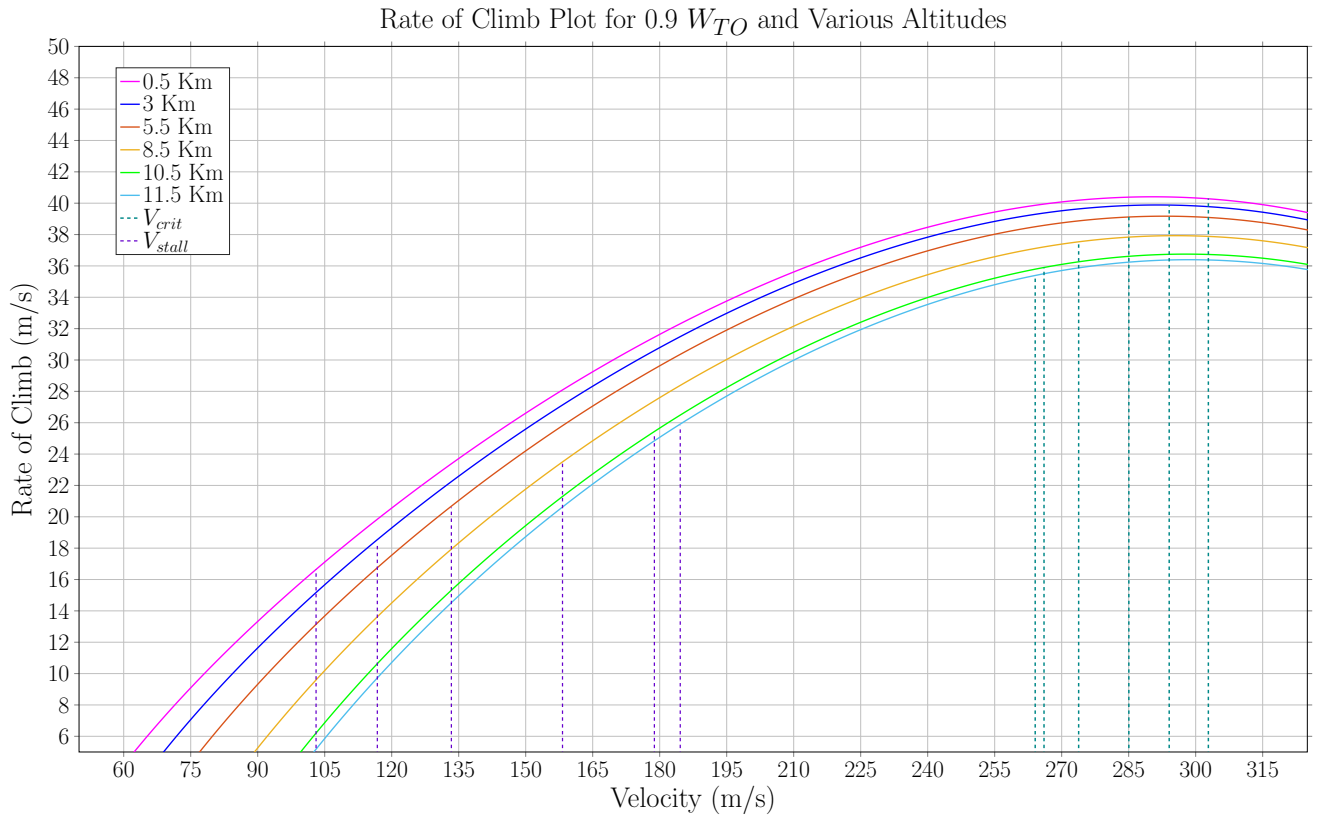
The critical velocity ( $V_{crit}$ ) was calculated from the initial value at sea level by varying the speed of sound according to the altitude.

The time to climb can be calculated from the relation,

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

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

## 4.2 Rate Of Climb Plot for 0.9 $W_{TO}$

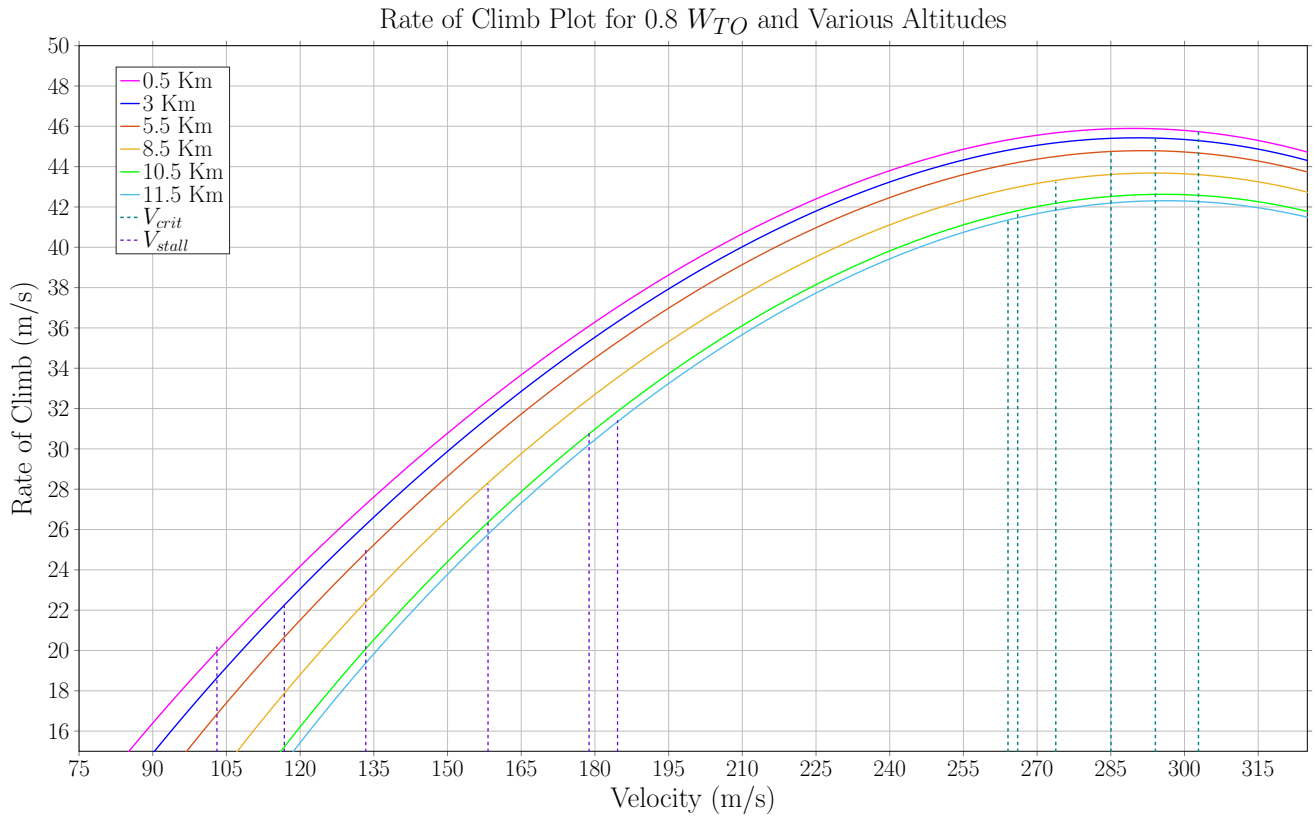


Parameter	Value
Take-off Weight ( $W_{TO}$ )	6025.5 kN
$V_{stall}$ at 0.5 km	103.06 m/s
$V_{stall}$ at 3 km	116.78 m/s
$V_{stall}$ at 5.5 km	133.36 m/s
$V_{stall}$ at 8.5 km	158.24 m/s
$V_{stall}$ at 10.5 km	178.81 m/s
$V_{stall}$ at 11.5 km	184.60 m/s

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 $W_{TO}$

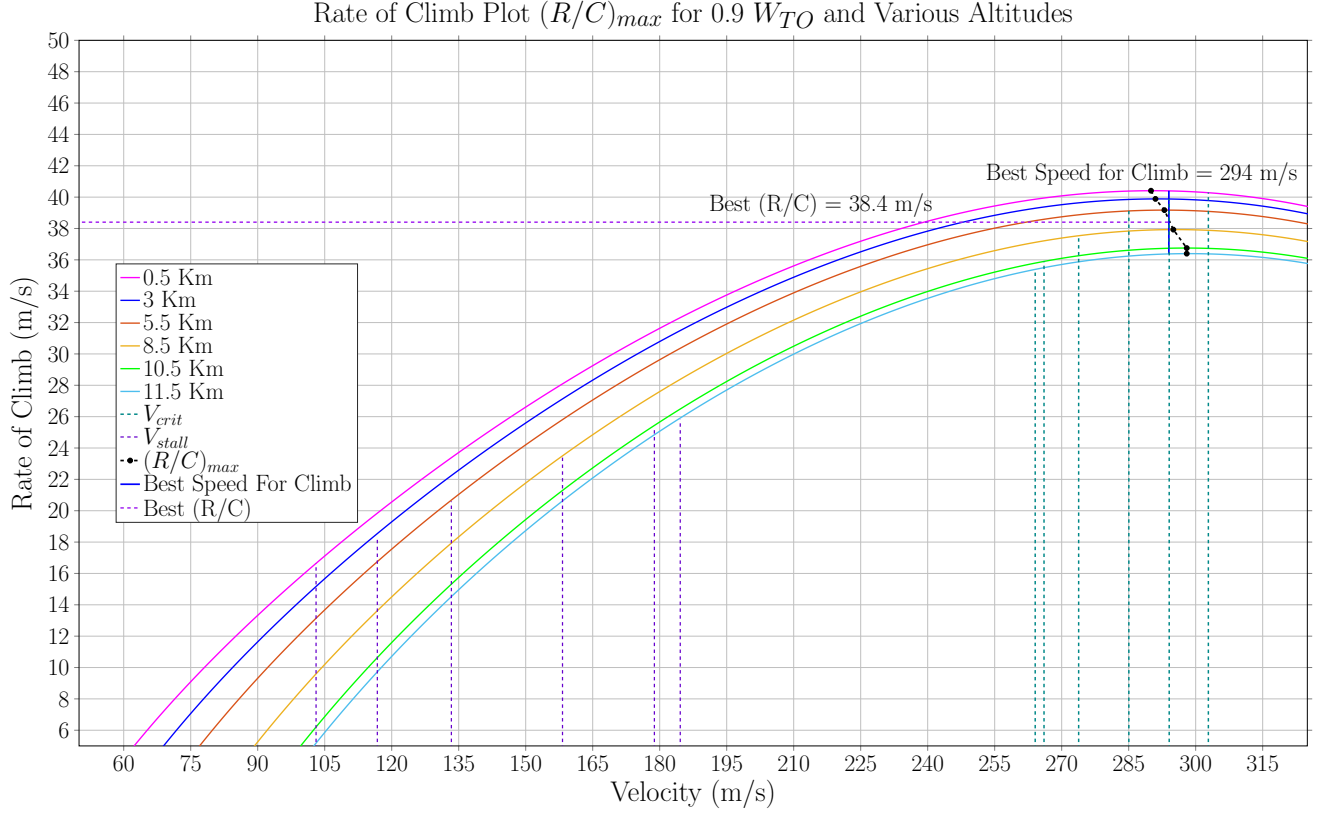


Parameter	Value
Take-off Weight ( $W_{TO}$ )	5356 kN
$V_{stall}$ at 0.5 km	97.17 m/s
$V_{stall}$ at 3 km	110.10 m/s
$V_{stall}$ at 5.5 km	125.73 m/s
$V_{stall}$ at 8.5 km	149.19 m/s
$V_{stall}$ at 10.5 km	168.58 m/s
$V_{stall}$ at 11.5 km	174.04 m/s

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 $W_{TO}$

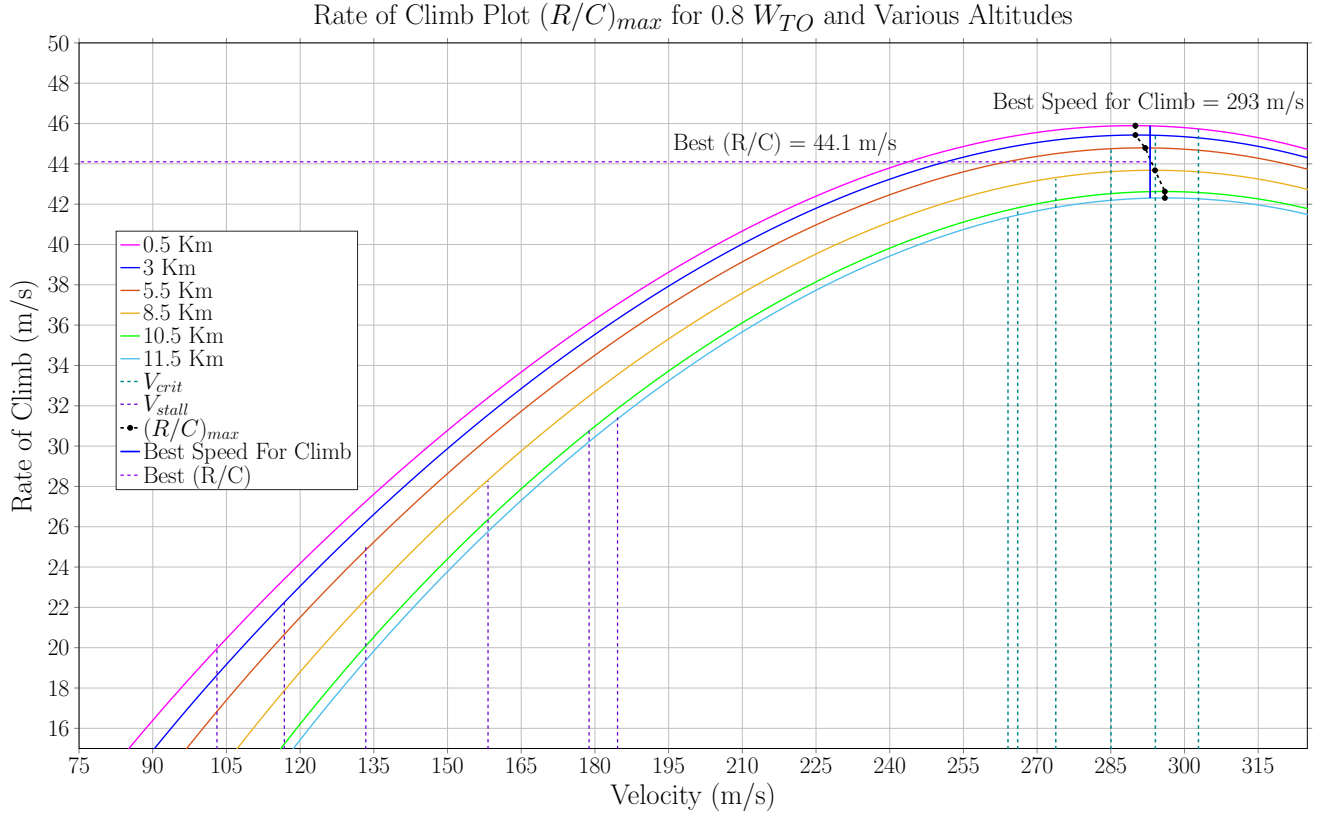


Parameter	Value
Take-off Weight ( $W_{TO}$ )	6025.5 kN
$V_{stall}$ at 0.5 km	103.06 m/s
$V_{stall}$ at 3 km	116.78 m/s
$V_{stall}$ at 5.5 km	133.36 m/s
$V_{stall}$ at 8.5 km	158.24 m/s
$V_{stall}$ at 10.5 km	178.81 m/s
$V_{stall}$ at 11.5 km	184.60 m/s
$(R/C)_{max}$ at 0.5 km	40.41 m/s
$(R/C)_{max}$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



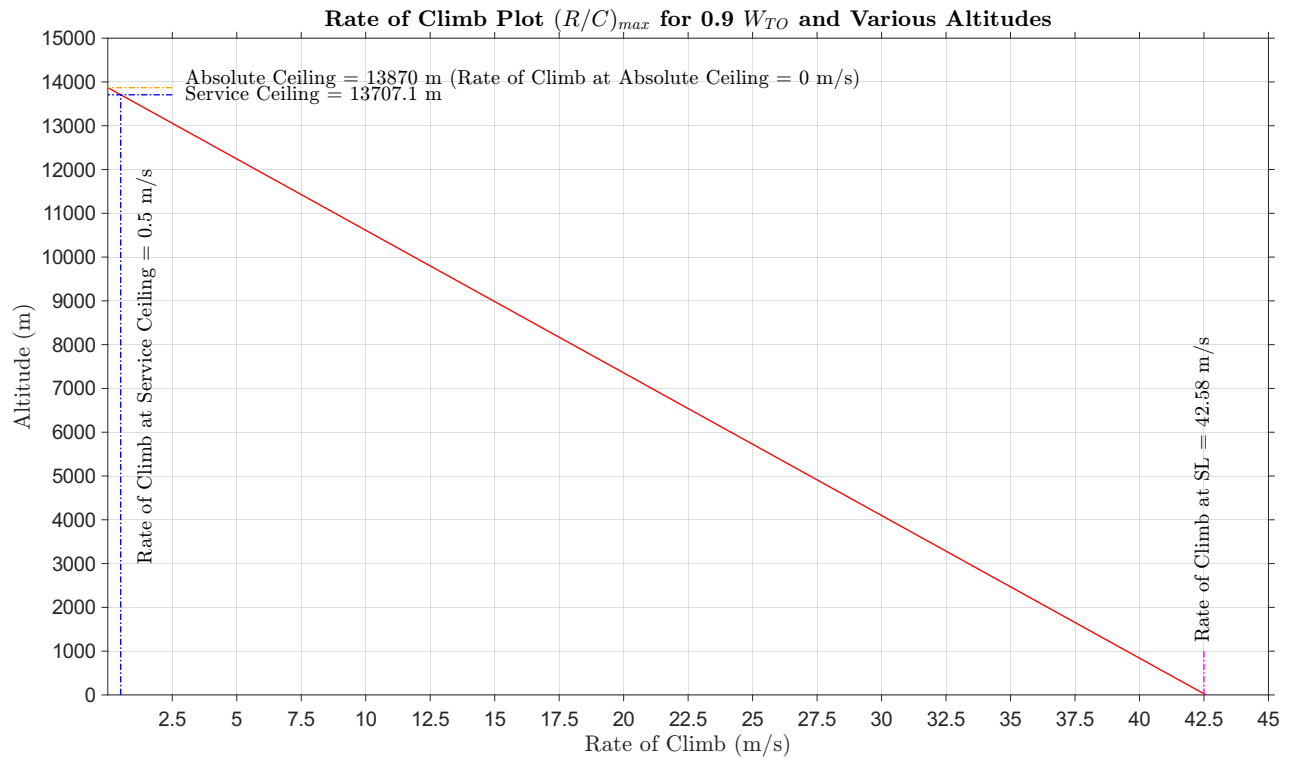
Parameter	Value
Take-off Weight ( $W_{TO}$ )	5356 kN
$V_{stall}$ at 0.5 km	97.17 m/s
$V_{stall}$ at 3 km	110.10 m/s
$V_{stall}$ at 5.5 km	125.73 m/s
$V_{stall}$ at 8.5 km	149.19 m/s
$V_{stall}$ at 10.5 km	168.58 m/s
$V_{stall}$ at 11.5 km	174.04 m/s
$(R/C)_{max}$ at 0.5 km	45.89 m/s
$(R/C)_{max}$ at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

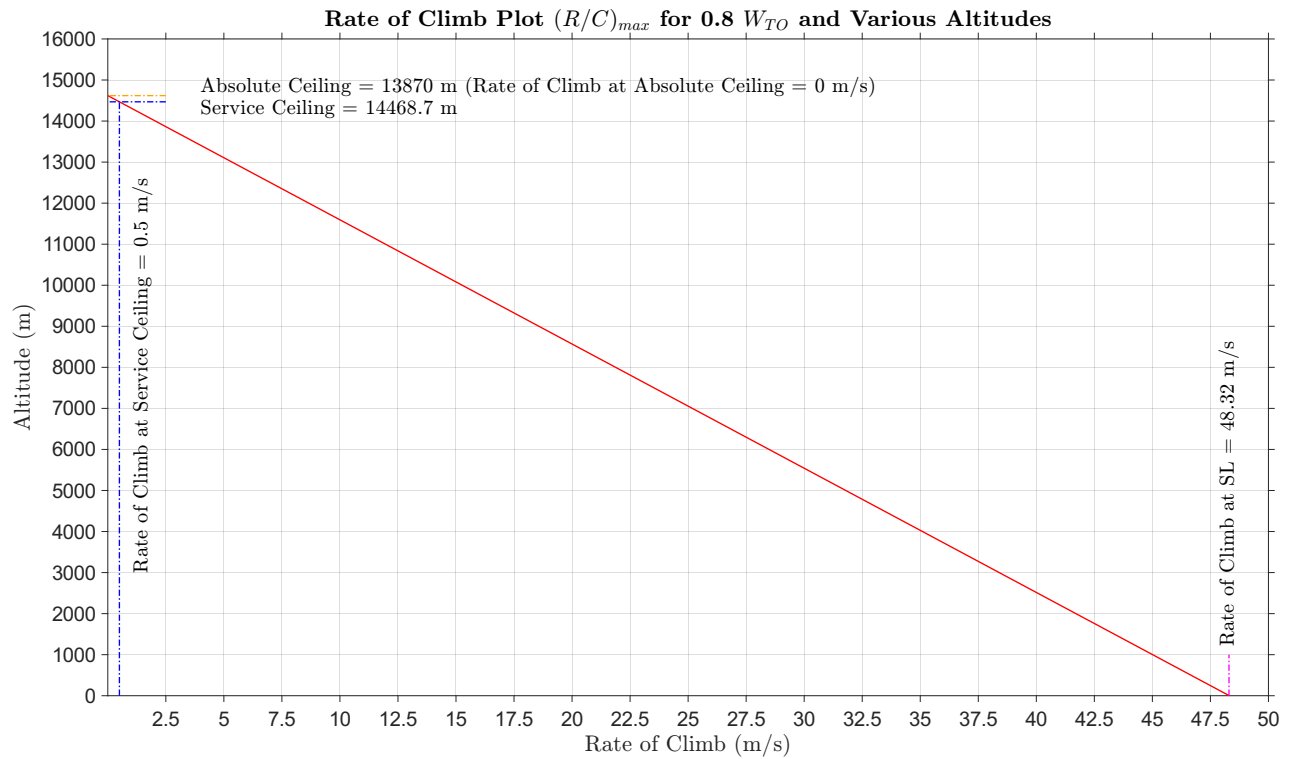
Table 14: Data for 0.8  $W_{TO}$



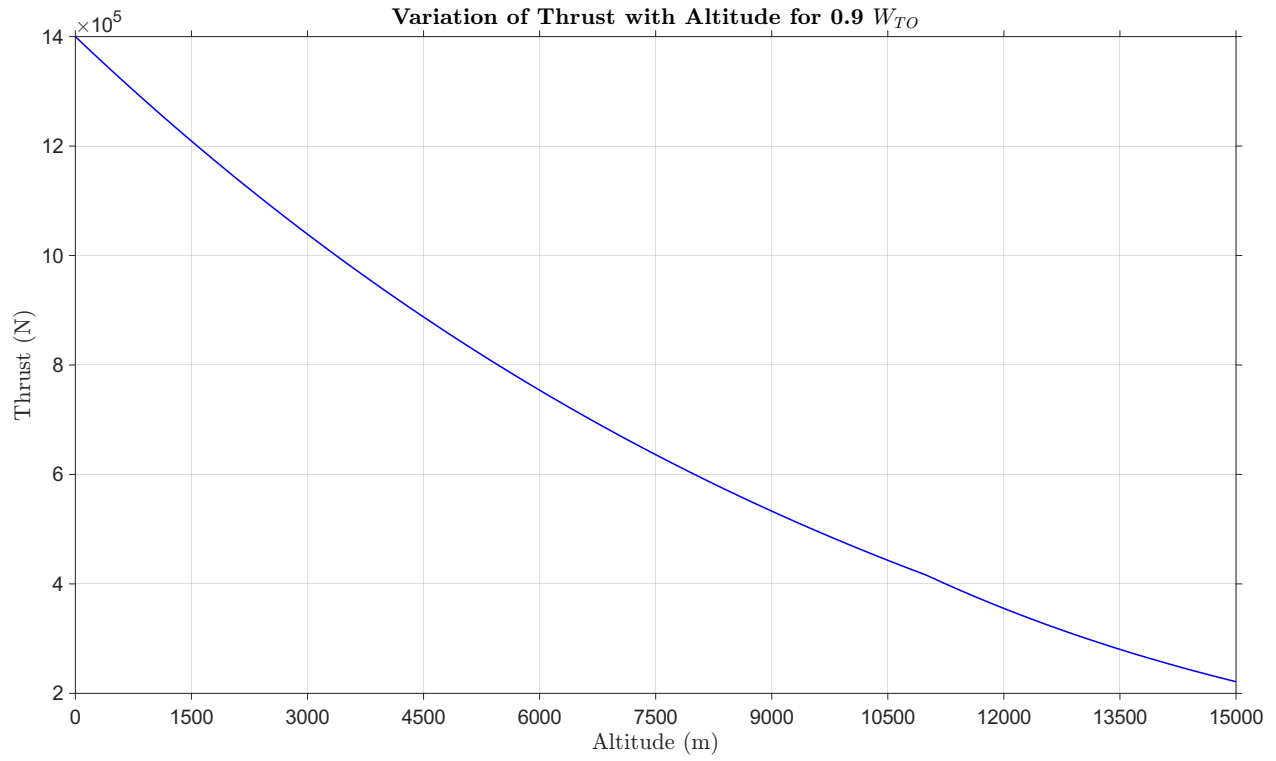
#### 4.6 h v/s $(R/C)_{max}$ for 0.9 $W_{TO}$



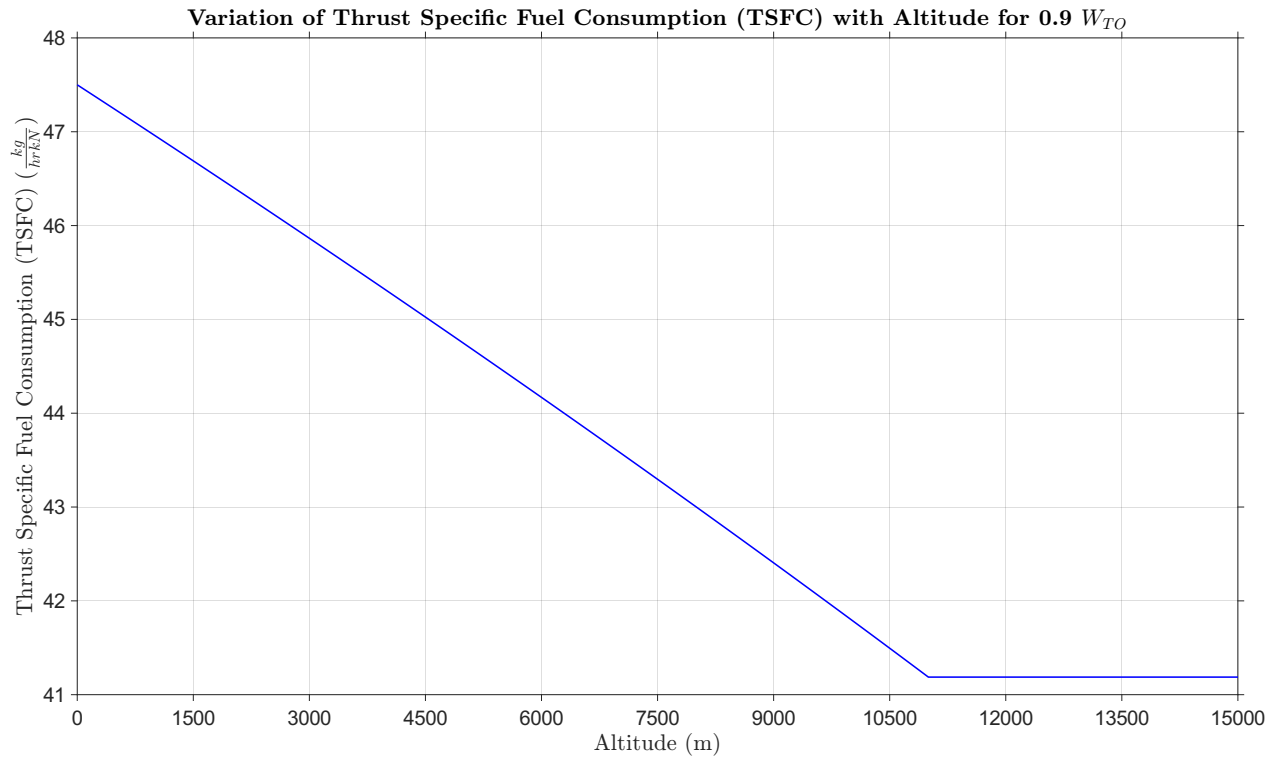
#### 4.7 h v/s $(R/C)_{max}$ for 0.8 $W_{TO}$



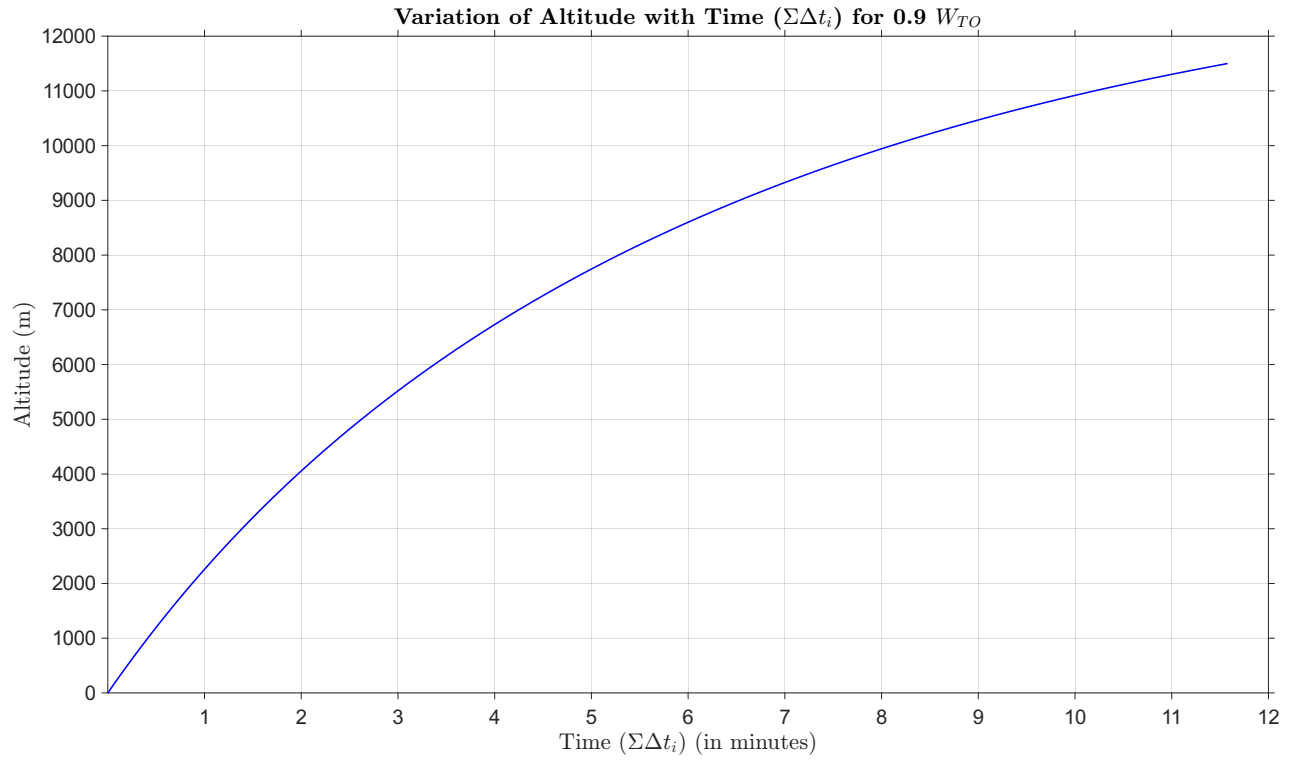
#### 4.8 Thrust v/s Altitude for 0.9 $W_{TO}$



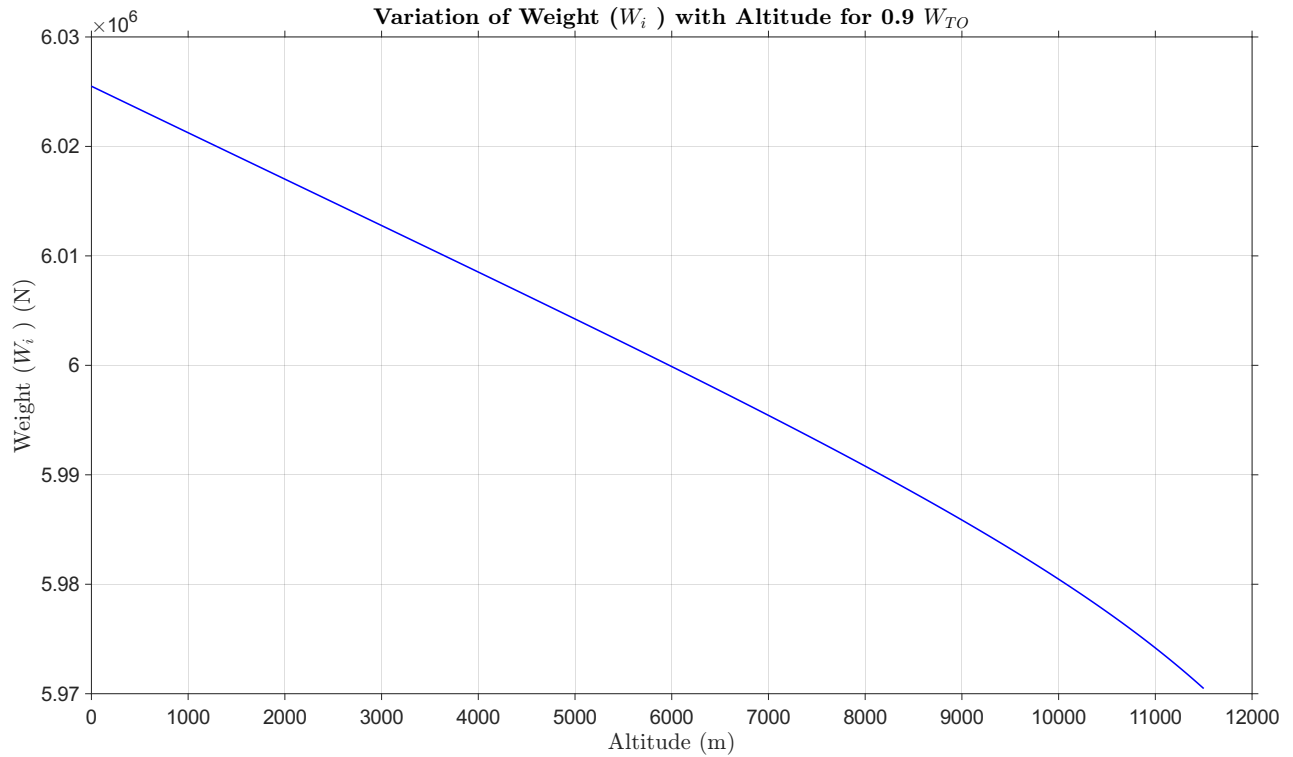
#### 4.9 TSFC v/s Altitude for 0.9 $W_{TO}$



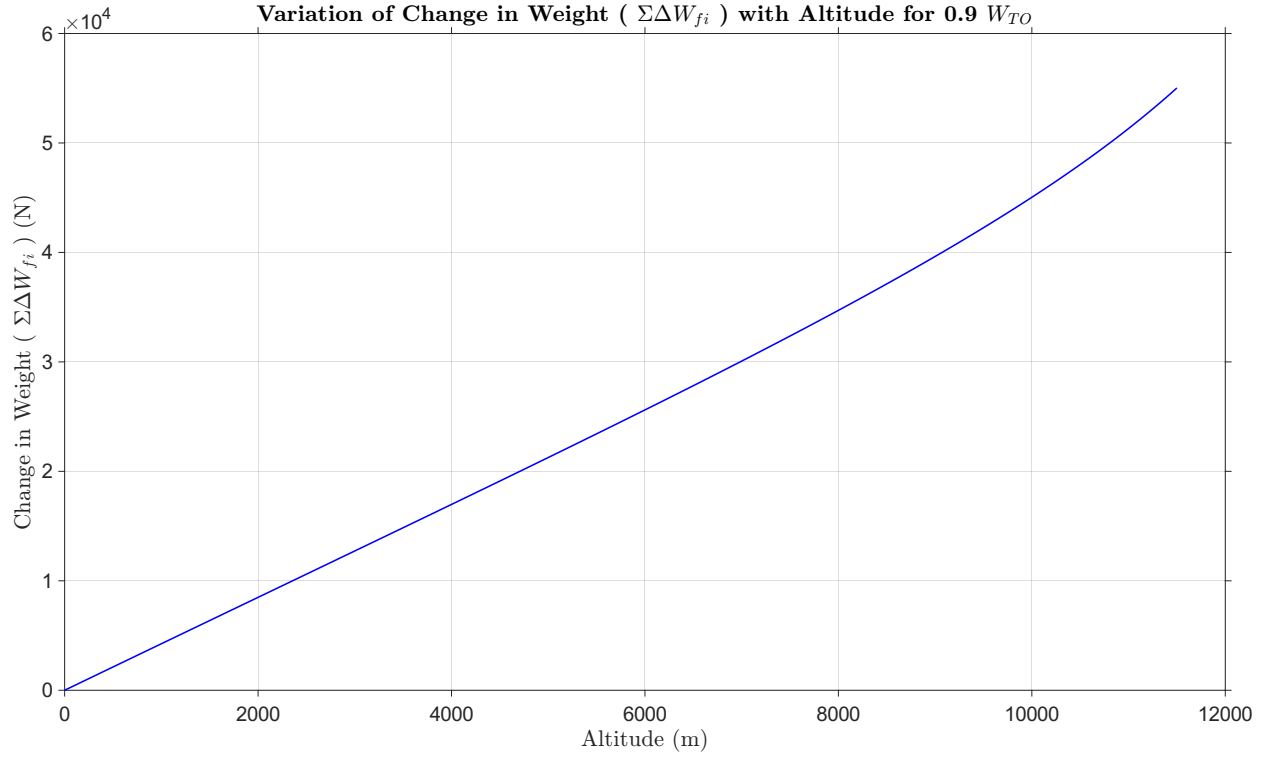
#### 4.10 Variation of Altitude with Time ( $\Sigma\Delta t_i$ ) for 0.9 $W_{TO}$



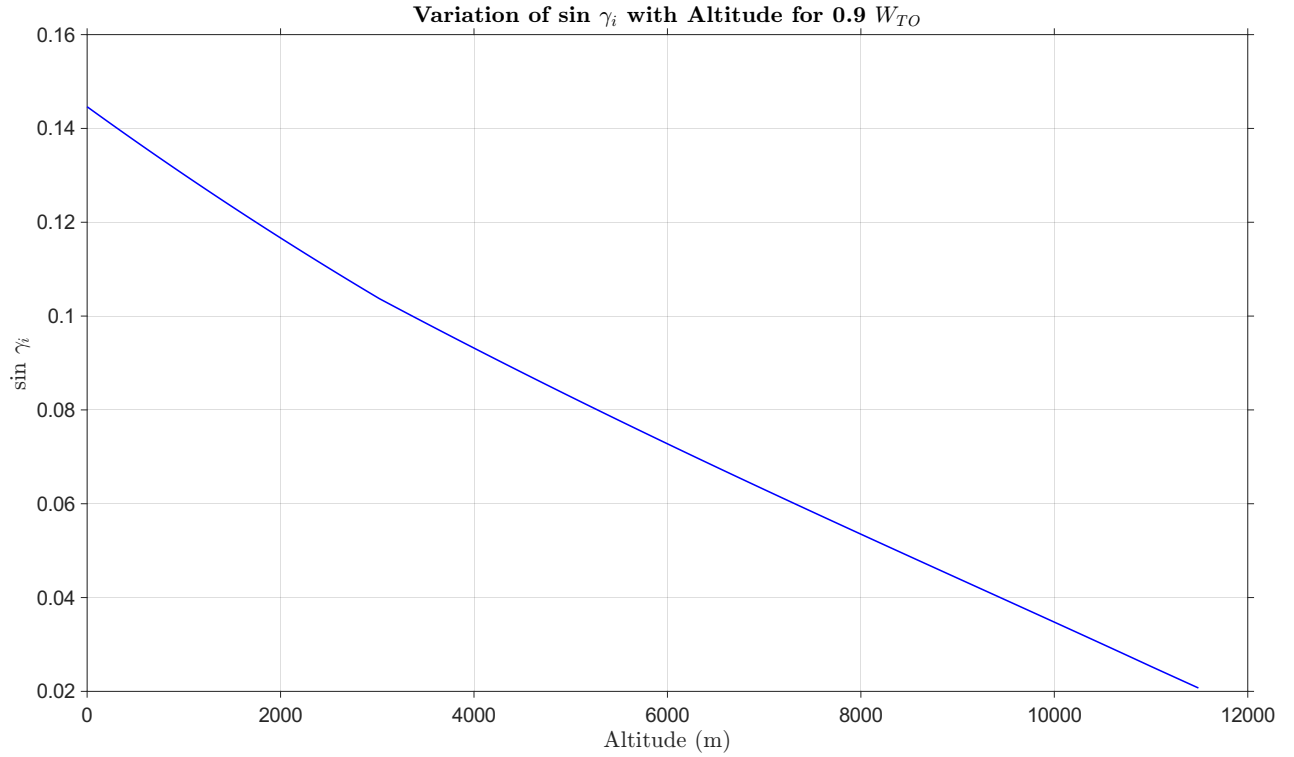
#### 4.11 Variation of Weight ( $W_i$ ) with Altitude for 0.9 $W_{TO}$



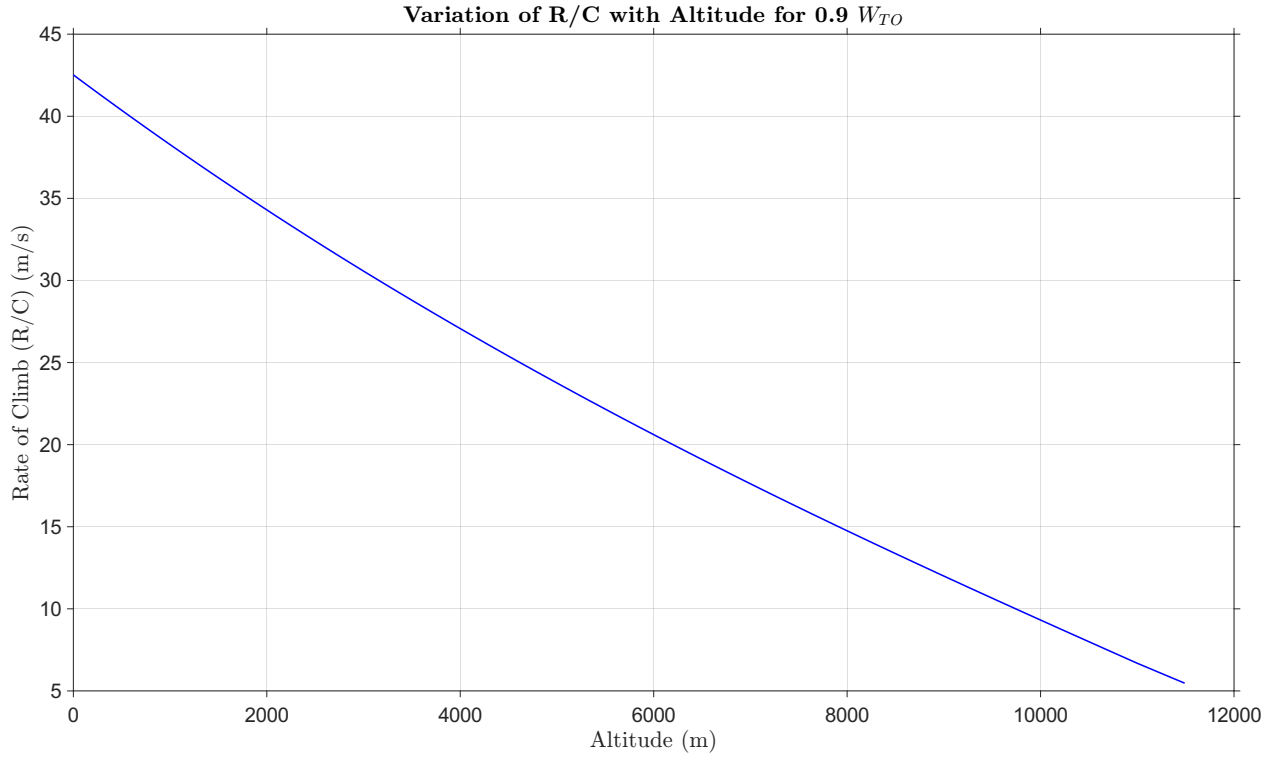
#### 4.12 Variation of Change in Weight ( $\Sigma\Delta W_{fi}$ ) with Altitude for 0.9 $W_{TO}$



#### 4.13 Variation of $\sin \gamma_i$ 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  $N$ ),

$$\Delta h = h/N \quad (25)$$

From ISA,

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

Hence,

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

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

$$q_i = \sigma_i q_{SL} \quad (28)$$

From ISA,

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

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

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

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

$$W_1 = W_0 \quad (31)$$

and,

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

Thus  $C_L$  can be calculated,

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

Further,  $C_D$  can be calculated,

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

From  $C_D$ , the drag can be calculated as,

$$D_i = C_{D_i} q_i S \quad (35)$$

To calculate the rate of climb,

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

Hence,

$$(R/C)_i = V \sin(\gamma_i) \quad (37)$$

The incremental time is given by,

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

The incremental fuel weight is given by,

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

This resulted in the following conclusions,

$$T_c = 11.57 \text{ minutes} \quad (40)$$

$$F_c = 5502.62 \text{ N} \quad (41)$$

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 ( $\omega$ ), 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 ( $\omega$ ) is given by,

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

Where n is the load factor and is given by,

$$n = \frac{L}{W} \quad (43)$$

It is also given by,

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

The turn rate is also given by,

$$\omega = \frac{V}{R} \quad (45)$$

The stall boundary is given by,

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

The sustained turn rate boundary is given by,

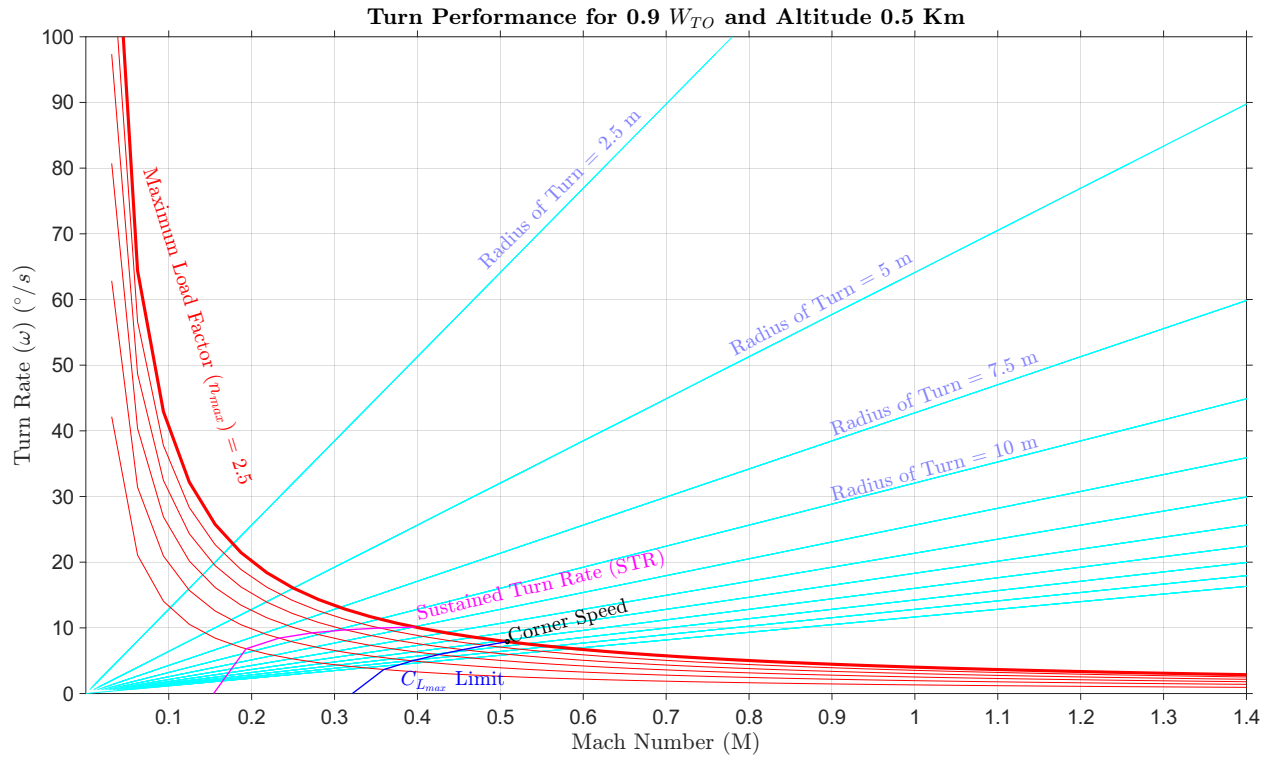
$$AV^4 - TV^2 + Bn^2 = 0 \quad (47)$$

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

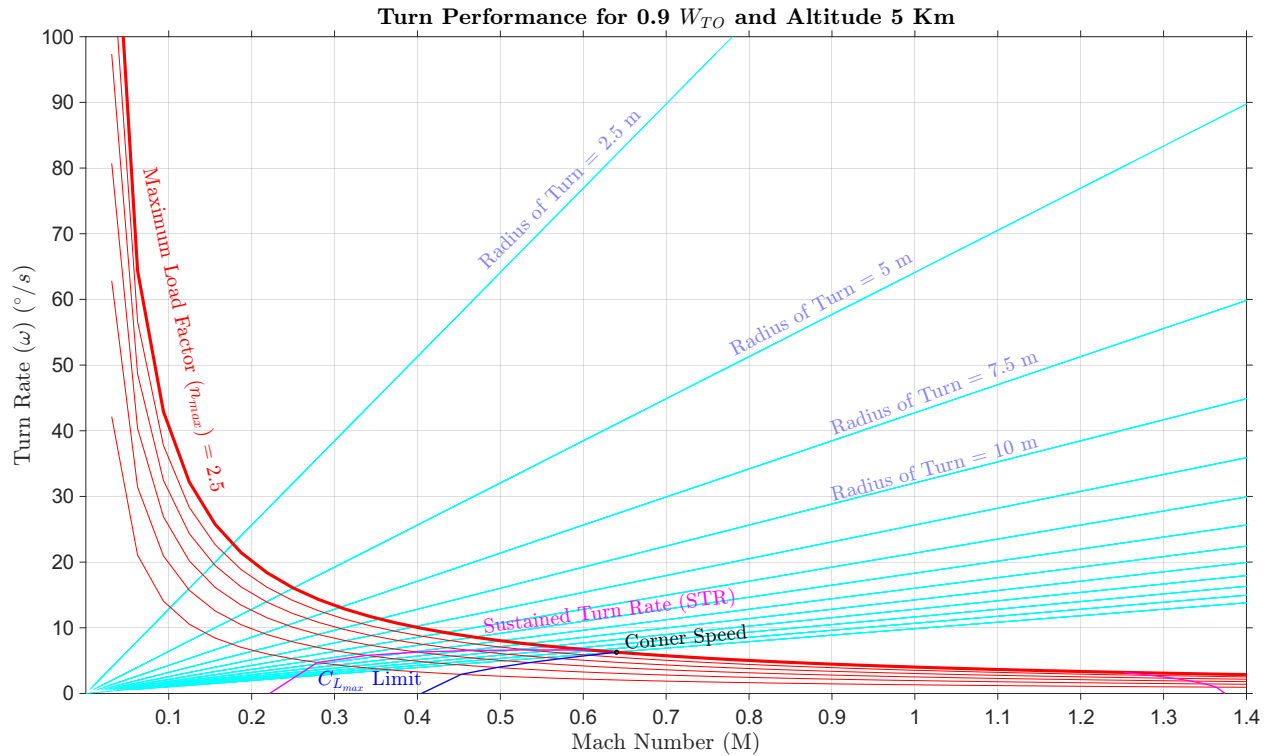
$$\phi = \tan^{-1}(\sqrt{n^2 - 1}) \quad (48)$$

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

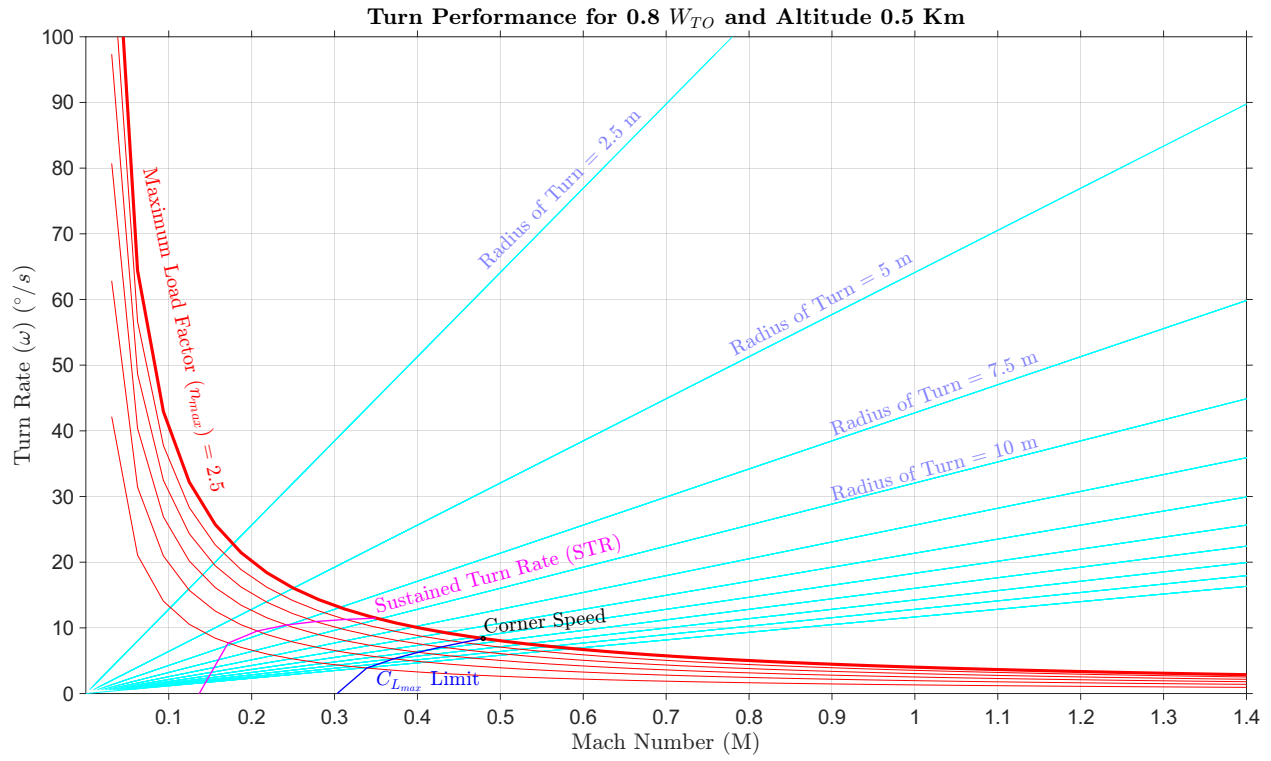


## 5.3 Turn Performance for 0.9 $W_{TO}$ and Altitude 5 Km

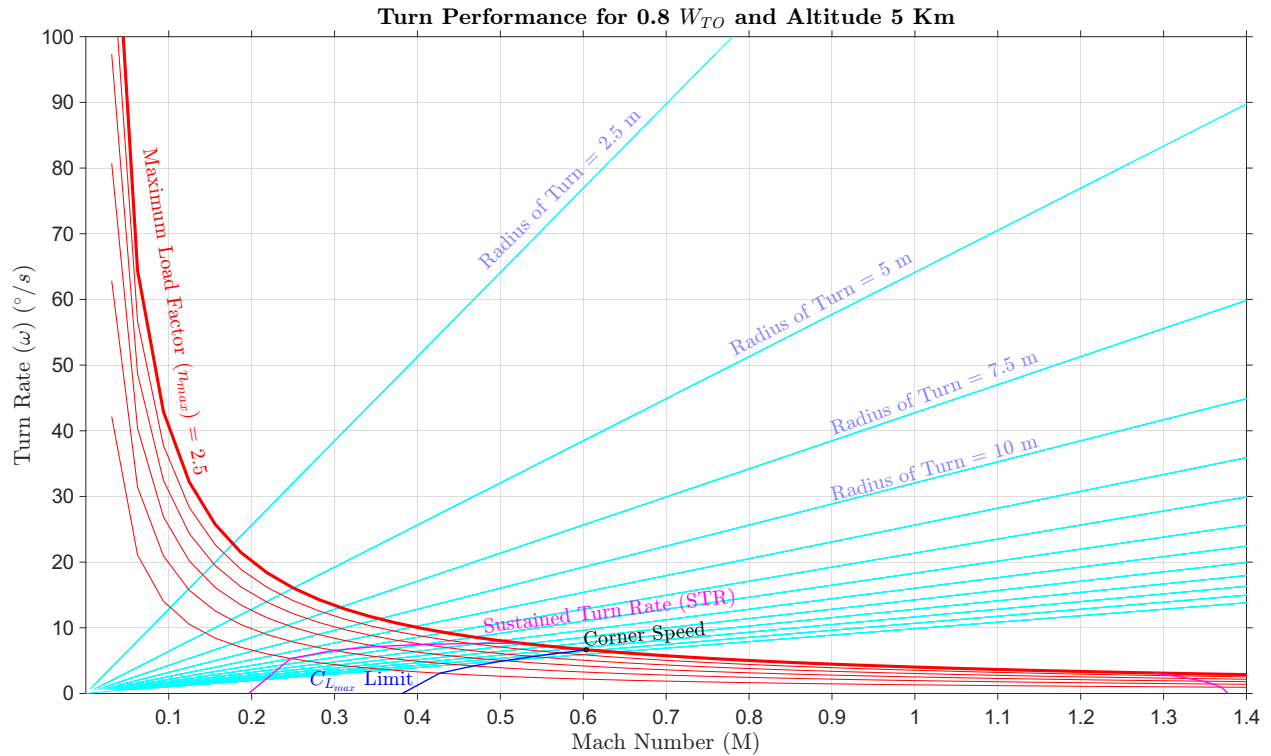




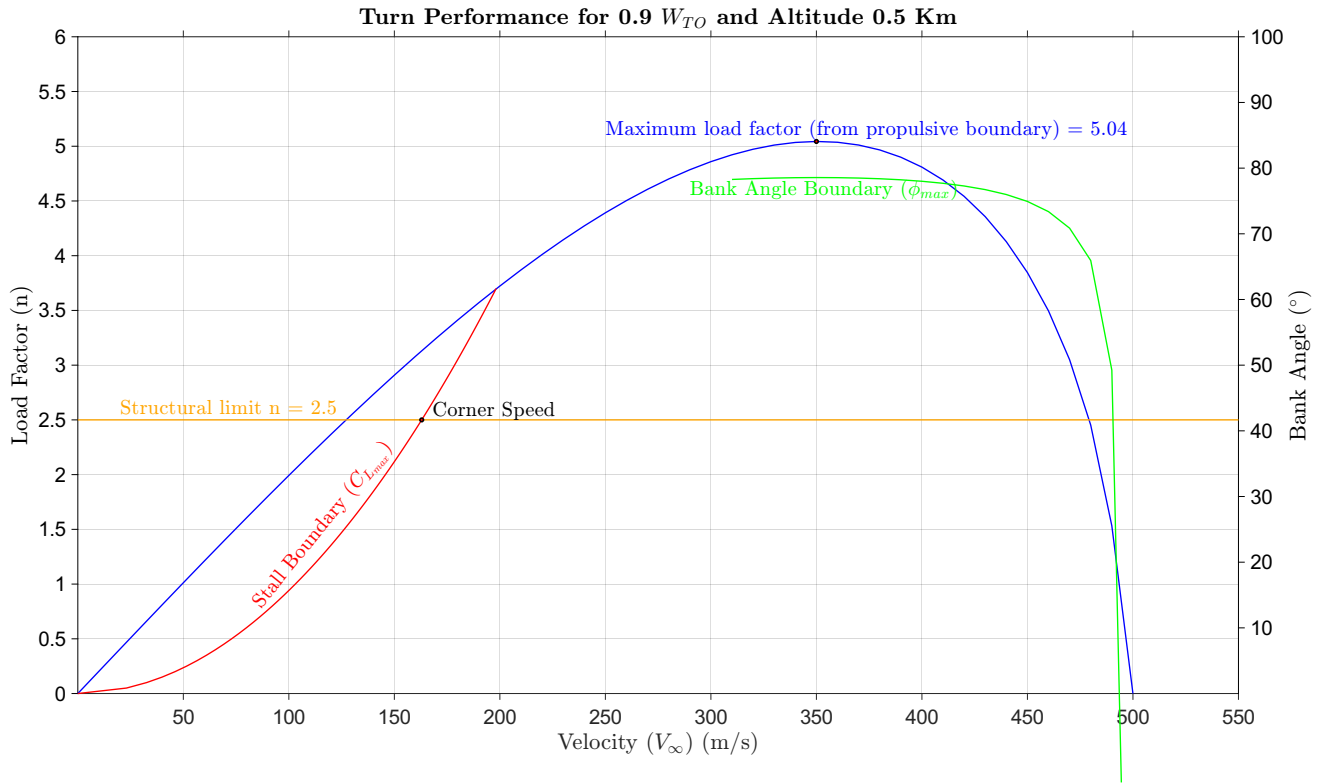
## 5.4 Turn Performance for 0.8 $W_{TO}$ and Altitude 0.5 Km



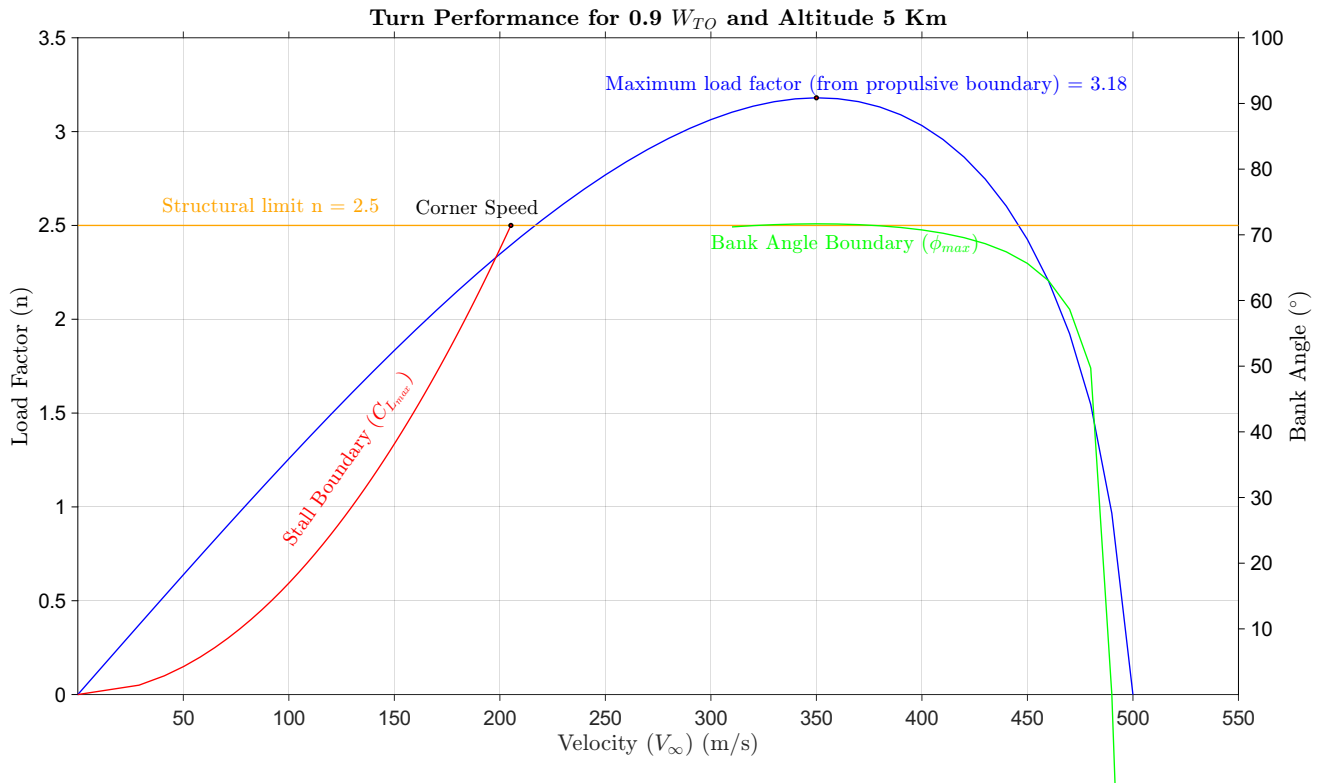
## 5.5 Turn Performance for 0.8 $W_{TO}$ and Altitude 5 Km



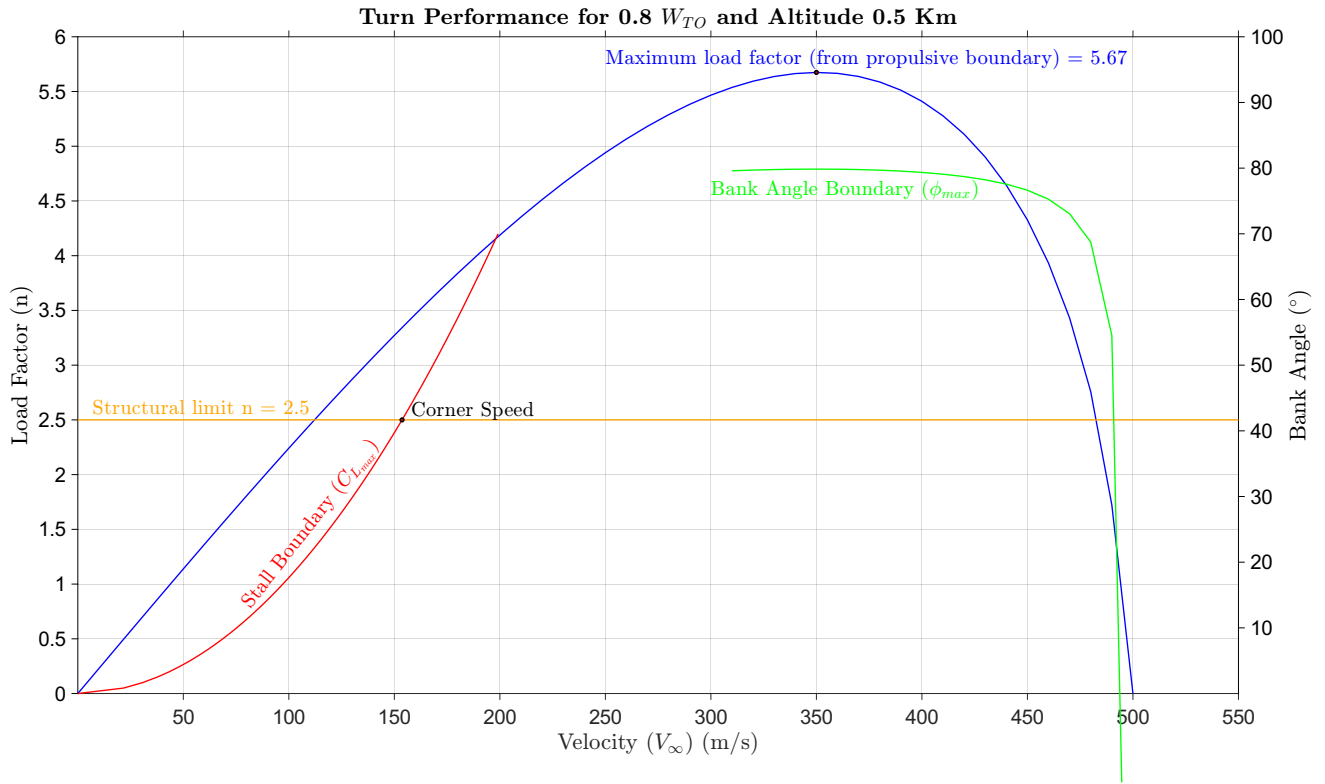
## 5.6 Turn Performance for $0.9 W_{TO}$ and Altitude 0.5 Km



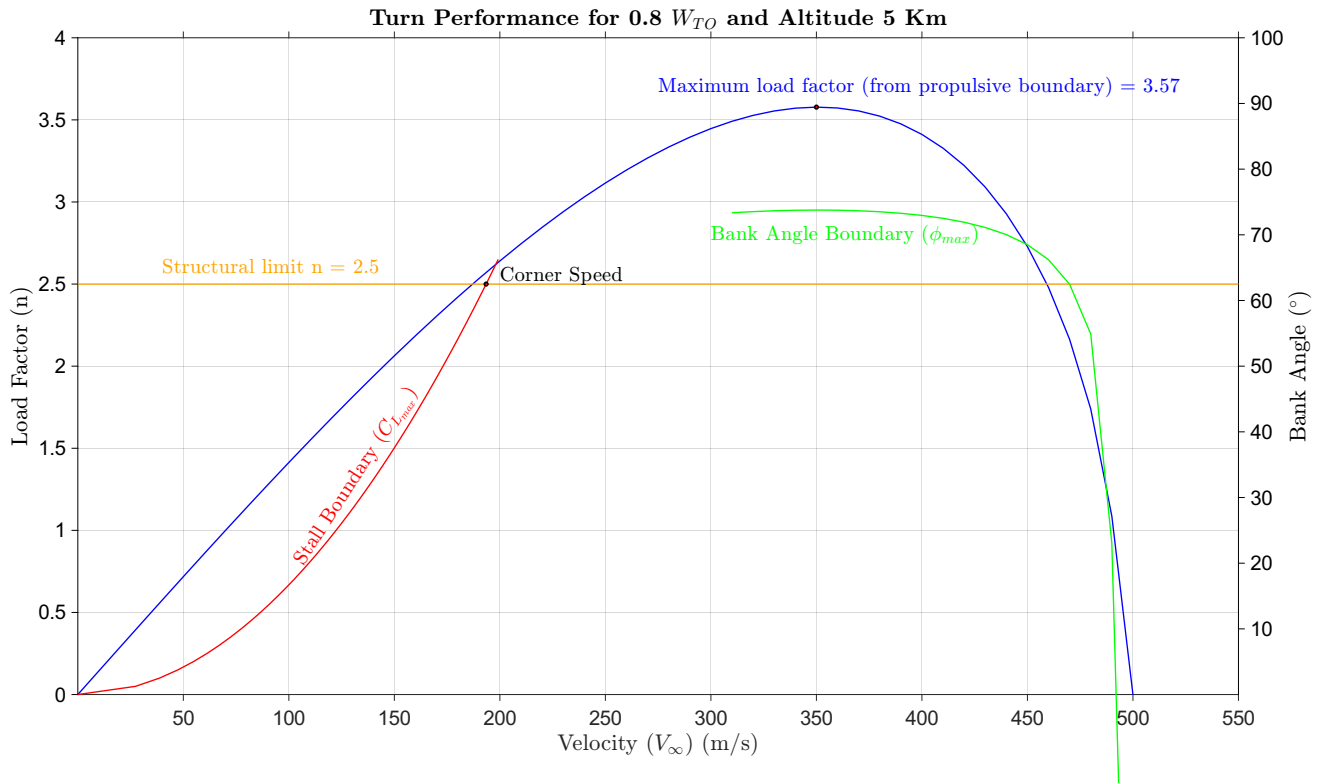
## 5.7 Turn Performance for $0.9 W_{TO}$ and Altitude 5 Km



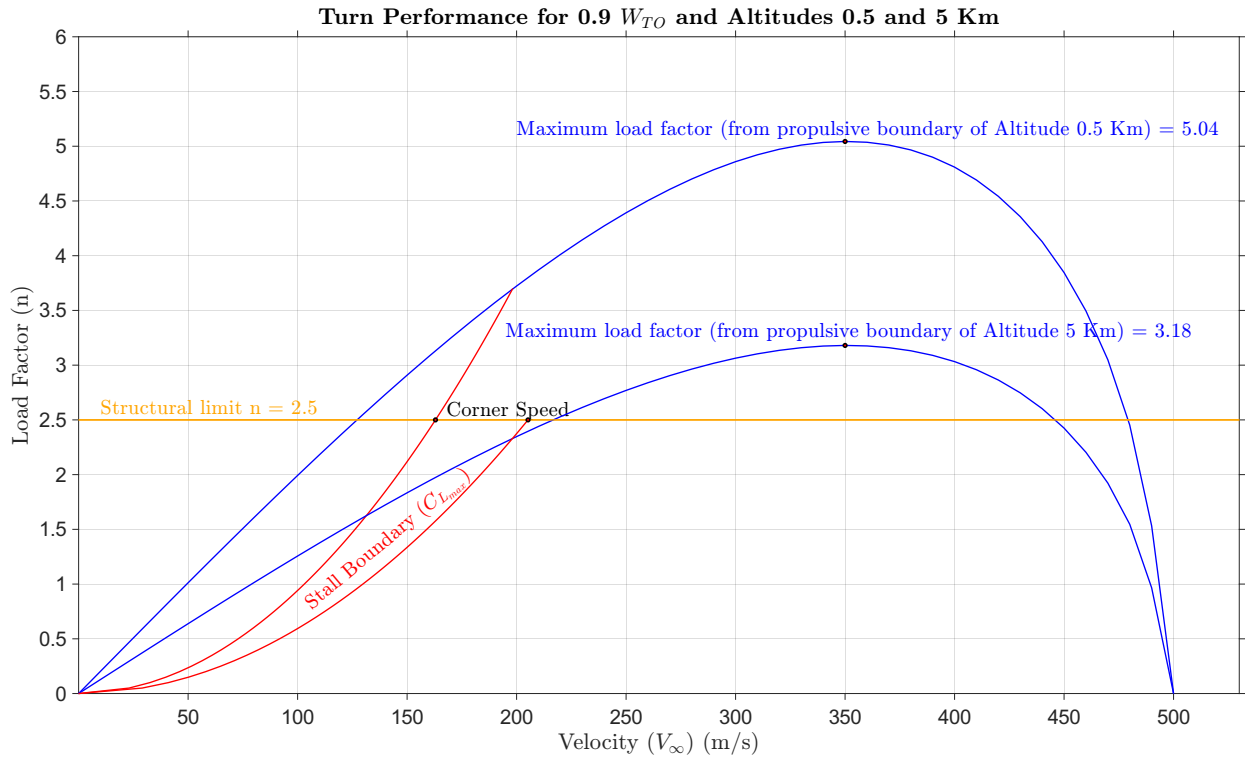
## 5.8 Turn Performance for 0.8 $W_{TO}$ and Altitude 0.5 Km



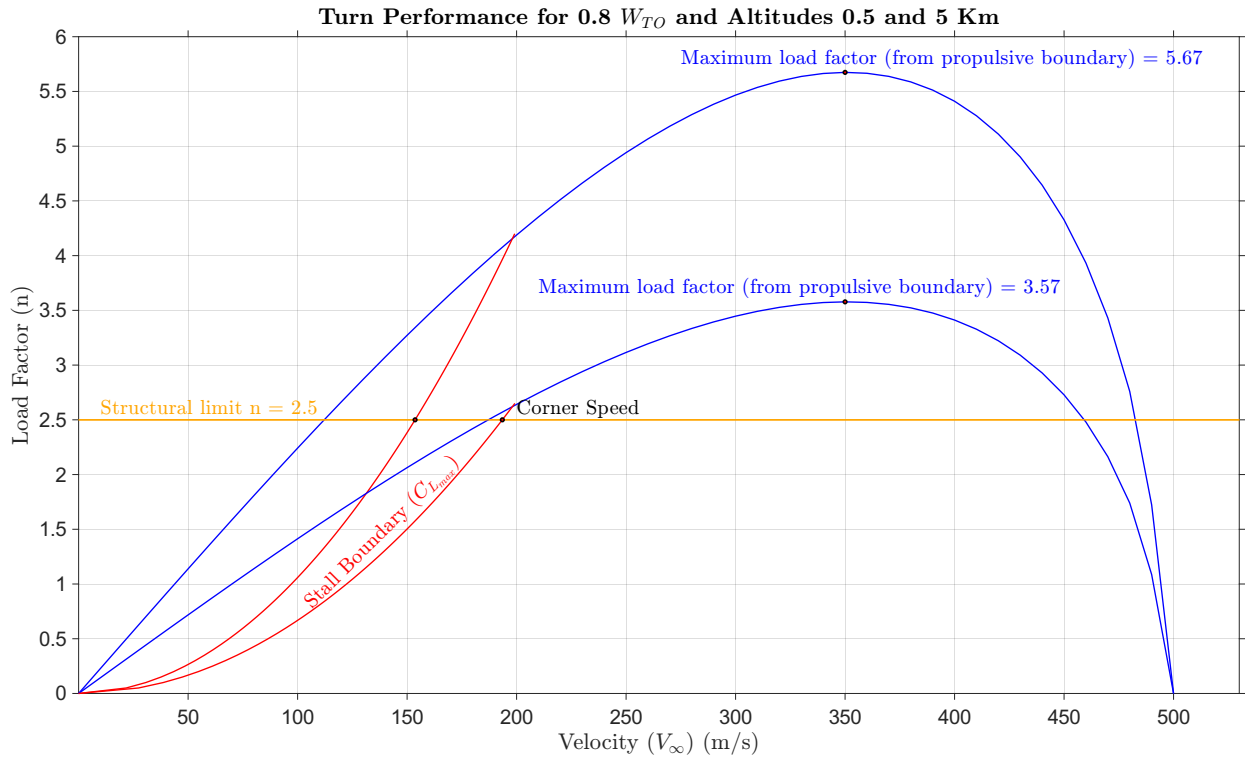
## 5.9 Turn Performance for 0.8 $W_{TO}$ and Altitude 5 Km



## 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 ( $\omega$  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 0.9 $W_{TO}$  and 0.8 $W_{TO}$  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,

$$\Delta t = 0.25 \text{ s} \quad (49)$$

$$q_i S = \frac{1}{2} \rho V_i^2 S \quad (50)$$

Thus lift and drag can be calculated,

$$L_i = C_L q_i S \quad (51)$$

$$D_i = C_D q_i S \quad (52)$$

Hence acceleration can be calculated,

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

The change in velocity is given by,

$$\Delta V_i = a_i \Delta t \quad (54)$$

The change in distance is given by,

$$\Delta s_i = V_i \Delta t + \frac{1}{2} a_i \Delta t^2 \quad (55)$$

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

$$V_{i+1} = V_i + \Delta V_i \quad (56)$$

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

$$s_{i+1} = s_i + \Delta s_i \quad (57)$$

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

$$t_{i+1} = t_i + \Delta t_i \quad (58)$$

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

$$s_{rot} = 3 \times V_{rot} \quad (59)$$

where,

$$V_{rot} = 1.2 \times V_{stall} \quad (60)$$

The distance to climb is given by,

$$s_{climb} = \frac{10.7}{\tan \gamma} \quad (61)$$

where,

$$\sin \gamma = \frac{T - D}{W} \quad (62)$$

The time to climb is given by,

$$t_{climb} = \frac{10.7}{V_{rot} \tan \gamma} \quad (63)$$

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

$$t = t_{gr\ accn} + t_{rot} + t_{climb} \quad (64)$$

$$s = s_{gr\ accn} + s_{rot} + s_{climb} \quad (65)$$

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  $V_{R_{0.5\text{ km}}} = 87.45\text{ m/s}$  and  $V_{R_{1.5\text{ km}}} = 91.86\text{ m/s}$ .

### 6.3.2 Take-Off Distance Required (TODR)

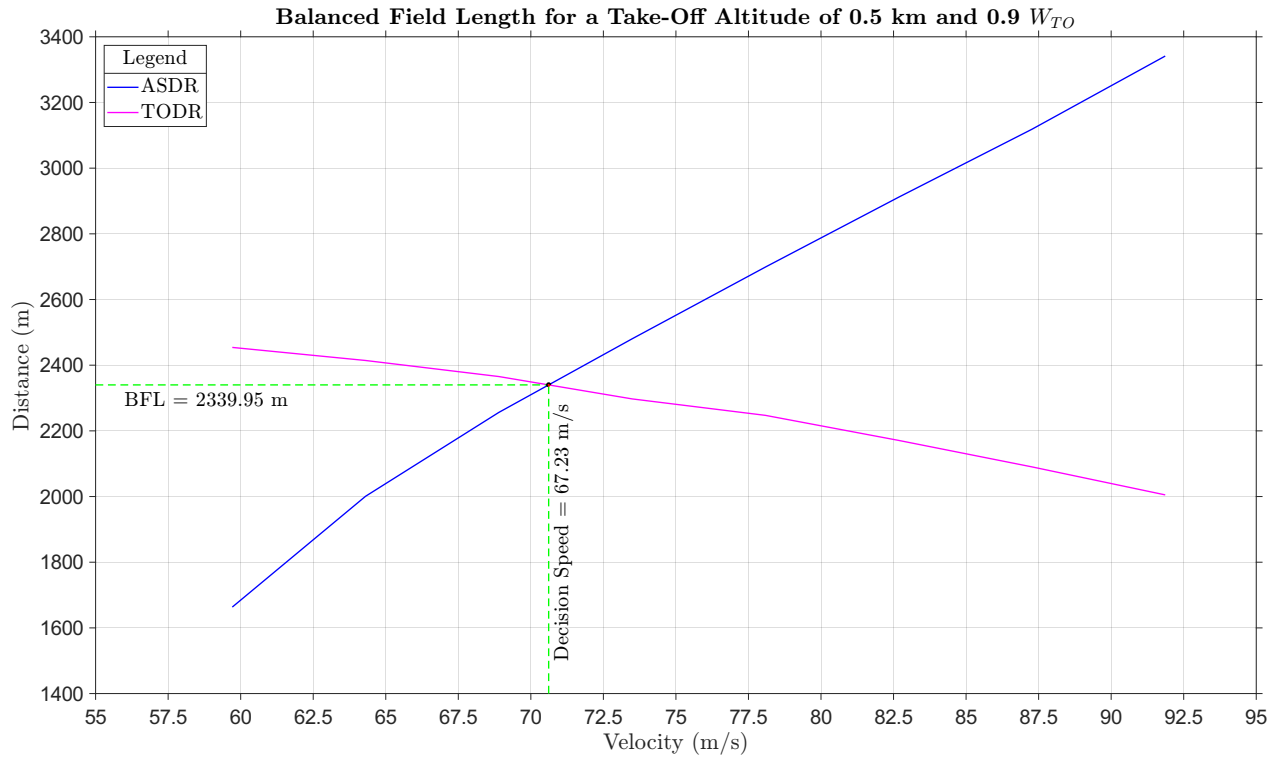
Velocity	TODR	Time
0.65 $V_R$	2,454.1 m	51.50 s
0.70 $V_R$	2,414.3 m	50.75 s
0.75 $V_R$	2,365.4 m	50.00 s
0.80 $V_R$	2,297.3 m	49.00 s
0.85 $V_R$	2,247.2 m	48.25 s
0.90 $V_R$	2,170.9 m	47.25 s
0.95 $V_R$	2,090.3 m	46.25 s
$V_R$	2,005.0 m	45.25 s

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

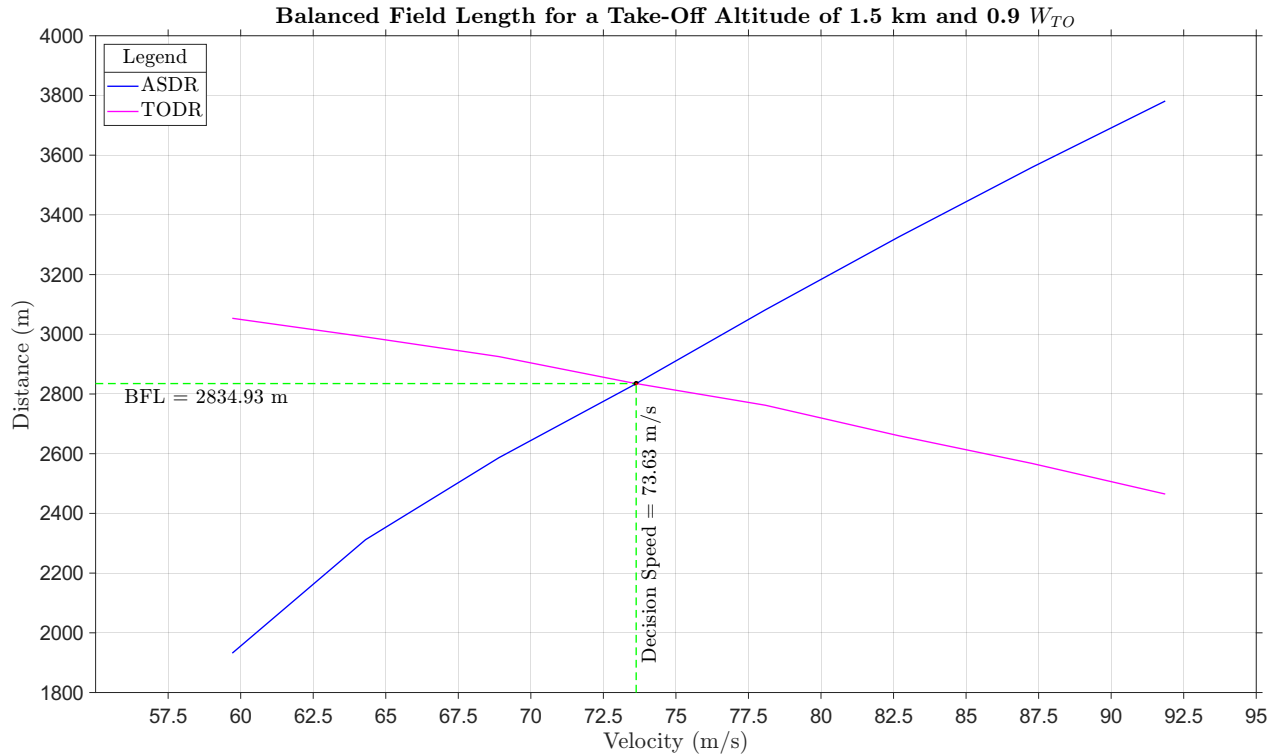
Table 20: Data for 0.9  $W_{TO}$  corresponding to 0.5 km and 1.5 km (left to right)

Where  $V_{R_{0.5\text{ km}}} = 87.45\text{ m/s}$  and  $V_{R_{1.5\text{ km}}} = 91.86\text{ m/s}$ .

## 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,

$$s = 2,663.98 \text{ m}$$

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

$$s = 2,834.93 \text{ m}$$

## 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 with and 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,

$$s_a = \frac{15.2}{\tan \gamma_a} \quad (66)$$

where,

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

$\gamma_a$  is in radians. For a civil transport aircraft,  $\gamma_a$  is  $3^\circ$ . The approach speed is given by,

$$V_a = 1.3 \times V_{stall} \quad (68)$$

The flare distance is given by,

$$s_f = 0.1248 \times V_{stall}^2 \times \gamma_f \quad (69)$$

where,

$$\gamma_f = \gamma_a \quad (70)$$

The rotation distance is given by,

$$s_r = 3 \times V_a \quad (71)$$

The braking distance is given by,

$$s_b = \frac{V_a^2}{2a} \quad (72)$$

Hence the landing distance is given by,

$$s = s_a + s_f + s_r + s_b \quad (73)$$

## 7.2 Landing Distance

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

$$s = 1771.73 \text{ m}$$

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

$$s = 1428.53 \text{ m}$$

## 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,

$$W_A = W_{TO} - 0.05 W_{Fuel} \quad (74)$$

$$W_B = W_{TO} - 0.93 W_{Fuel} \quad (75)$$

$$W_E = W_{TO} - 0.05 W_{Fuel} \quad (76)$$

$$W_C = W_{TO} - 1.23 W_{Fuel} \quad (77)$$

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

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

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

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

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

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

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

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

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

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

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

$$C_{L_{opt}} = \sqrt{\frac{C_{D_0}}{k}} \quad (86)$$

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

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

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

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

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

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

The Breguet Range is given by,

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

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

$$C_D = 2C_{D_0} \quad (91)$$

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

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

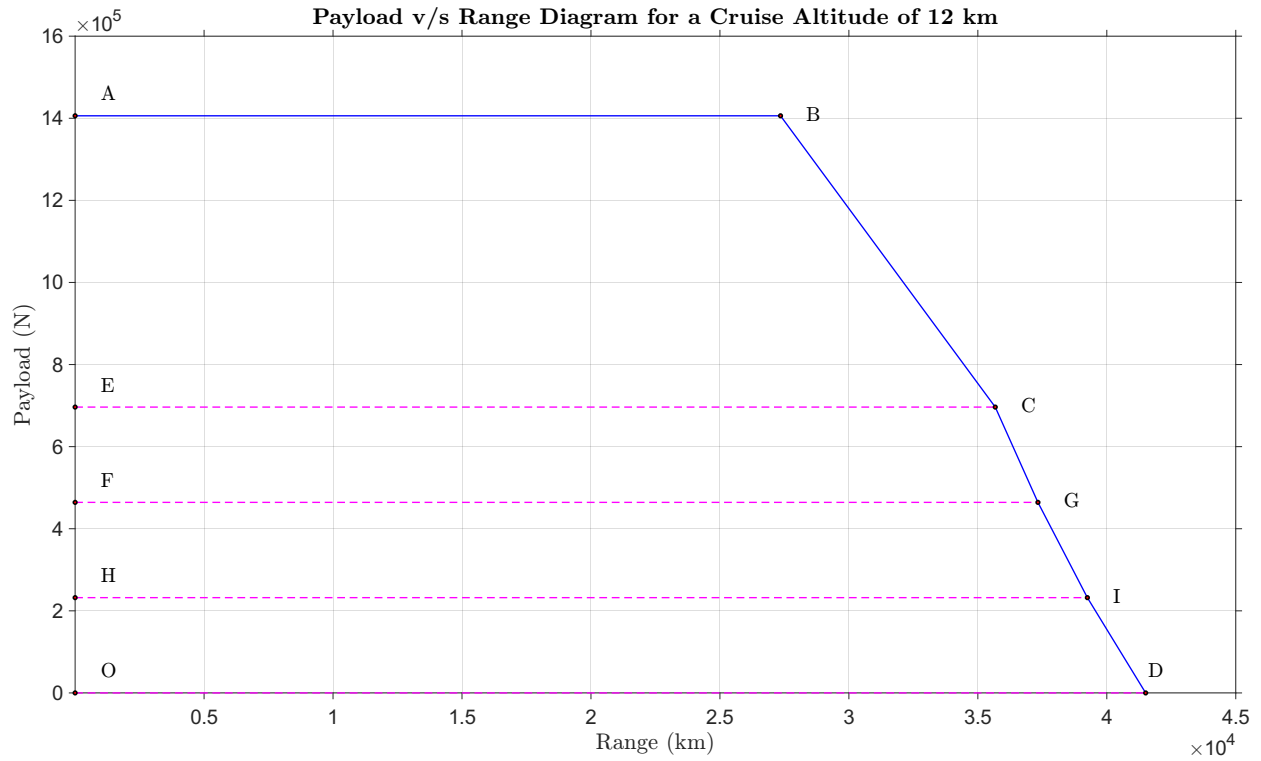
The following results were obtained,

$$V_{R_{max}} = 314.19 \text{ m/s} \quad (93)$$

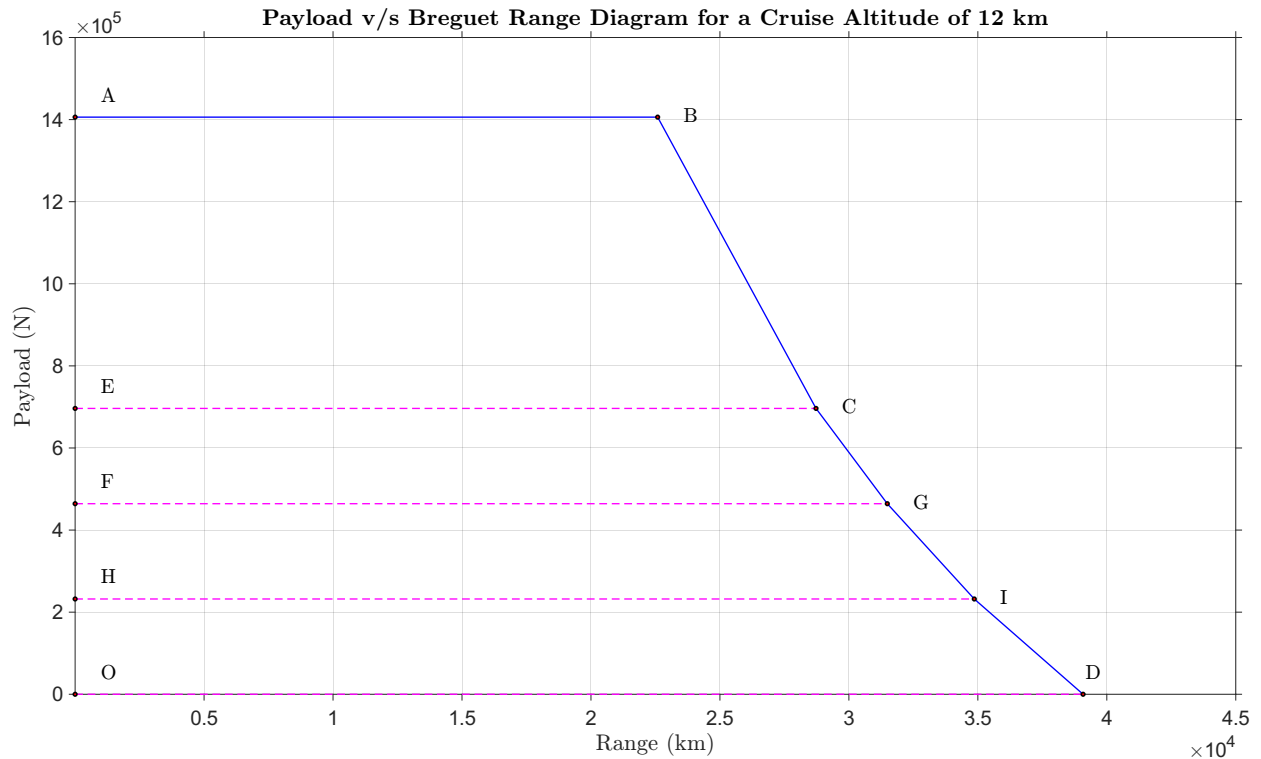
$$V_{crit} = 264.09 \text{ m/s} \quad (94)$$

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.

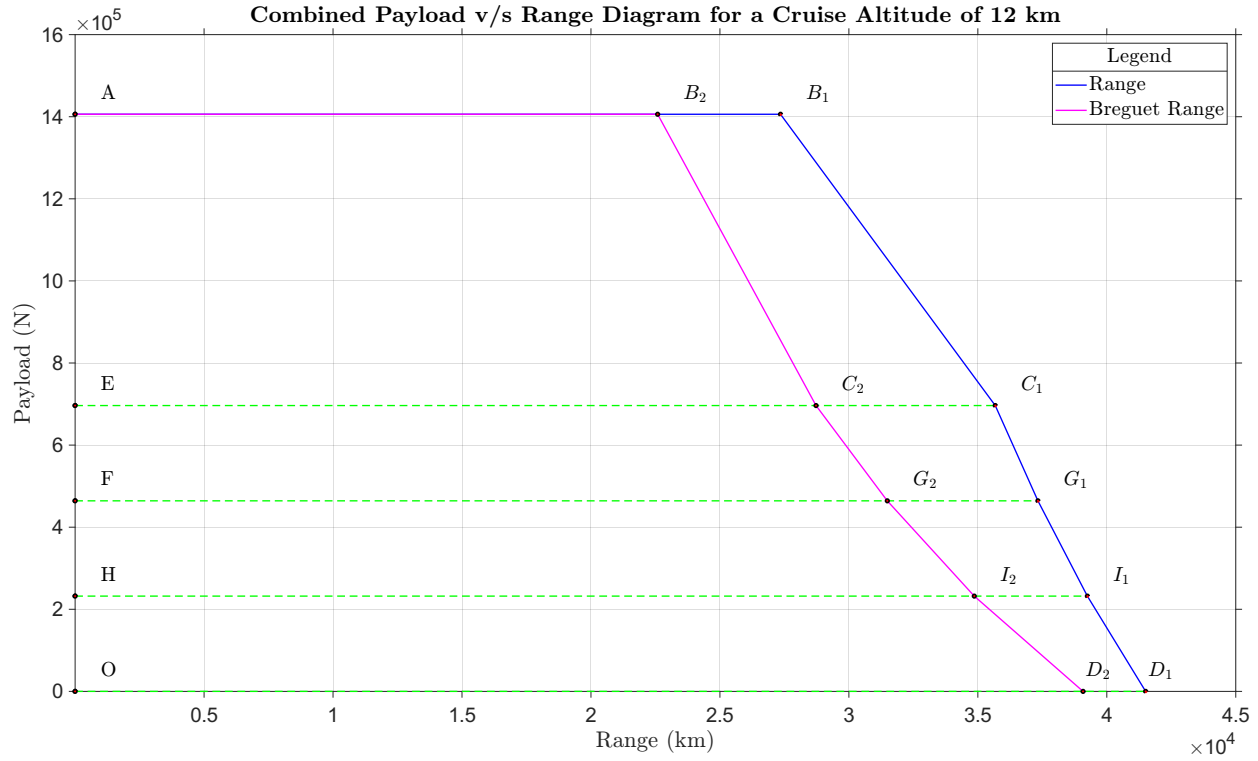
## 8.2 Payload v/s Range Diagram for a Cruise Altitude of 12 km



## 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,

$$W_{OE} = 2725 \text{ kN} \quad (95)$$

$$W_{PL} = 1406 \text{ kN} \quad (96)$$

$$W_{Fuel} = 2365.5 \text{ kN} \quad (97)$$

$$W_{TO} = 6496.5 \text{ kN} \quad (98)$$

$$S = 845 \text{ m}^2 \quad (99)$$

For maximum range,

$$C_{LR_{max}} = 0.2893 \quad (100)$$

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

The TSFC is given by,

$$c_{t_{SL}} = 1.2943e^{-04} \quad (102)$$

$$c_{t_{12 \text{ km}}} = 1.1224e^{-04} \quad (103)$$

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 ( $\theta$  can be determined from ISA).

$$c_T = 49.5\sqrt{\theta} \quad (104)$$

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

- \* Dr. Tonse Gokuldas Pai, "AAE 2256 Flight Mechanics Scope of Group Projects & Annexure on Aircraft Data 31 Jan 2023", *Manipal Institute of Technology - FM, 2022-23*
- \* Dr. Tonse Gokuldas Pai, "AAE 2256 Ch 05 Level Flight and Aircraft Flight Envelope", *Manipal Institute of Technology - FM, 2022-23*
- \* Dr. Tonse Gokuldas Pai, "AAE 2256 Ch 03 Review of Aerodynamics", *Manipal Institute of Technology - FM, 2022-23*
- \* Dr. Tonse Gokuldas Pai, "AAE 2256 Ch 06 Climb Performance", *Manipal Institute of Technology - FM, 2022-23*
- \* Dr. Tonse Gokuldas Pai, "AAE 2256 Ch 08 Turn Performance", *Manipal Institute of Technology - FM, 2022-23*
- \* Dr. Tonse Gokuldas Pai, "AAE 2256 Ch 10 Take Off Performance and Balanced Field Length", *Manipal Institute of Technology - FM, 2022-23*
- \* Dr. Tonse Gokuldas Pai, "AAE 2256 Ch 11 Landing Performance", *Manipal Institute of Technology - FM, 2022-23*

- \* Dr. Tonse Gokuldas Pai, "AAE 2256 Ch 12 Range & Endurance", *Manipal Institute of Technology - FM, 2022-23*
- \* Dr. Tonse Gokuldas Pai, "AAE 2256 Trade off between Range and Pay Load Gp Proj Q 6", *Manipal Institute of Technology - FM, 2022-23*

## 11 Appendix

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### 11.3 List of Symbols and Abbreviations

Symbol	Description	Symbol	Description
FM	Flight Mechanics	S	Planform Area
AR	Aspect Ratio	$q_{\infty}$	Dynamic Pressure
$V_{\infty}$	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	$\rho$	Density
$\sigma$	Density Ratio	$\theta$	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	$\omega$	Turn rate
$n_{max}$	Maximum Load Factor (n)	$\phi$	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
$\mu$	Coefficient of Rolliing Friction	$\Delta V$	Incremental Velocity
$\Delta t$	Incremental Time	$\Delta s$	Incremental Distance
$\gamma$	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

```
1 import ISA.*
2 format short
3 import InterX.*
4 height = [0:10:20000]; % meters
5 [T, a, P, rho] = atmosisa(height);
6 %% DATA A380 800M
7 wto = 6695; %kN
8 WTO = 6695*1000; %N
9 WEmpty= 2725; %kN
10 WPayLoad = 1480; %kN
11 WFuel = 2490; %kN
12 % T = 350; % *sigma Thrust per Engine sigmakN (sigma is density ratio at altitude h)
13 % No of Engines:4
14 TSFC_SL = 47.5; %root theta kg/hr/kN (theta is temperature ratio at altitude h)
15 S = 845; %m2
16 AR = 7.53;
17 e = 0.965;
18 Mcrit_orig = 0.895;
19 AL = 55; %kN/m2 Maximum permissible dynamic head (Aeroelastic limit)
20 q_max = AL*1000; %N/m2
21 CDo= 0.011; %Parasite drag coefficient
22 CLmax= 1.15; %Aircraft CLmaxwithout HLD (plain wing)
23 CLmax_HLD.full = 1.85; %DeltaCLmaxfrom full HLD for landing
24 CLmax_HLD.part = 1.15; %DeltaCLmaxfrom partial HLD for take off
25 CLmax_climb = 0.9; % CLmaxTO (CLmax for climb segment of take off)
26 CDo_Land.Gear =0.0042; % DELTA
27 CDo_Flap = 0.0034; % DELTA (for take off ground run and climb segments)
28 CL_Ground.Run = 0.12;
29 mu = 0.02; %Rolling friction coefficient mu
30 n_max= 2.5; %Load factor
31 % Seats: 3 Class 575 and 1 Class 853
32 Range = 14800; %km
33 Take_off_dist = 3000; %m
34 Rho_SL = 1.225;
35 T_SL = T(1);
36 k = 1/(pi*AR*e);
37 g = 9.81; % m/s2
38 %% PLOT 1
39 %% DRAG POLAR CALCULATION
40 % 0.9 WTO, 0.8 WTO and 0.6 WTO for 0.5, 3, 5.5, 8.5,10.5 & 11.5 km
41 [r,a_1,r, rho_1] = ISA(500);
42 [r,a_2,r, rho_2] = ISA(3000);
43 [r,a_3,r, rho_3] = ISA(5500);
44 [r,a_4,r, rho_4] = ISA(8500);
45 [r,a_5,r, rho_5] = ISA(10500);
46 [r,a_6,r, rho_6] = ISA(11000);
47 % Mcrit for diff altitudes
48 Mcrit_1 = 0.895*a_1;
49 Mcrit_2 = 0.895*a_2;
50 Mcrit_3 = 0.895*a_3;
51 Mcrit_4 = 0.895*a_4;
52 Mcrit_5 = 0.895*a_5;
53 Mcrit_6 = 0.895*a_6;
54 % Density ratio
55 sigma_1 = rho_1/Rho_SL;
56 sigma_2 = rho_2/Rho_SL;
57 sigma_3 = rho_3/Rho_SL;
58 sigma_4 = rho_4/Rho_SL;
59 sigma_5 = rho_5/Rho_SL;
60 sigma_6 = rho_6/Rho_SL;
61 % V_stall Calculation
62 % 0.9 WTO
```

```

63 V_stall_1.9 = ((2*0.9*WTO)/(rho_1*S*CLmax))^0.5;
64 V_stall_2.9 = ((2*0.9*WTO)/(rho_2*S*CLmax))^0.5;
65 V_stall_3.9 = ((2*0.9*WTO)/(rho_3*S*CLmax))^0.5;
66 V_stall_4.9 = ((2*0.9*WTO)/(rho_4*S*CLmax))^0.5;
67 V_stall_5.9 = ((2*0.9*WTO)/(rho_5*S*CLmax))^0.5;
68 V_stall_6.9 = ((2*0.9*WTO)/(rho_6*S*CLmax))^0.5;
69 % 0.8 WTO
70 V_stall_1.8 = ((2*0.8*WTO)/(rho_1*S*CLmax))^0.5;
71 V_stall_2.8 = ((2*0.8*WTO)/(rho_2*S*CLmax))^0.5;
72 V_stall_3.8 = ((2*0.8*WTO)/(rho_3*S*CLmax))^0.5;
73 V_stall_4.8 = ((2*0.8*WTO)/(rho_4*S*CLmax))^0.5;
74 V_stall_5.8 = ((2*0.8*WTO)/(rho_5*S*CLmax))^0.5;
75 V_stall_6.8 = ((2*0.8*WTO)/(rho_6*S*CLmax))^0.5;
76 % 0.6 WTO
77 V_stall_1.6 = ((2*0.6*WTO)/(rho_1*S*CLmax))^0.5;
78 V_stall_2.6 = ((2*0.6*WTO)/(rho_2*S*CLmax))^0.5;
79 V_stall_3.6 = ((2*0.6*WTO)/(rho_3*S*CLmax))^0.5;
80 V_stall_4.6 = ((2*0.6*WTO)/(rho_4*S*CLmax))^0.5;
81 V_stall_5.6 = ((2*0.6*WTO)/(rho_5*S*CLmax))^0.5;
82 V_stall_6.6 = ((2*0.6*WTO)/(rho_6*S*CLmax))^0.5;
83 % A for various altitudes
84 A_0 = CDo*Rho_SL*S*0.5;
85 A_1 = CDo*rho_1*S*0.5;
86 A_2 = CDo*rho_2*S*0.5;
87 A_3 = CDo*rho_3*S*0.5;
88 A_4 = CDo*rho_4*S*0.5;
89 A_5 = CDo*rho_5*S*0.5;
90 A_6 = CDo*rho_6*S*0.5;
91 % B for various altitudes at 0.9 WTO
92 B_0.9 = (2*k*((0.9*WTO)^2))/(Rho_SL*S);
93 B_1.9 = (2*k*((0.9*WTO)^2))/(rho_1*S);
94 B_2.9 = (2*k*((0.9*WTO)^2))/(rho_2*S);
95 B_3.9 = (2*k*((0.9*WTO)^2))/(rho_3*S);
96 B_4.9 = (2*k*((0.9*WTO)^2))/(rho_4*S);
97 B_5.9 = (2*k*((0.9*WTO)^2))/(rho_5*S);
98 B_6.9 = (2*k*((0.9*WTO)^2))/(rho_6*S);
99 % B for various altitudes at 0.8 WTO
100 B_0.8 = (2*k*((0.8*WTO)^2))/(Rho_SL*S);
101 B_1.8 = (2*k*((0.8*WTO)^2))/(rho_1*S);
102 B_2.8 = (2*k*((0.8*WTO)^2))/(rho_2*S);
103 B_3.8 = (2*k*((0.8*WTO)^2))/(rho_3*S);
104 B_4.8 = (2*k*((0.8*WTO)^2))/(rho_4*S);
105 B_5.8 = (2*k*((0.8*WTO)^2))/(rho_5*S);
106 B_6.8 = (2*k*((0.8*WTO)^2))/(rho_6*S);
107 % B for various altitudes at 0.6 WTO
108 B_0.6 = (2*k*((0.6*WTO)^2))/(Rho_SL*S);
109 B_1.6 = (2*k*((0.6*WTO)^2))/(rho_1*S);
110 B_2.6 = (2*k*((0.6*WTO)^2))/(rho_2*S);
111 B_3.6 = (2*k*((0.6*WTO)^2))/(rho_3*S);
112 B_4.6 = (2*k*((0.6*WTO)^2))/(rho_4*S);
113 B_5.6 = (2*k*((0.6*WTO)^2))/(rho_5*S);
114 B_6.6 = (2*k*((0.6*WTO)^2))/(rho_6*S);
115 % Drag Calculation
116 V = 25:1:500;
117 % D for various altitudes at 0.9 WTO
118 D_0.9 = ((A_0).*(V.^2))+((B_0.9)./(V.^2));
119 D_1.9 = ((A_1).*(V.^2))+((B_1.9)./(V.^2));
120 D_2.9 = ((A_2).*(V.^2))+((B_2.9)./(V.^2));
121 D_3.9 = ((A_3).*(V.^2))+((B_3.9)./(V.^2));
122 D_4.9 = ((A_4).*(V.^2))+((B_4.9)./(V.^2));
123 D_5.9 = ((A_5).*(V.^2))+((B_5.9)./(V.^2));
124 D_6.9 = ((A_6).*(V.^2))+((B_6.9)./(V.^2));
125 % D for various altitudes at 0.8 WTO
126 D_0.8 = ((A_0).*(V.^2))+((B_0.8)./(V.^2));
127 D_1.8 = ((A_1).*(V.^2))+((B_1.8)./(V.^2));

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128 D_2_8 = ((A_1).*(V.^2))+((B_2_8)./(V.^2));
129 D_3_8 = ((A_1).*(V.^2))+((B_3_8)./(V.^2));
130 D_4_8 = ((A_1).*(V.^2))+((B_4_8)./(V.^2));
131 D_5_8 = ((A_1).*(V.^2))+((B_5_8)./(V.^2));
132 D_6_8 = ((A_1).*(V.^2))+((B_6_8)./(V.^2));
133 % D for various altitudes at 0.6 WTO
134 D_0_6 = ((A_0).*(V.^2))+((B_0_6)./(V.^2));
135 D_1_6 = ((A_1).*(V.^2))+((B_1_6)./(V.^2));
136 D_2_6 = ((A_1).*(V.^2))+((B_2_6)./(V.^2));
137 D_3_6 = ((A_1).*(V.^2))+((B_3_6)./(V.^2));
138 D_4_6 = ((A_1).*(V.^2))+((B_4_6)./(V.^2));
139 D_5_6 = ((A_1).*(V.^2))+((B_5_6)./(V.^2));
140 D_6_6 = ((A_1).*(V.^2))+((B_6_6)./(V.^2));
141 % V_D_min for 0.9 WTO and various Altitudes
142 V_D_min_1_9 = (((2*(0.9*WTO))/(rho_1*S))*((k/CD0)^0.5))^0.5;
143 V_D_min_2_9 = (((2*(0.9*WTO))/(rho_2*S))*((k/CD0)^0.5))^0.5;
144 V_D_min_3_9 = (((2*(0.9*WTO))/(rho_3*S))*((k/CD0)^0.5))^0.5;
145 V_D_min_4_9 = (((2*(0.9*WTO))/(rho_4*S))*((k/CD0)^0.5))^0.5;
146 V_D_min_5_9 = (((2*(0.9*WTO))/(rho_5*S))*((k/CD0)^0.5))^0.5;
147 V_D_min_6_9 = (((2*(0.9*WTO))/(rho_6*S))*((k/CD0)^0.5))^0.5;
148 % V_D_min for 0.8 WTO and various Altitudes
149 V_D_min_1_8 = (((2*(0.8*WTO))/(rho_1*S))*((k/CD0)^0.5))^0.5;
150 V_D_min_2_8 = (((2*(0.8*WTO))/(rho_2*S))*((k/CD0)^0.5))^0.5;
151 V_D_min_3_8 = (((2*(0.8*WTO))/(rho_3*S))*((k/CD0)^0.5))^0.5;
152 V_D_min_4_8 = (((2*(0.8*WTO))/(rho_4*S))*((k/CD0)^0.5))^0.5;
153 V_D_min_5_8 = (((2*(0.8*WTO))/(rho_5*S))*((k/CD0)^0.5))^0.5;
154 V_D_min_6_8 = (((2*(0.8*WTO))/(rho_6*S))*((k/CD0)^0.5))^0.5;
155 % V_D_min for 0.6 WTO and various Altitudes
156 V_D_min_1_6 = (((2*(0.6*WTO))/(rho_1*S))*((k/CD0)^0.5))^0.5;
157 V_D_min_2_6 = (((2*(0.6*WTO))/(rho_2*S))*((k/CD0)^0.5))^0.5;
158 V_D_min_3_6 = (((2*(0.6*WTO))/(rho_3*S))*((k/CD0)^0.5))^0.5;
159 V_D_min_4_6 = (((2*(0.6*WTO))/(rho_4*S))*((k/CD0)^0.5))^0.5;
160 V_D_min_5_6 = (((2*(0.6*WTO))/(rho_5*S))*((k/CD0)^0.5))^0.5;
161 V_D_min_6_6 = (((2*(0.6*WTO))/(rho_6*S))*((k/CD0)^0.5))^0.5;
162 % Altitude plot
163 A_0 = CD0*Rho_SL*S*0.5;
164 B_0_9 = (2*k*((0.9*WTO)^2))/(Rho_SL*S);
165 B_0_8 = (2*k*((0.8*WTO)^2))/(Rho_SL*S);
166 B_0_6 = (2*k*((0.6*WTO)^2))/(Rho_SL*S);
167 % Drag 0.9 WTO and various altitudes
168 D_0_9_1 = ((A_0).*(V.*(sigma_1)^0.5).^2)+((B_0_9)./(V.*(sigma_1)^0.5).^2));
169 D_0_9_2 = ((A_0).*(V.*(sigma_2)^0.5).^2)+((B_0_9)./(V.*(sigma_2)^0.5).^2));
170 D_0_9_3 = ((A_0).*(V.*(sigma_3)^0.5).^2)+((B_0_9)./(V.*(sigma_3)^0.5).^2));
171 D_0_9_4 = ((A_0).*(V.*(sigma_4)^0.5).^2)+((B_0_9)./(V.*(sigma_4)^0.5).^2));
172 D_0_9_5 = ((A_0).*(V.*(sigma_5)^0.5).^2)+((B_0_9)./(V.*(sigma_5)^0.5).^2));
173 D_0_9_6 = ((A_0).*(V.*(sigma_6)^0.5).^2)+((B_0_9)./(V.*(sigma_6)^0.5).^2));
174 % Drag 0.8 WTO and various altitudes
175 D_0_8_1 = ((A_0).*(V.*(sigma_1)^0.5).^2)+((B_0_8)./(V.*(sigma_1)^0.5).^2));
176 D_0_8_2 = ((A_0).*(V.*(sigma_2)^0.5).^2)+((B_0_8)./(V.*(sigma_2)^0.5).^2));
177 D_0_8_3 = ((A_0).*(V.*(sigma_3)^0.5).^2)+((B_0_8)./(V.*(sigma_3)^0.5).^2));
178 D_0_8_4 = ((A_0).*(V.*(sigma_4)^0.5).^2)+((B_0_8)./(V.*(sigma_4)^0.5).^2));
179 D_0_8_5 = ((A_0).*(V.*(sigma_5)^0.5).^2)+((B_0_8)./(V.*(sigma_5)^0.5).^2));
180 D_0_8_6 = ((A_0).*(V.*(sigma_6)^0.5).^2)+((B_0_8)./(V.*(sigma_6)^0.5).^2));
181 % Drag 0.6 WTO and various altitudes
182 D_0_6_1 = ((A_0).*(V.*(sigma_1)^0.5).^2)+((B_0_6)./(V.*(sigma_1)^0.5).^2));
183 D_0_6_2 = ((A_0).*(V.*(sigma_2)^0.5).^2)+((B_0_6)./(V.*(sigma_2)^0.5).^2));
184 D_0_6_3 = ((A_0).*(V.*(sigma_3)^0.5).^2)+((B_0_6)./(V.*(sigma_3)^0.5).^2));
185 D_0_6_4 = ((A_0).*(V.*(sigma_4)^0.5).^2)+((B_0_6)./(V.*(sigma_4)^0.5).^2));
186 D_0_6_5 = ((A_0).*(V.*(sigma_5)^0.5).^2)+((B_0_6)./(V.*(sigma_5)^0.5).^2));
187 D_0_6_6 = ((A_0).*(V.*(sigma_6)^0.5).^2)+((B_0_6)./(V.*(sigma_6)^0.5).^2));
188 % % D_min at Various Weights
189 D_min_9 = (2*0.9*WTO)*((k*CD0)^0.5);
190 D_min_8 = (2*0.8*WTO)*((k*CD0)^0.5);
191 D_min_6 = (2*0.6*WTO)*((k*CD0)^0.5);
192 %% D_min indices

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193 % 0.9 WTO
194 [D.min_1_9,index_1_9] = min(D_0_9_1);
195 [D.min_2_9,index_2_9] = min(D_0_9_2);
196 [D.min_3_9,index_3_9] = min(D_0_9_3);
197 [D.min_4_9,index_4_9] = min(D_0_9_4);
198 [D.min_5_9,index_5_9] = min(D_0_9_5);
199 [D.min_6_9,index_6_9] = min(D_0_9_6);
200
201 % 0.8 WTO
202 [D.min_1_8,index_1_8] = min(D_0_8_1);
203 [D.min_2_8,index_2_8] = min(D_0_8_2);
204 [D.min_3_8,index_3_8] = min(D_0_8_3);
205 [D.min_4_8,index_4_8] = min(D_0_8_4);
206 [D.min_5_8,index_5_8] = min(D_0_8_5);
207 [D.min_6_8,index_6_8] = min(D_0_8_6);
208
209 % 0.6 WTO
210 [D.min_1_6,index_1_6] = min(D_0_6_1);
211 [D.min_2_6,index_2_6] = min(D_0_6_2);
212 [D.min_3_6,index_3_6] = min(D_0_6_3);
213 [D.min_4_6,index_4_6] = min(D_0_6_4);
214 [D.min_5_6,index_5_6] = min(D_0_6_5);
215 [D.min_6_6,index_6_6] = min(D_0_6_6);
216
217 % Alt 1
218 [D.min_1_9_n,index_1_9_n] = min(D_1_9);
219 [D.min_1_8_n,index_1_8_n] = min(D_1_8);
220 [D.min_1_6_n,index_1_6_n] = min(D_1_6);
221
222 % Alt 2
223 [D.min_2_9_n,index_2_9_n] = min(D_2_9);
224 [D.min_2_8_n,index_2_8_n] = min(D_2_8);
225 [D.min_2_6_n,index_2_6_n] = min(D_2_6);
226
227 % Alt 3
228 [D.min_3_9_n,index_3_9_n] = min(D_3_9);
229 [D.min_3_8_n,index_3_8_n] = min(D_3_8);
230 [D.min_3_6_n,index_3_6_n] = min(D_3_6);
231
232 % Alt 4
233 [D.min_4_9_n,index_4_9_n] = min(D_4_9);
234 [D.min_4_8_n,index_4_8_n] = min(D_4_8);
235 [D.min_4_6_n,index_4_6_n] = min(D_4_6);
236
237 % Alt 5
238 [D.min_5_9_n,index_5_9_n] = min(D_5_9);
239 [D.min_5_8_n,index_5_8_n] = min(D_5_8);
240 [D.min_5_6_n,index_5_6_n] = min(D_5_6);
241
242 % Alt 6
243 [D.min_6_9_n,index_6_9_n] = min(D_6_9);
244 [D.min_6_8_n,index_6_8_n] = min(D_6_8);
245 [D.min_6_6_n,index_6_6_n] = min(D_6_6);
246 %% DRAG POLAR PLOT
247 %% 0.9 WTO
248 title("Drag Polar for Various Altitudes at 0.9 $W_{TO}$", "Interpreter", "latex", 'FontSize', 20)
249 hold on
250 % Curves
251 plot(V(78:280), D_0_9_1(78:280), 'Color', 'magenta', 'LineWidth', 1.2)
252 plot(V(88:270), D_0_9_2(88:270), 'Color', 'blue', 'LineWidth', 1.2)
253 plot(V(105:265), D_0_9_3(105:265), 'Color', '#D95319', 'LineWidth', 1.2)
254 plot(V(130:255), D_0_9_4(130:255), 'Color', '#EDB120', 'LineWidth', 1.2)
255 plot(V(150:245), D_0_9_5(150:245), 'Color', 'green', 'LineWidth', 1.2)
256 plot(V(160:243), D_0_9_6(160:243), 'Color', '#4DBEEE', 'LineWidth', 1.2)
257 % V_D_min for legend

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258 plot([V(index_1.9) V(index_1.9)], [0 D_min_1.9], '-', 'Color', "#A2142F", 'LineWidth', 1.1)
259 % M_crit for legend
260 plot([Mcrit_1 Mcrit_1], [0 D_0.9_1 (278)], '-', 'Color', "#009899", 'LineWidth', 1.3)
261 % V_stall for legend
262 plot([V_stall_1.9 V_stall_1.9], [0 D_0.9_1 (79)], '-', 'Color', "#6600cc", 'LineWidth', 1.1)
263 % V_stall lines
264 plot([V_stall_2.9 V_stall_2.9], [0 D_0.9_2 (92)], '-', 'Color', "#6600cc", 'LineWidth', 1.1)
265 plot([V_stall_3.9 V_stall_3.9], [0 D_0.9_3 (109)], '-', 'Color', "#6600cc", 'LineWidth', 1.1)
266 plot([V_stall_4.9 V_stall_4.9], [0 D_0.9_4 (134)], '-', 'Color', "#6600cc", 'LineWidth', 1.1)
267 plot([V_stall_5.9 V_stall_5.9], [0 D_0.9_5 (154)], '-', 'Color', "#6600cc", 'LineWidth', 1.1)
268 plot([V_stall_6.9 V_stall_6.9], [0 D_0.9_6 (160)], '-', 'Color', "#6600cc", 'LineWidth', 1.1)
269 % D_min line
270 yline(264549, '--', 'Color', 'black', 'LineWidth', 1.1)
271 % D_min text
272 text(40, 240000, '$D_{min}$ = 264549 N', 'Interpreter', 'latex', 'FontSize', 15)
273 % V_D_min line
274 plot([V(index_2.9) V(index_2.9)], [0 D_min_2.9], '-', 'Color', "#A2142F", 'LineWidth', 1.1)
275 plot([V(index_3.9) V(index_3.9)], [0 D_min_3.9], '-', 'Color', "#A2142F", 'LineWidth', 1.1)
276 plot([V(index_4.9) V(index_4.9)], [0 D_min_4.9], '-', 'Color', "#A2142F", 'LineWidth', 1.1)
277 plot([V(index_5.9) V(index_5.9)], [0 D_min_5.9], '-', 'Color', "#A2142F", 'LineWidth', 1.1)
278 plot([V(index_6.9) V(index_6.9)], [0 D_min_6.9], '-', 'Color', "#A2142F", 'LineWidth', 1.1)
279 % M_crit line
280 plot([Mcrit_2 Mcrit_2], [0 D_0.9_2 (270)], '-', 'Color', "#009899", 'LineWidth', 1.3)
281 plot([Mcrit_3 Mcrit_3], [0 D_0.9_3 (261)], '-', 'Color', "#009899", 'LineWidth', 1.3)
282 plot([Mcrit_4 Mcrit_4], [0 D_0.9_4 (249)], '-', 'Color', "#009899", 'LineWidth', 1.3)
283 plot([Mcrit_5 Mcrit_5], [0 D_0.9_5 (242)], '-', 'Color', "#009899", 'LineWidth', 1.3)
284 plot([Mcrit_6 Mcrit_6], [0 D_0.9_6 (240)], '-', 'Color', "#009899", 'LineWidth', 1.3)
285 hold off
286 grid on
287 xlabel("Velocity (m/s)", 'Interpreter', 'latex', 'FontSize', 17)
288 ylabel("Drag (N)", 'Interpreter', 'latex', 'FontSize', 17)
289 xlim([0 340])
290 ylim([0 700000])
291 xticks(25:25:330)
292 leg1 = legend("0.5 Km", "3 Km", "5.5 Km", "8.5 Km", "10.5 Km", "11.5 Km", "$V_{D_{min}}$", ...
293     "$V_{crit}$", "$V_{stall}$", 'Interpreter', 'latex', 'Location', 'northwest', 'FontSize', 16);
294 title(leg1, 'Legend')
295 ax = gca;
296 ax.TickDir = 'out';
297 ax.TickLength = [0.005 0.005];
298 grid on
299 set(gcf, 'Position', get(0, 'ScreenSize'));
300 %% 0.8 WTO
301 title("Drag Polar for Various Altitudes at 0.8 $W_{TO}$", 'Interpreter', 'latex', 'FontSize', 20)
302 hold on
303 % Curves
304 plot(V(70:280), D_0.8_1 (70:280), 'Color', 'magenta', 'LineWidth', 1.2)
305 plot(V(85:273), D_0.8_2 (85:273), 'Color', 'blue', 'LineWidth', 1.2)
306 plot(V(100:263), D_0.8_3 (100:263), 'Color', "#D85318", 'LineWidth', 1.2)
307 plot(V(123:253), D_0.8_4 (123:253), 'Color', "#EDB120", 'LineWidth', 1.2)
308 plot(V(140:243), D_0.8_5 (140:243), 'Color', 'green', 'LineWidth', 1.2)
309 plot(V(148:233), D_0.8_6 (148:233), 'Color', "#4DBEEE", 'LineWidth', 1.2)
310 % V_D_min for legend
311 plot([V(index_1.8) V(index_1.8)], [0 D_min_1.8], '-', 'Color', "#A2142F", 'LineWidth', 1.1)
312 % M_crit for legend
313 plot([Mcrit_1 Mcrit_1], [0 D_0.8_1 (278)], '-', 'Color', "#008888", 'LineWidth', 1.3)
314 % V_stall for legend
315 plot([V_stall_1.8 V_stall_1.8], [0 D_0.8_1 (72)], '-', 'Color', "#6600cc", 'LineWidth', 1.1)
316 % V_stall lines
317 plot([V_stall_2.8 V_stall_2.8], [0 D_0.8_2 (85)], '-', 'Color', "#6600cc", 'LineWidth', 1.1)
318 plot([V_stall_3.8 V_stall_3.8], [0 D_0.8_3 (100)], '-', 'Color', "#6600cc", 'LineWidth', 1.1)
319 plot([V_stall_4.8 V_stall_4.8], [0 D_0.8_4 (124)], '-', 'Color', "#6600cc", 'LineWidth', 1.1)
320 plot([V_stall_5.8 V_stall_5.8], [0 D_0.8_5 (144)], '-', 'Color', "#6600cc", 'LineWidth', 1.1)
321 plot([V_stall_6.8 V_stall_6.8], [0 D_0.8_6 (149)], '-', 'Color', "#6600cc", 'LineWidth', 1.1)
322 % D_min line

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323 yline(235145, '--', 'Color', 'black', 'LineWidth', 1.1)
324 % D_min text
325 text(40, 190000, '$D_{min}$ = 235145 N', 'Interpreter', 'latex', 'FontSize', 14)
326 % V_D_min line
327 plot([V(index_2_8) V(index_2_8)], [0 D_min_2_8], '-', 'Color', '#A2142F', 'LineWidth', 1.1)
328 plot([V(index_3_8) V(index_3_8)], [0 D_min_3_8], '-', 'Color', '#A2142F', 'LineWidth', 1.1)
329 plot([V(index_4_8) V(index_4_8)], [0 D_min_4_8], '-', 'Color', '#A2142F', 'LineWidth', 1.1)
330 plot([V(index_5_8) V(index_5_8)], [0 D_min_5_8], '-', 'Color', '#A2142F', 'LineWidth', 1.1)
331 plot([V(index_6_8) V(index_6_8)], [0 D_min_6_8], '-', 'Color', '#A2142F', 'LineWidth', 1.1)
332 % M_crit line
333 plot([Mcrit_2 Mcrit_2], [0 D_0_8_2 (270)], '-', 'Color', '#008888', 'LineWidth', 1.3)
334 plot([Mcrit_3 Mcrit_3], [0 D_0_8_3 (261)], '-', 'Color', '#008888', 'LineWidth', 1.3)
335 plot([Mcrit_4 Mcrit_4], [0 D_0_8_4 (248)], '-', 'Color', '#008888', 'LineWidth', 1.3)
336 plot([Mcrit_5 Mcrit_5], [0 D_0_8_5 (242)], '-', 'Color', '#008888', 'LineWidth', 1.3)
337 plot([Mcrit_6 Mcrit_6], [0 D_0_8_6 (240)], '-', 'Color', '#008888', 'LineWidth', 1.3)
338 hold off
339 grid on
340 xlabel("Velocity (m/s)", 'Interpreter', 'latex', 'FontSize', 17)
341 ylabel("Drag (N)", 'Interpreter', 'latex', 'FontSize', 17)
342 leg1 = legend("0.5 Km", "3 Km", "5.5 Km", "8.5 Km", "10.5 Km", "11.5 Km", "$V_{D_{min}}$", ...
343 "$V_{crit}$", "$V_{stall}$", 'Interpreter', 'latex', 'Location', 'northwest', 'FontSize', 16);
344 title(leg1, 'Legend')
345 ax = gca;
346 ax.TickDir = 'out';
347 ax.TickLength = [0.005 0.005];
348 ylim([0 0.8e6])
349 xlim([0 340])
350 xticks(25:25:330)
351 grid on
352 set(gcf, 'Position', get(0, 'ScreenSize'));
353 % 0.6 WTO
354 hold on
355 title("Drag Polar for Various Altitudes at 0.6 $W_{TO}$", 'Interpreter', 'latex', 'FontSize', 20)
356 hold on
357 % Curves
358 plot(V(58:280), D_0_6_1 (58:280), 'Color', 'magenta', 'LineWidth', 1.2)
359 plot(V(70:271), D_0_6_2 (70:271), 'Color', 'blue', 'LineWidth', 1.2)
360 plot(V(83:263), D_0_6_3 (83:263), 'Color', '#D65316', 'LineWidth', 1.2)
361 plot(V(105:252), D_0_6_4 (105:252), 'Color', '#EDB120', 'LineWidth', 1.2)
362 plot(V(120:243), D_0_6_5 (120:243), 'Color', 'green', 'LineWidth', 1.2)
363 plot(V(125:241), D_0_6_6 (125:241), 'Color', '#4DBEEE', 'LineWidth', 1.2)
364 % V_D_min for legend
365 plot([V(index_1_6) V(index_1_6)], [0 D_min_1_6], '-', 'Color', '#A2142F', 'LineWidth', 1.1)
366 % M_crit for legend
367 plot([Mcrit_1 Mcrit_1], [0 D_0_6_1 (278)], '-', 'Color', '#006666', 'LineWidth', 1.3)
368 % V_stall for legend
369 plot([V_stall_1_6 V_stall_1_6], [0 D_0_6_1 (60)], '-', 'Color', '#6600cc', 'LineWidth', 1.1)
370 % V_stall lines
371 plot([V_stall_2_6 V_stall_2_6], [0 D_0_6_2 (71)], '-', 'Color', '#6600cc', 'LineWidth', 1.1)
372 plot([V_stall_3_6 V_stall_3_6], [0 D_0_6_3 (84)], '-', 'Color', '#6600cc', 'LineWidth', 1.1)
373 plot([V_stall_4_6 V_stall_4_6], [0 D_0_6_4 (105)], '-', 'Color', '#6600cc', 'LineWidth', 1.1)
374 plot([V_stall_5_6 V_stall_5_6], [0 D_0_6_5 (121)], '-', 'Color', '#6600cc', 'LineWidth', 1.1)
375 plot([V_stall_6_6 V_stall_6_6], [0 D_0_6_6 (126)], '-', 'Color', '#6600cc', 'LineWidth', 1.1)
376 % D_min line
377 yline(176492, '--', 'Color', 'black', 'LineWidth', 1.1)
378 % D_min text
379 text(40, 150000, '$D_{min}$ = 176492 N', 'Interpreter', 'latex', 'FontSize', 15)
380 % V_D_min line
381 plot([V(index_2_6) V(index_2_6)], [0 D_min_2_6], '-', 'Color', '#A2142F', 'LineWidth', 1.1)
382 plot([V(index_3_6) V(index_3_6)], [0 D_min_3_6], '-', 'Color', '#A2142F', 'LineWidth', 1.1)
383 plot([V(index_4_6) V(index_4_6)], [0 D_min_4_6], '-', 'Color', '#A2142F', 'LineWidth', 1.1)
384 plot([V(index_5_6) V(index_5_6)], [0 D_min_5_6], '-', 'Color', '#A2142F', 'LineWidth', 1.1)
385 plot([V(index_6_6) V(index_6_6)], [0 D_min_6_6], '-', 'Color', '#A2142F', 'LineWidth', 1.1)
386 % M_crit line
387 plot([Mcrit_2 Mcrit_2], [0 D_0_6_2 (270)], '-', 'Color', '#006666', 'LineWidth', 1.3)

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388 plot([Mcrit_3 Mcrit_3],[0 D_0_6_3(261)], '-.', 'Color', "#006666", 'LineWidth', 1.3)
389 plot([Mcrit_4 Mcrit_4],[0 D_0_6_4(246)], '-.', 'Color', "#006666", 'LineWidth', 1.3)
390 plot([Mcrit_5 Mcrit_5],[0 D_0_6_5(242)], '-.', 'Color', "#006666", 'LineWidth', 1.3)
391 plot([Mcrit_6 Mcrit_6],[0 D_0_6_6(240)], '-.', 'Color', "#006666", 'LineWidth', 1.3)
392 hold off
393 xlabel("Velocity (m/s)", 'Interpreter', 'latex', 'FontSize', 17)
394 ylabel("Drag (N)", 'Interpreter', 'latex', 'FontSize', 17)
395 leg1 = legend("0.5 Km", "3 Km", "5.5 Km", "8.5 Km", "10.5 Km", "11.5 Km", "$V_{D_{\min}}$", ...
396             "$V_{\text{crit}}$", "$V_{\text{stall}}$", 'Interpreter', 'latex', 'Location', 'northwest', 'FontSize', 16);
397 title(leg1, 'Legend')
398 ax = gca;
399 ax.TickDir = 'out';
400 grid on
401 ax.TickLength = [0.005 0.005];
402 ylim([0 6.5e5])
403 xlim([0 340])
404 xticks(25:25:330)
405 set(gcf, 'Position', get(0, 'ScreenSize'));
406 %% Alt 1
407 hold on
408 title("Drag Polar at 0.5 Km for Various $W_{\text{TO}}$", "Interpreter", "latex", 'FontSize', 20)
409 hold on
410 % Curves
411 plot(V(78:280), D_1_9(78:280), 'Color', 'magenta', 'LineWidth', 1.2)
412 plot(V(71:280), D_1_8(71:280), 'Color', 'blue', 'LineWidth', 1.2)
413 plot(V(60:280), D_1_6(60:280), 'Color', "#D65316", 'LineWidth', 1.2)
414 % V_D_min for legend
415 plot([V(index_1_9_n) V(index_1_9_n)], [0 D_min_1_9_n], '-.', 'Color', "#A2142F", 'LineWidth', 1.1)
416 % M_crit for legend
417 plot([Mcrit_1 Mcrit_1], [0 D_1_9(278)], '-.', 'Color', "#006666", 'LineWidth', 1.3)
418 % V_stall for legend
419 plot([V_stall_1_9 V_stall_1_9], [0 D_1_9(79)], '-.', 'Color', "#6600cc", 'LineWidth', 1.1)
420 % V_stall lines
421 plot([V_stall_1_8 V_stall_1_8], [0 D_1_8(72)], '-.', 'Color', "#6600cc", 'LineWidth', 1.1)
422 plot([V_stall_1_6 V_stall_1_6], [0 D_1_6(60)], '-.', 'Color', "#6600cc", 'LineWidth', 1.1)
423 % V_D_min line
424 plot([V(index_1_8_n) V(index_1_8_n)], [0 D_min_1_8_n], '-.', 'Color', "#A2142F", 'LineWidth', 1.1)
425 plot([V(index_1_6_n) V(index_1_6_n)], [0 D_min_1_6_n], '-.', 'Color', "#A2142F", 'LineWidth', 1.1)
426 % M_crit line
427 plot([Mcrit_1 Mcrit_1], [0 D_1_8(278)], '-.', 'Color', "#006666", 'LineWidth', 1.3)
428 plot([Mcrit_1 Mcrit_1], [0 D_1_6(276)], '-.', 'Color', "#006666", 'LineWidth', 1.3)
429 hold off
430 grid on
431 xlabel("Velocity (m/s)", 'Interpreter', 'latex', 'FontSize', 17)
432 ylabel("Drag (N)", 'Interpreter', 'latex', 'FontSize', 17)
433 leg1 = legend("0.9 $W_{\text{TO}}$", "0.8 $W_{\text{TO}}$", "0.6 $W_{\text{TO}}$", "$V_{D_{\min}}$", "$V_{\text{crit}}$", ...
434             "$V_{\text{stall}}$", 'Interpreter', 'latex', 'Location', 'northwest', 'FontSize', 16);
435 title(leg1, 'Legend')
436 ax = gca;
437 ax.TickDir = 'out';
438 grid on
439 ax.TickLength = [0.005 0.005];
440 xlim([0 340])
441 ylim([0 6.5e5])
442 xticks(25:25:330)
443 set(gcf, 'Position', get(0, 'ScreenSize'));
444 %% Alt 2
445 hold on
446 title("Drag Polar at 3 Km for Various $W_{\text{TO}}$", "Interpreter", "latex", 'FontSize', 20)
447 hold on
448 % Curves
449 plot(V(88:272), D_2_9(88:272), 'Color', 'magenta', 'LineWidth', 1.2)
450 plot(V(85:272), D_2_8(85:272), 'Color', 'blue', 'LineWidth', 1.2)
451 plot(V(70:272), D_2_6(70:272), 'Color', "#D65316", 'LineWidth', 1.2)
452 % V_D_min for legend

```



```

453 plot([V(index_2_9_n) V(index_2_9_n)], [0 D_min_2_9_n], '-', 'Color', "#A2142F", 'LineWidth', 1.1)
454 % M_crit for legend
455 plot([Mcrit_2 Mcrit_2], [0 D_2_9 (270)], '-', 'Color', "#006666", 'LineWidth', 1.3)
456 % V_stall for legend
457 plot([V_stall_2_9 V_stall_2_9], [0 D_2_9 (92)], '-', 'Color', "#6600cc", 'LineWidth', 1.1)
458 % V_stall lines
459 plot([V_stall_2_8 V_stall_2_8], [0 D_2_8 (86)], '-', 'Color', "#6600cc", 'LineWidth', 1.1)
460 plot([V_stall_2_6 V_stall_2_6], [0 D_2_6 (71)], '-', 'Color', "#6600cc", 'LineWidth', 1.1)
461 % V_D_min line
462 plot([V(index_2_8_n) V(index_2_8_n)], [0 D_min_2_8_n], '-', 'Color', "#A2142F", 'LineWidth', 1.1)
463 plot([V(index_2_6_n) V(index_2_6_n)], [0 D_min_2_6_n], '-', 'Color', "#A2142F", 'LineWidth', 1.1)
464 % M_crit line
465 plot([Mcrit_2 Mcrit_2], [0 D_2_8 (270)], '-', 'Color', "#006666", 'LineWidth', 1.3)
466 plot([Mcrit_2 Mcrit_2], [0 D_2_6 (270)], '-', 'Color', "#006666", 'LineWidth', 1.3)
467 hold off
468 grid on
469 xlabel("Velocity (m/s)", 'Interpreter', 'latex', 'FontSize', 17)
470 ylabel("Drag (N)", 'Interpreter', 'latex', 'FontSize', 17)
471 leg1 = legend("0.9 $W_{TO}$", "0.8 $W_{TO}$", "0.6 $W_{TO}$", "$V_{D_{min}}$", "$V_{crit}$", ...
472 "$V_{stall}$", 'Interpreter', 'latex', 'Location', 'northwest', 'FontSize', 16);
473 title(leg1, 'Legend')
474 ax = gca;
475 ax.TickDir = 'out';
476 grid on
477 ax.TickLength = [0.005 0.005];
478 grid on
479 xlim([0 330])
480 ylim([0 7e5])
481 xticks(25:25:330)
482 set(gcf, 'Position', get(0, 'ScreenSize'));
483 %% Alt 3
484 hold on
485 title("Drag Polar at 5.5 Km for Various $W_{TO}$", 'Interpreter', 'latex', 'FontSize', 20)
486 hold on
487 % Curves
488 plot(V(108:265), D_3_9(108:265), 'Color', 'magenta', 'LineWidth', 1.2)
489 plot(V(100:265), D_3_8(100:265), 'Color', 'blue', 'LineWidth', 1.2)
490 plot(V(83:265), D_3_6(83:265), 'Color', "#D65316", 'LineWidth', 1.2)
491 % V_D_min for legend
492 plot([V(index_3_9_n) V(index_3_9_n)], [0 D_min_3_9_n], '-', 'Color', "#A2142F", 'LineWidth', 1.1)
493 % M_crit for legend
494 plot([Mcrit_3 Mcrit_3], [0 D_3_9 (261)], '-', 'Color', "#006666", 'LineWidth', 1.3)
495 % V_stall for legend
496 plot([V_stall_3_9 V_stall_3_9], [0 D_3_9 (109)], '-', 'Color', "#6600cc", 'LineWidth', 1.1)
497 % V_stall lines
498 plot([V_stall_3_8 V_stall_3_8], [0 D_3_8 (101)], '-', 'Color', "#6600cc", 'LineWidth', 1.1)
499 plot([V_stall_3_6 V_stall_3_6], [0 D_3_6 (84)], '-', 'Color', "#6600cc", 'LineWidth', 1.1)
500 % V_D_min line
501 plot([V(index_3_8_n) V(index_3_8_n)], [0 D_min_3_8_n], '-', 'Color', "#A2142F", 'LineWidth', 1.1)
502 plot([V(index_3_6_n) V(index_3_6_n)], [0 D_min_3_6_n], '-', 'Color', "#A2142F", 'LineWidth', 1.1)
503 % M_crit line
504 plot([Mcrit_3 Mcrit_3], [0 D_3_8 (100)], '-', 'Color', "#006666", 'LineWidth', 1.3)
505 plot([Mcrit_3 Mcrit_3], [0 D_3_6 (261)], '-', 'Color', "#006666", 'LineWidth', 1.3)
506 hold off
507 grid on
508 xlabel("Velocity (m/s)", 'Interpreter', 'latex', 'FontSize', 17)
509 ylabel("Drag (N)", 'Interpreter', 'latex', 'FontSize', 17)
510 leg1 = legend("0.9 $W_{TO}$", "0.8 $W_{TO}$", "0.6 $W_{TO}$", "$V_{D_{min}}$", "$V_{crit}$", ...
511 "$V_{stall}$", 'Interpreter', 'latex', 'Location', 'northwest', 'FontSize', 16);
512 title(leg1, 'Legend')
513 ax = gca;
514 ax.TickDir = 'out';
515 grid on
516 ax.TickLength = [0.005 0.005];
517 xlim([0 320])

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```

518 ylim([0 6.5e5])
519 xticks(25:25:330)
520 set(gcf, 'Position', get(0,'ScreenSize'));
521 %% Alt 4
522 hold on
523 title("Drag Polar at 8.5 Km for Various  $\$W_{TO}\$", "Interpreter", "latex", 'FontSize', 20)
524 hold on
525 % Curves
526 plot(V(133:253), D_4_9(133:253), 'Color', 'magenta', 'LineWidth', 1.2)
527 plot(V(123:253), D_4_8(123:253), 'Color', 'blue', 'LineWidth', 1.2)
528 plot(V(103:253), D_4_6(103:253), 'Color', '#D65416', 'LineWidth', 1.2)
529 % V_D_min for legend
530 plot([V(index_4_9_n) V(index_4_9_n)], [0 D_min_4_9_n], '-.', 'Color', '#A2142F', 'LineWidth', 1.1)
531 % M_crit for legend
532 plot([Mcrit_4 Mcrit_4], [0 D_4_9(250)], '-.', 'Color', '#006666', 'LineWidth', 1.4)
533 % V_stall for legend
534 plot([V_stall_4_9 V_stall_4_9], [0 D_4_9(134)], '-.', 'Color', '#6600cc', 'LineWidth', 1.1)
535 % V_stall lines
536 plot([V_stall_4_8 V_stall_4_8], [0 D_4_8(124)], '-.', 'Color', '#6600cc', 'LineWidth', 1.1)
537 plot([V_stall_4_6 V_stall_4_6], [0 D_4_6(105)], '-.', 'Color', '#6600cc', 'LineWidth', 1.1)
538 % V_D_min line
539 plot([V(index_4_8_n) V(index_4_8_n)], [0 D_min_4_8_n], '-.', 'Color', '#A2142F', 'LineWidth', 1.1)
540 plot([V(index_4_6_n) V(index_4_6_n)], [0 D_min_4_6_n], '-.', 'Color', '#A2142F', 'LineWidth', 1.1)
541 % M_crit line
542 plot([Mcrit_4 Mcrit_4], [0 D_4_8(250)], '-.', 'Color', '#006666', 'LineWidth', 1.4)
543 plot([Mcrit_4 Mcrit_4], [0 D_4_6(250)], '-.', 'Color', '#006666', 'LineWidth', 1.4)
544 hold off
545 grid on
546 xlabel("Velocity (m/s)", 'Interpreter', 'latex', 'FontSize', 17)
547 ylabel("Drag (N)", 'Interpreter', 'latex', 'FontSize', 17)
548 leg1 = legend("0.9  $\$W_{TO}\$", "0.8  $\$W_{TO}\$", "0.6  $\$W_{TO}\$", " $\$V_{D_{min}}\$", " $\$V_{crit}\$", ...
549 " $\$V_{stall}\$", 'Interpreter', 'latex', 'Location', 'northwest', 'FontSize', 16);
550 title(leg1, 'Legend')
551 xlim([0 300])
552 ylim([0 6e5])
553 xticks(25:25:330)
554 set(gcf, 'Position', get(0,'ScreenSize'));
555 %% Alt 5
556 hold on
557 title("Drag Polar at 10.5 Km for Various  $\$W_{TO}\$", "Interpreter", "latex", 'FontSize', 20)
558 hold on
559 % Curves
560 plot(V(153:245), D_5_9(153:245), 'Color', 'magenta', 'LineWidth', 1.2)
561 plot(V(142:245), D_5_8(142:245), 'Color', 'blue', 'LineWidth', 1.2)
562 plot(V(120:245), D_5_6(120:245), 'Color', '#D65516', 'LineWidth', 1.2)
563 % V_D_min for legend
564 plot([V(index_5_9_n) V(index_5_9_n)], [0 D_min_5_9_n], '-.', 'Color', '#A2142F', 'LineWidth', 1.1)
565 % M_crit for legend
566 plot([Mcrit_5 Mcrit_5], [0 D_5_9(242)], '-.', 'Color', '#006666', 'LineWidth', 1.4)
567 % V_stall for legend
568 plot([V_stall_5_9 V_stall_5_9], [0 D_5_9(154)], '-.', 'Color', '#6600cc', 'LineWidth', 1.1)
569 % V_stall lines
570 plot([V_stall_5_8 V_stall_5_8], [0 D_5_8(144)], '-.', 'Color', '#6600cc', 'LineWidth', 1.1)
571 plot([V_stall_5_6 V_stall_5_6], [0 D_5_6(121)], '-.', 'Color', '#6600cc', 'LineWidth', 1.1)
572 % V_D_min line
573 plot([V(index_5_8_n) V(index_5_8_n)], [0 D_min_5_8_n], '-.', 'Color', '#A2142F', 'LineWidth', 1.1)
574 plot([V(index_5_6_n) V(index_5_6_n)], [0 D_min_5_6_n], '-.', 'Color', '#A2142F', 'LineWidth', 1.1)
575 % M_crit line
576 plot([Mcrit_5 Mcrit_5], [0 D_5_8(242)], '-.', 'Color', '#006666', 'LineWidth', 1.4)
577 plot([Mcrit_5 Mcrit_5], [0 D_5_6(121)], '-.', 'Color', '#006666', 'LineWidth', 1.4)
578 hold off
579 grid on
580 h=gca;
581 h.XAxis.TickLength = [0 0];
582 h.YAxis.TickLength = [0 0];$$$$$$$$ 
```

```

583 xlabel("Velocity (m/s)", 'Interpreter', 'latex', 'FontSize', 17)
584 ylabel("Drag (N)", 'Interpreter', 'latex', 'FontSize', 17)
585 leg1 = legend("0.9 $W_{TO}$", "0.8 $W_{TO}$", "0.6 $W_{TO}$", "$V_{D_{min}}$", "$V_{crit}$", ...
586 "$V_{stall}$", 'Interpreter', 'latex', 'Location', 'northwest', 'FontSize', 16);
587 title(leg1, 'Legend')
588 ax = gca;
589 ax.TickDir = 'out';
590 grid on
591 ax.TickLength = [0.005 0.005];
592 xlim([0 290])
593 ylim([0 6e5])
594 xticks(25:25:330)
595 set(gcf, 'Position', get(0, 'ScreenSize'));
596 %% Alt 6
597 hold on
598 title("Drag Polar at 11.5 Km for Various $W_{TO}$", "Interpreter", "latex", 'FontSize', 20)
599 % Curves
600 plot(V(158:243), D_6_9(158:243), 'Color', 'magenta', 'LineWidth', 1.2)
601 plot(V(148:243), D_6_8(148:243), 'Color', 'blue', 'LineWidth', 1.2)
602 plot(V(123:243), D_6_6(123:243), 'Color', '#D66616', 'LineWidth', 1.2)
603 % V.D_min for legend
604 plot([V(index_6_9_n) V(index_6_9_n)], [0 D_min_6_9_n], '-.', 'Color', '#A2142F', 'LineWidth', 1.1)
605 % M_crit for legend
606 plot([Mcrit_6 Mcrit_6], [0 D_6_9(240)], '-.', 'Color', '#006666', 'LineWidth', 1.4)
607 % V_stall for legend
608 plot([V_stall_6_9 V_stall_6_9], [0 D_6_9(160)], '-.', 'Color', '#6600cc', 'LineWidth', 1.1)
609 % V_stall lines
610 plot([V_stall_6_8 V_stall_6_8], [0 D_6_8(149)], '-.', 'Color', '#6600cc', 'LineWidth', 1.1)
611 plot([V_stall_6_6 V_stall_6_6], [0 D_6_6(126)], '-.', 'Color', '#6600cc', 'LineWidth', 1.1)
612 % V.D_min line
613 plot([V(index_6_8_n) V(index_6_8_n)], [0 D_min_6_8_n], '-.', 'Color', '#A2142F', 'LineWidth', 1.1)
614 plot([V(index_6_6_n) V(index_6_6_n)], [0 D_min_6_6_n], '-.', 'Color', '#A2142F', 'LineWidth', 1.1)
615 % M_crit line
616 plot([Mcrit_6 Mcrit_6], [0 D_6_8(240)], '-.', 'Color', '#006666', 'LineWidth', 1.4)
617 plot([Mcrit_6 Mcrit_6], [0 D_6_6(240)], '-.', 'Color', '#006666', 'LineWidth', 1.4)
618 hold off
619 grid on
620 h=gca;
621 h.XAxis.TickLength = [0 0];
622 h.YAxis.TickLength = [0 0];
623 xlabel("Velocity (m/s)", 'Interpreter', 'latex', 'FontSize', 17)
624 ylabel("Drag (N)", 'Interpreter', 'latex', 'FontSize', 17)
625 leg1 = legend("0.9 $W_{TO}$", "0.8 $W_{TO}$", "0.6 $W_{TO}$", "$V_{D_{min}}$", "$V_{crit}$", ...
626 "$V_{stall}$", 'Interpreter', 'latex', 'Location', 'northwest', 'FontSize', 16);
627 title(leg1, 'Legend')
628 ax = gca;
629 ax.TickDir = 'out';
630 grid on
631 ax.TickLength = [0.005 0.005];
632 xlim([0 300])
633 ylim([0 6e5])
634 xticks(25:25:330)
635 set(gcf, 'Position', get(0, 'ScreenSize'));
636 %% PLOT 2 - h-V CALCULATION
637 Tasl = 350*4;
638 v_q = sqrt((2*q_max)./rho);
639 %% 0.9 WTO and 100% Throttle
640 % Calculations
641 sigma_9_100 = (2*(k*CDo)^0.5)/(Tasl/(0.9*wto));
642 rho_9_a = sigma_9_100*Rho_SL;
643 A = CDo.*rho.*S.*0.5;
644 B = (2*k*((0.9*wto*1000)^2))./(rho.*S);
645 h_abs_9 = height(1388);
646 sigma = rho./Rho_SL;
647 v = [];

```

```

648 for i=1:1388
649     v1 = sqrt(((Tas1*1000*sigma(i))+sqrt(((Tas1*1000*sigma(i))^2)-(4*A(i)*B(i))))/(2*A(i)));
650     v = [v v1];
651 end
652 for i=1:1388
653     v2 = sqrt(((Tas1*1000*sigma(i))-sqrt(((Tas1*1000*sigma(i))^2)-(4*A(i)*B(i))))/(2*A(i)));
654     v = [v v2];
655 end
656
657 % Boundaries
658 v_stall_9 = ((2*0.9*wto*1000)./(rho(1:1190).*S.*CLmax)).^0.5;
659 v_crit_9 = 0.895*a(1:1320);
660
661 % Plot
662 hold on
663 title("\textbf{V-h Plot for 0.9 $W_{TO}$ and 100 \% Throttle}","Interpreter","latex",'FontSize',30)
664 plot(v(1:1388),height(1:1388),'Color','magenta','LineWidth',1.2)
665 plot(v(1389:2776),height(1:1388),'Color','magenta','LineWidth',1.2)
666 plot(v_stall_9,height(1:1190),'Color','blue','LineWidth',1.5)
667 plot(v_crit_9,height(1:1320),'Color','red','LineWidth',1.5)
668 plot(v_q(1:885),height(1:885),'Color','green','LineWidth',1.3)
669 xlabel("Velocity (m/s)","Interpreter','latex','FontSize',25)
670 ylabel("Altitude (m)","Interpreter','latex','FontSize',25)
671 plot([0 350],[h_abs_9 h_abs_9],'--','Color','#FFA500','LineWidth',1.1)
672 ylim([0 16000])
673 xlim([0 500])
674 % Text
675 text(115,4000,'Stall Boundary','Interpreter','latex','FontSize',20,'Rotation',65)
676 text(350,3800,'Aeroelastic Boundary ($q_{max}$)','Interpreter','latex','FontSize',20,'Rotation',38)
677 text(180,6200,'Flight Envelope','Interpreter','latex','FontSize',30,'Rotation',0)
678 text(280,8000,'Critical Velocity Boundary','Interpreter','latex','FontSize',20,'Rotation',-75)
679 text(100,h_abs_9+200,'Absolute Ceiling = 13870 m','Interpreter','latex','FontSize',20,'Rotation',0)
680 hold off
681 xticks(50:50:500)
682 grid on
683 set(gcf,'Position',get(0,'ScreenSize'));
684 set(gca,'Box','on');
685 ax = gca;
686 ax.TickDir = 'out';
687 ax.FontSize = 20;
688 ax.TickLength = [0.005 0.005];
689 %% 0.8 WTO and 100% Throttle
690 % Calculations
691 sigma_8_100 = (2*(k*CD0)^0.5)/(Tas1/(0.8*wto));
692 rho_8_a = sigma_8_100*Rho_SL;
693 A = CD0.*rho.*S.*0.5;
694 B = (2*k*((0.8*wto*1000)^2))./(rho.*S);
695 sigma = rho./Rho_SL;
696 h_abs_8 = height(1463);
697 v = [];
698 for i=1:1470
699     v1 = sqrt(((Tas1*1000*sigma(i))+sqrt(((Tas1*1000*sigma(i))^2)-(4*A(i)*B(i))))/(2*A(i)));
700     v = [v v1];
701 end
702 for i=1:1470
703     v2 = sqrt(((Tas1*1000*sigma(i))-sqrt(((Tas1*1000*sigma(i))^2)-(4*A(i)*B(i))))/(2*A(i)));
704     v = [v v2];
705 end
706
707 % Boundaries
708 v_stall_8 = ((2*0.8*wto*1000)./(rho(1:1270).*S.*CLmax)).^0.5;
709 v_crit_8 = 0.895*a(1:1400);
710
711 % Plot
712 hold on

```

```

713 title("\textbf{V-h Plot for 0.8 $W_{TO}$ and 100 \% Throttle}","Interpreter","latex",'FontSize',30)
714 plot(v(1:1470),height(1:1470),'Color','magenta','LineWidth',1.2)
715 plot(v(1471:2940),height(1:1470),'Color','magenta','LineWidth',1.2)
716 plot(v_stall_8,height(1:1270),'Color','blue','LineWidth',1.5)
717 plot(v_crit_8,height(1:1400),'Color','red','LineWidth',1.5)
718 plot(v_q(1:895),height(1:895),'Color','green','LineWidth',1.3)
719 xlabel("Velocity (m/s)","Interpreter','latex','FontSize',25)
720 ylabel("Altitude (m)","Interpreter','latex','FontSize',25)
721 plot([0 350],[h_abs_8 h_abs_8],'--','Color','#FFA500','LineWidth',1.1)
722 ylim([0 16000])
723 xlim([0 500])
724 % Text
725 text(110,4000,'Stall Boundary','Interpreter','latex','FontSize',20,'Rotation',67)
726 text(350,3700,'Aeroelastic Boundary ($q_{\max}$)','Interpreter','latex','FontSize',20,'Rotation',40)
727 text(175,6200,'Flight Envelope','Interpreter','latex','FontSize',30,'Rotation',0)
728 text(280,8000,'Critical Velocity Boundary','Interpreter','latex','FontSize',20,'Rotation',-75)
729 text(100,h_abs_8+200,'Absolute Ceiling = 14620 m','Interpreter','latex','FontSize',20,'Rotation',0)
730 hold off
731 xticks(50:50:500)
732 ax = gca;
733 ax.TickDir = 'out';
734 ax.TickLength = [0.005 0.005];
735 grid on
736 set(gcf,'Position',get(0,'ScreenSize'));
737 set(gca,'Box','on');
738 ax = gca;
739 ax.TickDir = 'out';
740 ax.FontSize = 20;
741 ax.TickLength = [0.005 0.005];
742 %% 0.6 WTO and 100% Throttle
743 % Calculations
744 sigma_6_100 = (2*(k*CDo)^0.5)/(Tas1/(0.6*wto));
745 rho_6_a = sigma_6_100*Rho_SL;
746 A = CDo.*rho.*S.*0.5;
747 B = (2*k*((0.6*wto*1000)^2))./(rho.*S);
748 h_abs_6 = 16440;
749 sigma = rho./Rho_SL;
750 v = [];
751 for i=1:1650
752     v1 = sqrt(((Tas1*1000*sigma(i))+sqrt(((Tas1*1000*sigma(i))^2)-(4*A(i)*B(i))))/(2*A(i)));
753     v = [v v1];
754 end
755 for i=1:1650
756     v2 = sqrt(((Tas1*1000*sigma(i))-sqrt(((Tas1*1000*sigma(i))^2)-(4*A(i)*B(i))))/(2*A(i)));
757     v = [v v2];
758 end
759
760 % Boundaries
761 v_stall_8 = ((2*0.8*wto*1000)./(rho(1:1550).*S.*CLmax)).^0.5;
762 v_crit_8 = 0.895*a(1:1580);
763
764 % Plot
765 hold on
766 title("\textbf{V-h Plot for 0.6 $W_{TO}$ and 100 \% Throttle}","Interpreter","latex",'FontSize',30)
767 plot(v(1:1650),height(1:1650),'Color','magenta','LineWidth',1.2)
768 plot(v(1651:3300),height(1:1650),'Color','magenta','LineWidth',1.2)
769 plot(v_stall_8,height(1:1550),'Color','blue','LineWidth',1.5)
770 plot(v_crit_8,height(1:1580),'Color','red','LineWidth',1.5)
771 plot(v_q(1:910),height(1:910),'Color','green','LineWidth',1.3)
772 xlabel("Velocity (m/s)","Interpreter','latex','FontSize',25)
773 ylabel("Altitude (m)","Interpreter','latex','FontSize',25)
774 plot([0 350],[h_abs_6 h_abs_6],'--','Color','#FFA500','LineWidth',1.1)
775 ylim([0 18000])
776 xlim([0 500])
777 % Text

```

```

778 text(110,4000,'Stall Boundary','Interpreter','latex','FontSize',20,'Rotation',65)
779 text(350,3800,'Aeroelastic Boundary ($q_{\max}$)','Interpreter','latex','FontSize',20,'Rotation',35)
780 text(175,6200,'Flight Envelope','Interpreter','latex','FontSize',30,'Rotation',0)
781 text(275,9500,'Critical Velocity Boundary','Interpreter','latex','FontSize',20,'Rotation',-75)
782 text(100,h_abs_6+200,'Absolute Ceiling = 16440 m','Interpreter','latex','FontSize',20,'Rotation',0)
783 hold off
784 xticks(50:50:500)
785 ax = gca;
786 ax.TickDir = 'out';
787 ax.TickLength = [0.005 0.005];
788 grid on
789 set(gcf, 'Position', get(0,'ScreenSize'));
790 set(gca, 'Box', 'on');
791 ax = gca;
792 ax.TickDir = 'out';
793 ax.FontSize = 20;
794 ax.TickLength = [0.005 0.005];
795 %% 0.9 WTO and 95% Throttle
796 sigma_9_95 = (2*(k*CD0)^0.5)/(Tas1*0.95/(0.9*wto));
797 rho_9_a_1 = sigma_9_95*Rho_SL;
798 A = CDo.*rho.*S.*0.5;
799 B = (2*k*((0.9*wto*1000)^2))./(rho.*S);
800 h_abs_9_1 = 13540;
801 sigma = rho./Rho_SL;
802 v = [];
803 for i=1:1360
804     v1 = sqrt(((Tas1*0.95*1000*sigma(i))+sqrt(((Tas1*0.95*1000*sigma(i))^2)-(4*A(i)*B(i)))))/(2*A(i)));
805     v = [v v1];
806 end
807 for i=1:1360
808     v2 = sqrt(((Tas1*0.95*1000*sigma(i))-sqrt(((Tas1*0.95*1000*sigma(i))^2)-(4*A(i)*B(i)))))/(2*A(i)));
809     v = [v v2];
810 end
811
812 % Boundaries
813 v_stall_9 = ((2*0.9*wto*1000)./(rho(1:1150).*S.*CLmax)).^0.5;
814 v_crit_9 = 0.895*a(1:1300);
815
816 % Plot
817 hold on
818 title("\textbf{V-h Plot for 0.9 $W_{TO}$ and 95 \% Throttle}","Interpreter","latex","FontSize",30)
819 plot(v(1:1360),height(1:1360),'Color','magenta','LineWidth',1.2)
820 plot(v(1361:2720),height(1:1360),'Color','magenta','LineWidth',1.2)
821 plot(v_stall_9,height(1:1150),'Color','blue','LineWidth',1.5)
822 plot(v_crit_9,height(1:1300),'Color','red','LineWidth',1.5)
823 plot(v_q(1:840),height(1:840),'Color','green','LineWidth',1.3)
824 xlabel("Velocity (m/s)","Interpreter','latex','FontSize',25)
825 ylabel("Altitude (m)","Interpreter','latex','FontSize',25)
826 plot([0 350],[h_abs_9_1 h_abs_9_1],'--','Color','#FFA500','LineWidth',1.1)
827 ylim([0 16000])
828 xlim([0 500])
829 % Text
830 text(118,4000,'Stall Boundary','Interpreter','latex','FontSize',20,'Rotation',67)
831 text(350,3720,'Aeroelastic Boundary ($q_{\max}$)','Interpreter','latex','FontSize',20,'Rotation',40)
832 text(175,6200,'Flight Envelope','Interpreter','latex','FontSize',30,'Rotation',0)
833 text(280,8000,'Critical Velocity Boundary','Interpreter','latex','FontSize',15,'Rotation',-77)
834 text(100,h_abs_9_1+200,'Absolute Ceiling = 13540 m','Interpreter','latex','FontSize',20,'Rotation',0)
835 hold off
836 ax = gca;
837 ax.TickDir = 'out';
838 ax.TickLength = [0.005 0.005];
839 grid on
840 set(gcf, 'Position', get(0,'ScreenSize'));
841 set(gca, 'Box', 'on');
842 ax = gca;

```

```

843 ax.TickDir = 'out';
844 ax.FontSize = 20;
845 ax.TickLength = [0.005 0.005];
846 %% 0.9 WTO and 82.5% Throttle
847 sigma_9_82 = (2*(k*CD0)^0.5)/(Tas1*0.825/(0.9*wto));
848 rho_9_a_2 = sigma_9_82*Rho_SL;
849 A = CD0.*rho.*S.*0.5;
850 B = (2*k*((0.9*wto*1000)^2))./(rho.*S);
851 h_abs_9_2 = 12650;
852 sigma = rho./Rho_SL;
853 v = [];
854 for i=1:1270
855     v1 = sqrt(((Tas1*0.825*1000*sigma(i))+sqrt(((Tas1*0.825*1000*sigma(i))^2)-(4*A(i)*B(i))))/(2*A(i)));
856     v = [v v1];
857 end
858 for i=1:1270
859     v2 = sqrt(((Tas1*0.825*1000*sigma(i))-sqrt(((Tas1*0.825*1000*sigma(i))^2)-(4*A(i)*B(i))))/(2*A(i)));
860     v = [v v2];
861 end
862
863 % Boundaries
864 v_stall_9 = ((2*0.9*wto*1000)./(rho(1:1060).*S.*CLmax)).^0.5;
865 v_crit_9 = 0.895*a(1:1230);
866
867 % Plot
868 hold on
869 title("\textbf{V-h Plot for 0.9 $W_{TO}$ and 82.5 \% Throttle}","Interpreter","latex","FontSize",30)
870 plot(v(1:1270),height(1:1270),'Color','magenta','LineWidth',1.2)
871 plot(v(1271:2540),height(1:1270),'Color','magenta','LineWidth',1.2)
872 plot(v_stall_9,height(1:1060),'Color','blue','LineWidth',1.5)
873 plot(v_crit_9,height(1:1230),'Color','red','LineWidth',1.5)
874 plot(v_q(1:720),height(1:720),'Color','green','LineWidth',1.3)
875 plot([0 325],[h_abs_9_2 h_abs_9_2],'--','Color','#FFA500','LineWidth',1.1)
876 xlabel("Velocity (m/s)","Interpreter','latex','FontSize',25)
877 ylabel("Altitude (m)","Interpreter','latex','FontSize',25)
878 ylim([0 14000])
879 xlim([0 500])
880 % Text
881 text(117,4000,'Stall Boundary','Interpreter','latex','FontSize',20,'Rotation',69)
882 text(330,2500,'Aeroelastic Boundary ($q_{\max}$)','Interpreter','latex','FontSize',20,'Rotation',47)
883 text(175,5000,'Flight Envelope','Interpreter','latex','FontSize',30,'Rotation',0)
884 text(280,8000,'Critical Velocity Boundary','Interpreter','latex','FontSize',20,'Rotation',-78)
885 text(100,h_abs_9_2+200,'Absolute Ceiling = 12650 m','Interpreter','latex','FontSize',20,'Rotation',0)
886 hold off
887 ax = gca;
888 ax.TickDir = 'out';
889 ax.TickLength = [0.005 0.005];
890 grid on
891 set(gcf, 'Position', get(0,'ScreenSize'));
892 set(gca, 'Box', 'on');
893 ax = gca;
894 ax.TickDir = 'out';
895 ax.FontSize = 20;
896 ax.TickLength = [0.005 0.005];
897 %% 0.9 WTO and 70% Throttle
898 % Calculations
899 sigma_9_7 = (2*(k*CD0)^0.5)/(Tas1*0.7/(0.9*wto));
900 rho_9_a_3 = sigma_9_7*Rho_SL;
901 A = CD0.*rho.*S.*0.5;
902 B = (2*k*((0.9*wto*1000)^2))./(rho.*S);
903 h_abs_9_3 = 11610;
904 sigma = rho./Rho_SL;
905 v = [];
906 for i=1:1165
907     v1 = sqrt(((Tas1*0.7*1000*sigma(i))+sqrt(((Tas1*0.7*1000*sigma(i))^2)-(4*A(i)*B(i))))/(2*A(i)));

```

```

908     v = [v v1];
909 end
910 for i=1:1165
911     v2 = sqrt(((Tasl*0.7*1000*sigma(i))-sqrt(((Tasl*0.7*1000*sigma(i))^2)-(4*A(i)*B(i))))/(2*A(i)));
912     v = [v v2];
913 end
914
915 % Boundaries
916 v_stall_9 = ((2*0.9*wto*1000)./(rho(1:925).*S.*CLmax)).^0.5;
917 v_crit_9 = 0.895*a(1:1150);
918
919 % Plot
920 hold on
921 title("\textbf{V-h Plot for 0.9 $W_{TO}$ and 70 \% Throttle}", "Interpreter", "latex", 'FontSize', 30)
922 plot(v(1:1165), height(1:1165), 'Color', 'magenta', 'LineWidth', 1.2)
923 plot(v(1166:2330), height(1:1165), 'Color', 'magenta', 'LineWidth', 1.2)
924 plot(v_stall_9, height(1:925), 'Color', 'blue', 'LineWidth', 1.5)
925 plot(v_crit_9, height(1:1150), 'Color', 'red', 'LineWidth', 1.5)
926 plot(v_q(1:575), height(1:575), 'Color', 'green', 'LineWidth', 1.3)
927 plot([0 300], [h_abs_9_3 h_abs_9_3], '--', 'Color', "#FFA500", 'LineWidth', 1.1)
928 xlabel("Velocity (m/s)", 'Interpreter', 'latex', 'FontSize', 25)
929 ylabel("Altitude (m)", 'Interpreter', 'latex', 'FontSize', 25)
930 ylim([0 13000])
931 xlim([0 500])
932 % Text
933 text(112, 3300, 'Stall Boundary', 'Interpreter', 'latex', 'FontSize', 20, 'Rotation', 70)
934 text(315, 1600, 'Aeroelastic Boundary ($q_{\max}$)', 'Interpreter', 'latex', 'FontSize', 20, 'Rotation', 50)
935 text(180, 6200, 'Flight Envelope', 'Interpreter', 'latex', 'FontSize', 30, 'Rotation', 0)
936 text(284, 7000, 'Critical Velocity Boundary', 'Interpreter', 'latex', 'FontSize', 20, 'Rotation', -79)
937 text(100, h_abs_9_3+200, 'Absolute Ceiling = 11610 m', 'Interpreter', 'latex', 'FontSize', 20, 'Rotation', 0)
938 hold off
939 ax = gca;
940 ax.TickDir = 'out';
941 ax.TickLength = [0.005 0.005];
942 grid on
943 set(gcf, 'Position', get(0, 'ScreenSize'));
944 set(gca, 'Box', 'on');
945 ax = gca;
946 ax.TickDir = 'out';
947 ax.FontSize = 20;
948 ax.TickLength = [0.005 0.005];
949 %% Combined V-h Plot
950 % 0.9 WTO and 100% Throttle
951 % Calculations
952 sigma_9_100 = (2*(k*CDo)^0.5)/(Tasl/(0.9*wto));
953 rho_9_a = sigma_9_100*Rho_SL;
954 A = CDo.*rho.*S.*0.5;
955 B = (2*k*((0.9*wto*1000)^2))./(rho.*S);
956 h_abs_9 = height(1388);
957 sigma = rho./Rho_SL;
958 v = [];
959 for i=1:1388
960     v1 = sqrt(((Tasl*1000*sigma(i))+sqrt(((Tasl*1000*sigma(i))^2)-(4*A(i)*B(i))))/(2*A(i)));
961     v = [v v1];
962 end
963 for i=1:1388
964     v2 = sqrt(((Tasl*1000*sigma(i))-sqrt(((Tasl*1000*sigma(i))^2)-(4*A(i)*B(i))))/(2*A(i)));
965     v = [v v2];
966 end
967
968 % Boundaries
969 v_stall_9 = ((2*0.9*wto*1000)./(rho(1:1190).*S.*CLmax)).^0.5;
970 v_crit_9 = 0.895*a(1:1320);
971
972 % Plot

```



```

973 hold on
974 plot(v(1:1388),height(1:1388),'Color','magenta','LineWidth',1.2)
975 plot(v(1389:2776),height(1:1388),'Color','magenta','LineWidth',1.2)
976 plot(v_stall_9,height(1:1190),'Color','blue','LineWidth',1.5)
977 plot(v_crit_9,height(1:1320),'Color','red','LineWidth',1.5)
978 plot(v_q(1:885),height(1:885),'Color','green','LineWidth',1.3)
979 plot([0 350],[h_abs_9 h_abs_9],'--','Color','black','LineWidth',1.1)
980
981 % Text
982 text(100,h_abs_9+200,'Absolute Ceiling = 13870 m','Interpreter','latex','FontSize',20,'Rotation',0)
983
984 % 0.9 WTO and 95% Throttle
985 sigma_9_95 = (2*(k*CD0)^0.5)/(Tas1*0.95/(0.9*wto));
986 rho_9_a_1 = sigma_9_95*Rho_SL;
987 A = CD0.*rho.*S.*0.5;
988 B = (2*k*((0.9*wto*1000)^2))./(rho.*S);
989 h_abs_9_1 = 13540;
990 sigma = rho./Rho_SL;
991 v = [];
992 for i=1:1360
993     v1 = sqrt(((Tas1*0.95*1000*sigma(i))+sqrt(((Tas1*0.95*1000*sigma(i))^2)-(4*A(i)*B(i)))))/(2*A(i)));
994     v = [v v1];
995 end
996 for i=1:1360
997     v2 = sqrt(((Tas1*0.95*1000*sigma(i))-sqrt(((Tas1*0.95*1000*sigma(i))^2)-(4*A(i)*B(i)))))/(2*A(i)));
998     v = [v v2];
999 end
1000
1001 % Boundaries
1002 v_stall_9 = ((2*0.9*wto*1000)./(rho(1:1150).*S.*CLmax)).^0.5;
1003 v_crit_9 = 0.895*a(1:1300);
1004
1005 % Plot
1006
1007 plot(v(1:1360),height(1:1360),'Color','cyan','LineWidth',1.2)
1008 plot(v(1361:2720),height(1:1360),'Color','cyan','LineWidth',1.2)
1009 plot(v_stall_9,height(1:1150),'Color','blue','LineWidth',1.5)
1010 plot(v_crit_9,height(1:1300),'Color','red','LineWidth',1.5)
1011 plot(v_q(1:840),height(1:840),'Color','green','LineWidth',1.3)
1012 plot([0 350],[h_abs_9_1 h_abs_9_1],'--','Color','black','LineWidth',1.1)
1013 % Text
1014 text(100,h_abs_9_1-200,'Absolute Ceiling = 13540 m','Interpreter','latex','FontSize',20,'Rotation',0)
1015
1016 % 0.9 WTO and 82.5% Throttle
1017 sigma_9_82 = (2*(k*CD0)^0.5)/(Tas1*0.825/(0.9*wto));
1018 rho_9_a_2 = sigma_9_82*Rho_SL;
1019 A = CD0.*rho.*S.*0.5;
1020 B = (2*k*((0.9*wto*1000)^2))./(rho.*S);
1021 h_abs_9_2 = 12650;
1022 sigma = rho./Rho_SL;
1023 v = [];
1024 for i=1:1270
1025     v1 = sqrt(((Tas1*0.825*1000*sigma(i))+sqrt(((Tas1*0.825*1000*sigma(i))^2)-(4*A(i)*B(i)))))/(2*A(i)));
1026     v = [v v1];
1027 end
1028 for i=1:1270
1029     v2 = sqrt(((Tas1*0.825*1000*sigma(i))-sqrt(((Tas1*0.825*1000*sigma(i))^2)-(4*A(i)*B(i)))))/(2*A(i)));
1030     v = [v v2];
1031 end
1032
1033 % Boundaries
1034 v_stall_9 = ((2*0.9*wto*1000)./(rho(1:1060).*S.*CLmax)).^0.5;
1035 v_crit_9 = 0.895*a(1:1230);
1036
1037 % Plot

```

```

1038
1039 plot(v(1:1270),height(1:1270),'Color','#808000','LineWidth',1.2)
1040 plot(v(1271:2540),height(1:1270),'Color','#808000','LineWidth',1.2)
1041 plot(v_stall_9,height(1:1060),'Color','blue','LineWidth',1.5)
1042 plot(v_crit_9,height(1:1230),'Color','red','LineWidth',1.5)
1043 plot(v_q(1:720),height(1:720),'Color','green','LineWidth',1.3)
1044 plot([0 325],[h_abs_9_2 h_abs_9_2],'--','Color','black','LineWidth',1.1)
1045
1046 % Text
1047 text(100,h_abs_9_2-200,'Absolute Ceiling = 12650 m','Interpreter','latex','FontSize',20,'Rotation',0)
1048
1049 % 0.9 WTO and 70% Throttle
1050 % Calculations
1051 sigma_9_7 = (2*(k*CD0)^0.5)/(Tas1*0.7/(0.9*wto));
1052 rho_9_a_3 = sigma_9_7*Rho_SL;
1053 A = CDo.*rho.*S.*0.5;
1054 B = (2*k*((0.9*wto*1000)^2))./(rho.*S);
1055 h_abs_9_3 = 11610;
1056 sigma = rho./Rho_SL;
1057 v = [];
1058 for i=1:1165
1059     v1 = sqrt(((Tas1*0.7*1000*sigma(i))+sqrt(((Tas1*0.7*1000*sigma(i))^2)-(4*A(i)*B(i)))))/(2*A(i)));
1060     v = [v v1];
1061 end
1062 for i=1:1165
1063     v2 = sqrt(((Tas1*0.7*1000*sigma(i))-sqrt(((Tas1*0.7*1000*sigma(i))^2)-(4*A(i)*B(i)))))/(2*A(i)));
1064     v = [v v2];
1065 end
1066
1067 % Boundaries
1068 v_stall_9 = ((2*0.9*wto*1000)./(rho(1:925).*S.*CLmax)).^0.5;
1069 v_crit_9 = 0.895*a(1:1150);
1070
1071 % Plot
1072
1073 title("\textbf{Combined V-h Plot for 0.9 $W_{TO}$ and Various Throttle Settings}", ...
1074     "Interpreter","latex",'FontSize',30)
1075 plot(v(1:1165),height(1:1165),'Color','#FFA500','LineWidth',1.2)
1076 plot(v(1166:2330),height(1:1165),'Color','#FFA500','LineWidth',1.2)
1077 plot(v_stall_9,height(1:925),'Color','blue','LineWidth',1.5)
1078 plot(v_crit_9,height(1:1150),'Color','red','LineWidth',1.5)
1079 plot(v_q(1:575),height(1:575),'Color','green','LineWidth',1.3)
1080 plot([0 300],[h_abs_9_3 h_abs_9_3],'--','Color','black','LineWidth',1.1)
1081 xlabel("Velocity (m/s)","Interpreter','latex','FontSize',25)
1082 ylabel("Altitude (m)","Interpreter','latex','FontSize',25)
1083
1084 % Text
1085 text(112,3300,'Stall Boundary','Interpreter','latex','FontSize',20,'Rotation',70)
1086 text(315,1600,'Aeroelastic Boundary ($q_{\max}$)','Interpreter','latex','FontSize',20,'Rotation',47)
1087 text(180,6200,'Flight Envelope','Interpreter','latex','FontSize',30,'Rotation',0)
1088 text(284,7000,'Critical Velocity Boundary','Interpreter','latex','FontSize',20,'Rotation',-79)
1089 text(75,h_abs_9_3+200,'Absolute Ceiling = 11610 m','Interpreter','latex','FontSize',20,'Rotation',0)
1090 hold off
1091 ax = gca;
1092 ax.TickDir = 'out';
1093 ax.TickLength = [0.005 0.005];
1094 grid on
1095 ylim([0 15000])
1096 xticks(25:25:500)
1097 yticks(0:1000:15000)
1098 set(gcf, 'Position', get(0,'ScreenSize'));
1099 set(gca, 'Box', 'on');
1100 ax = gca;
1101 ax.TickDir = 'out';
1102 ax.FontSize = 20;

```

```

1103 ax.TickLength = [0.005 0.005];
1104 %% PLOT 3
1105 %% INITIALISATION
1106 %% V_stall Calculation
1107 % 0.9 WTO
1108 V_stall_1.9_t = ((2*0.9*WTO)/(rho_1*S*0.9*CLmax_HLD_part))^0.5;
1109 V_stall_2.9_t = ((2*0.9*WTO)/(rho_2*S*0.9*CLmax_HLD_part))^0.5;
1110 V_stall_3.9_t = ((2*0.9*WTO)/(rho_3*S*0.9*CLmax_HLD_part))^0.5;
1111 V_stall_4.9_t = ((2*0.9*WTO)/(rho_4*S*0.9*CLmax_HLD_part))^0.5;
1112 V_stall_5.9_t = ((2*0.9*WTO)/(rho_5*S*0.9*CLmax_HLD_part))^0.5;
1113 V_stall_6.9_t = ((2*0.9*WTO)/(rho_6*S*0.9*CLmax_HLD_part))^0.5;
1114 % 0.8 WTO
1115 V_stall_1.8_t = ((2*0.8*WTO)/(rho_1*S*0.9*CLmax_HLD_part))^0.5;
1116 V_stall_2.8_t = ((2*0.8*WTO)/(rho_2*S*0.9*CLmax_HLD_part))^0.5;
1117 V_stall_3.8_t = ((2*0.8*WTO)/(rho_3*S*0.9*CLmax_HLD_part))^0.5;
1118 V_stall_4.8_t = ((2*0.8*WTO)/(rho_4*S*0.9*CLmax_HLD_part))^0.5;
1119 V_stall_5.8_t = ((2*0.8*WTO)/(rho_5*S*0.9*CLmax_HLD_part))^0.5;
1120 V_stall_6.8_t = ((2*0.8*WTO)/(rho_6*S*0.9*CLmax_HLD_part))^0.5;
1121 %% THRUST DATA
1122 t_1 = sigma_1*4*350*1000;
1123 t_2 = sigma_1*4*350*1000;
1124 t_3 = sigma_1*4*350*1000;
1125 t_4 = sigma_1*4*350*1000;
1126 t_5 = sigma_1*4*350*1000;
1127 t_6 = sigma_1*4*350*1000;
1128 t_sl = 4*350*1000;
1129 %% Calculations
1130 % Sea Level and 0.9 WTO
1131 P_avb_0.9 = t_sl.*V;
1132 P_reqd_0.9 = D_0.9.*V;
1133 Delta_P_0.9 = P_avb_0.9 - P_reqd_0.9;
1134 ROC_0.9 = Delta_P_0.9./(0.9*WTO);
1135
1136 % Sea Level and 0.8 WTO
1137 P_avb_0.8 = t_sl.*V;
1138 P_reqd_0.8 = D_0.8.*V;
1139 Delta_P_0.8 = P_avb_0.8 - P_reqd_0.8;
1140 ROC_0.8 = Delta_P_0.8./(0.8*WTO);
1141
1142 % Alt 1 and 0.9 WTO
1143 P_avb_1.9 = t_1.*V;
1144 P_reqd_1.9 = D_1.9.*V;
1145 Delta_P_1.9 = P_avb_1.9 - P_reqd_1.9;
1146 ROC_1.9 = Delta_P_1.9./(0.9*WTO);
1147
1148 % Alt 1 and 0.8 WTO
1149 P_avb_1.8 = t_1.*V;
1150 P_reqd_1.8 = D_1.8.*V;
1151 Delta_P_1.8 = P_avb_1.8 - P_reqd_1.8;
1152 ROC_1.8 = Delta_P_1.8./(0.8*WTO);
1153
1154 % Alt 2 and 0.9 WTO
1155 P_avb_2.9 = t_2.*V;
1156 P_reqd_2.9 = D_2.9.*V;
1157 Delta_P_2.9 = P_avb_2.9 - P_reqd_2.9;
1158 ROC_2.9 = Delta_P_2.9./(0.9*WTO);
1159
1160 % Alt 2 and 0.8 WTO
1161 P_avb_2.8 = t_2.*V;
1162 P_reqd_2.8 = D_2.8.*V;
1163 Delta_P_2.8 = P_avb_2.8 - P_reqd_2.8;
1164 ROC_2.8 = Delta_P_2.8./(0.8*WTO);
1165
1166 % Alt 3 and 0.9 WTO
1167 P_avb_3.9 = t_3.*V;

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1168 P_reqd_3_9 = D_3_9.*V;
1169 Delta_P_3_9 = P_avb_3_9 - P_reqd_3_9;
1170 ROC_3_9 = Delta_P_3_9./(0.9*WTO);
1171
1172 % Alt 3 and 0.8 WTO
1173 P_avb_3_8 = t_3.*V;
1174 P_reqd_3_8 = D_3_8.*V;
1175 Delta_P_3_8 = P_avb_3_8 - P_reqd_3_8;
1176 ROC_3_8= Delta_P_3_8./(0.8*WTO);
1177
1178 % Alt 4 and 0.9 WTO
1179 P_avb_4_9 = t_4.*V;
1180 P_reqd_4_9 = D_4_9.*V;
1181 Delta_P_4_9 = P_avb_4_9 - P_reqd_4_9;
1182 ROC_4_9 = Delta_P_4_9./(0.9*WTO);
1183
1184 % Alt 4 and 0.8 WTO
1185 P_avb_4_8 = t_4.*V;
1186 P_reqd_4_8 = D_4_8.*V;
1187 Delta_P_4_8 = P_avb_4_8 - P_reqd_4_8;
1188 ROC_4_8= Delta_P_4_8./(0.8*WTO);
1189
1190 % Alt 5 and 0.9 WTO
1191 P_avb_5_9 = t_5.*V;
1192 P_reqd_5_9 = D_5_9.*V;
1193 Delta_P_5_9 = P_avb_5_9 - P_reqd_5_9;
1194 ROC_5_9 = Delta_P_5_9./(0.9*WTO);
1195
1196 % Alt 5 and 0.8 WTO
1197 P_avb_5_8 = t_5.*V;
1198 P_reqd_5_8 = D_5_8.*V;
1199 Delta_P_5_8 = P_avb_5_8 - P_reqd_5_8;
1200 ROC_5_8= Delta_P_5_8./(0.8*WTO);
1201
1202 % Alt 6 and 0.9 WTO
1203 P_avb_6_9 = t_6.*V;
1204 P_reqd_6_9 = D_6_9.*V;
1205 Delta_P_6_9 = P_avb_6_9 - P_reqd_6_9;
1206 ROC_6_9 = Delta_P_6_9./(0.9*WTO);
1207
1208 % Alt 6 and 0.8 WTO
1209 P_avb_6_8 = t_6.*V;
1210 P_reqd_6_8 = D_6_8.*V;
1211 Delta_P_6_8 = P_avb_6_8 - P_reqd_6_8;
1212 ROC_6_8= Delta_P_6_8./(0.8*WTO);
1213
1214 %% Plotting
1215 %% Plot 0.9 WTO and 6 Altitudes
1216 hold on
1217 title("\textbf{Rate of Climb Plot for 0.9 $W_{TO}$ and Various Altitudes}", ...
1218       "Interpreter","latex","FontSize",30)
1219 plot(V,ROC_1_9,'Color','magenta','LineWidth',1.2)
1220 plot(V,ROC_2_9,'Color','blue','LineWidth',1.2)
1221 plot(V,ROC_3_9,'Color','#D95319','LineWidth',1.2)
1222 plot(V,ROC_4_9,'Color','#EDB120','LineWidth',1.2)
1223 plot(V,ROC_5_9,'Color','green','LineWidth',1.2)
1224 plot(V,ROC_6_9,'Color','#4DBEEE','LineWidth',1.2)
1225 % M_crit for legend
1226 plot([Mcrit_1 Mcrit_1],[0 ROC_1_9(278)],'-.','Color','#008888','LineWidth',1.3)
1227 % V_stall for legend
1228 plot([V_stall_1_9 V_stall_1_9],[0 ROC_1_9(79)],'-.','Color','#6600cc','LineWidth',1.1)
1229 % V_stall lines
1230 plot([V_stall_2_9 V_stall_2_9],[0 ROC_2_9(92)],'-.','Color','#6600cc','LineWidth',1.1)
1231 plot([V_stall_3_9 V_stall_3_9],[0 ROC_3_9(109)],'-.','Color','#6600cc','LineWidth',1.1)
1232 plot([V_stall_4_9 V_stall_4_9],[0 ROC_4_9(134)],'-.','Color','#6600cc','LineWidth',1.1)

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1233 plot([V_stall_5_9 V_stall_5_9],[0 ROC_5_9(154)], '-.', 'Color', "#6600cc", 'LineWidth', 1.1)
1234 plot([V_stall_6_9 V_stall_6_9],[0 ROC_6_9(160)], '-.', 'Color', "#6600cc", 'LineWidth', 1.1)
1235 % M_crit line
1236 plot([Mcrit_2 Mcrit_2],[0 ROC_2_9(270)], '-.', 'Color', "#008888", 'LineWidth', 1.3)
1237 plot([Mcrit_3 Mcrit_3],[0 ROC_3_9(261)], '-.', 'Color', "#008888", 'LineWidth', 1.3)
1238 plot([Mcrit_4 Mcrit_4],[0 ROC_4_9(249)], '-.', 'Color', "#008888", 'LineWidth', 1.3)
1239 plot([Mcrit_5 Mcrit_5],[0 ROC_5_9(242)], '-.', 'Color', "#008888", 'LineWidth', 1.3)
1240 plot([Mcrit_6 Mcrit_6],[0 ROC_6_9(240)], '-.', 'Color', "#008888", 'LineWidth', 1.3)
1241 hold off
1242 xlabel("Velocity (m/s)", 'Interpreter', 'latex', 'FontSize', 25)
1243 ylabel("Rate of Climb (m/s)", 'Interpreter', 'latex', 'FontSize', 25)
1244 leg1 = legend("0.5 Km", "3 Km", "5.5 Km", "8.5 Km", "10.5 Km", "11.5 Km", "$V_{crit}$", ...
1245             "$V_{stall}$", 'Interpreter', 'latex', 'Location', 'northwest', 'FontSize', 20);
1246 title(leg1, 'Legend')
1247 ylim([5 50])
1248 xlim([50 325])
1249 xticks(45:15:325)
1250 ax = gca;
1251 ax.TickDir = 'out';
1252 ax.TickLength = [0.005 0.005];
1253 grid on
1254 set(gcf, 'Position', get(0, 'ScreenSize'));
1255 set(gca, 'Box', 'on');
1256 ax = gca;
1257 ax.TickDir = 'out';
1258 ax.FontSize = 20;
1259 ax.TickLength = [0.005 0.005];
1260 %% Plot 0.8 WTO and 6 Altitudes
1261 hold on
1262 title("\textbf{Rate of Climb Plot for 0.8 $W_{TO}$ and Various Altitudes}", ...
1263       "Interpreter", "latex", 'FontSize', 30)
1264 plot(V, ROC_1_8, 'Color', 'magenta', 'LineWidth', 1.2)
1265 plot(V, ROC_2_8, 'Color', 'blue', 'LineWidth', 1.2)
1266 plot(V, ROC_3_8, 'Color', "#D95319", 'LineWidth', 1.2)
1267 plot(V, ROC_4_8, 'Color', "#EDB120", 'LineWidth', 1.2)
1268 plot(V, ROC_5_8, 'Color', 'green', 'LineWidth', 1.2)
1269 plot(V, ROC_6_8, 'Color', "#4DBEEE", 'LineWidth', 1.2)
1270 % M_crit for legend
1271 plot([Mcrit_1 Mcrit_1],[0 ROC_1_8(278)], '-.', 'Color', "#008888", 'LineWidth', 1.3)
1272 % V_stall for legend
1273 plot([V_stall_1_9 V_stall_1_9],[0 ROC_1_8(80)], '-.', 'Color', "#6600cc", 'LineWidth', 1.1)
1274 % V_stall lines
1275 plot([V_stall_2_9 V_stall_2_9],[0 ROC_2_8(93)], '-.', 'Color', "#6600cc", 'LineWidth', 1.1)
1276 plot([V_stall_3_9 V_stall_3_9],[0 ROC_3_8(110)], '-.', 'Color', "#6600cc", 'LineWidth', 1.1)
1277 plot([V_stall_4_9 V_stall_4_9],[0 ROC_4_8(134)], '-.', 'Color', "#6600cc", 'LineWidth', 1.1)
1278 plot([V_stall_5_9 V_stall_5_9],[0 ROC_5_8(155)], '-.', 'Color', "#6600cc", 'LineWidth', 1.1)
1279 plot([V_stall_6_9 V_stall_6_9],[0 ROC_6_8(161)], '-.', 'Color', "#6600cc", 'LineWidth', 1.1)
1280 % M_crit line
1281 plot([Mcrit_2 Mcrit_2],[0 ROC_2_8(270)], '-.', 'Color', "#008888", 'LineWidth', 1.3)
1282 plot([Mcrit_3 Mcrit_3],[0 ROC_3_8(261)], '-.', 'Color', "#008888", 'LineWidth', 1.3)
1283 plot([Mcrit_4 Mcrit_4],[0 ROC_4_8(248)], '-.', 'Color', "#008888", 'LineWidth', 1.3)
1284 plot([Mcrit_5 Mcrit_5],[0 ROC_5_8(242)], '-.', 'Color', "#008888", 'LineWidth', 1.3)
1285 plot([Mcrit_6 Mcrit_6],[0 ROC_6_8(240)], '-.', 'Color', "#008888", 'LineWidth', 1.3)
1286 hold off
1287 xlabel("Velocity (m/s)", 'Interpreter', 'latex', 'FontSize', 25)
1288 ylabel("Rate of Climb (m/s)", 'Interpreter', 'latex', 'FontSize', 25)
1289 leg1 = legend("0.5 Km", "3 Km", "5.5 Km", "8.5 Km", "10.5 Km", "11.5 Km", "$V_{crit}$", ...
1290             "$V_{stall}$", 'Interpreter', 'latex', 'Location', 'northwest', 'FontSize', 20);
1291 title(leg1, 'Legend')
1292 ylim([15 50])
1293 xlim([75 325])
1294 xticks(45:15:325)
1295 ax = gca;
1296 ax.TickDir = 'out';
1297 ax.TickLength = [0.005 0.005];

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1298 grid on
1299 set(gcf, 'Position', get(0,'ScreenSize'));
1300 set(gca, 'Box', 'on');
1301 ax = gca;
1302 ax.TickDir = 'out';
1303 ax.FontSize = 20;
1304 ax.TickLength = [0.005 0.005];
1305 %% R/C Max Calculation
1306 [ROC_max_0_9, indexr_0_9] = max(ROC_0_9);
1307 [ROC_max_1_9, indexr_1_9] = max(ROC_1_9);
1308 [ROC_max_2_9, indexr_2_9] = max(ROC_2_9);
1309 [ROC_max_3_9, indexr_3_9] = max(ROC_3_9);
1310 [ROC_max_4_9, indexr_4_9] = max(ROC_4_9);
1311 [ROC_max_5_9, indexr_5_9] = max(ROC_5_9);
1312 [ROC_max_6_9, indexr_6_9] = max(ROC_6_9);
1313
1314 [ROC_max_0_8, indexr_0_8] = max(ROC_0_8);
1315 [ROC_max_1_8, indexr_1_8] = max(ROC_1_8);
1316 [ROC_max_2_8, indexr_2_8] = max(ROC_2_8);
1317 [ROC_max_3_8, indexr_3_8] = max(ROC_3_8);
1318 [ROC_max_4_8, indexr_4_8] = max(ROC_4_8);
1319 [ROC_max_5_8, indexr_5_8] = max(ROC_5_8);
1320 [ROC_max_6_8, indexr_6_8] = max(ROC_6_8);
1321
1322 ROC_Best_9 = (ROC_max_1_9+ROC_max_6_9)/2;
1323 ROC_Best_8 = (ROC_max_1_8+ROC_max_6_8)/2;
1324
1325 V_Best_9 = (V(indexr_1_9)+V(indexr_6_9))/2;
1326 V_Best_8 = (V(indexr_1_8)+V(indexr_6_8))/2;
1327 %% Plot for R/C MAX 0.9 WTO
1328
1329 hold on
1330 title("Rate of Climb Plot $(R/C)-\{max\}$ for 0.9 $W-\{TO\}$ and Various Altitudes", ...
1331       "Interpreter", "latex", 'FontSize', 20)
1332 plot(V, ROC_1_9, 'Color', 'magenta', 'LineWidth', 1.2)
1333 plot(V, ROC_2_9, 'Color', 'blue', 'LineWidth', 1.2)
1334 plot(V, ROC_3_9, 'Color', "#D95319", 'LineWidth', 1.2)
1335 plot(V, ROC_4_9, 'Color', "#EDB120", 'LineWidth', 1.2)
1336 plot(V, ROC_5_9, 'Color', 'green', 'LineWidth', 1.2)
1337 plot(V, ROC_6_9, 'Color', "#4DBEEE", 'LineWidth', 1.2)
1338 % M_crit for legend
1339 plot([Mcrit_1 Mcrit_1], [0 ROC_1_9(278)], '-.', 'Color', "#008888", 'LineWidth', 1.3)
1340 % V_stall for legend
1341 plot([V_stall_1_9 V_stall_1_9], [0 ROC_1_9(79)], '-.', 'Color', "#6600cc", 'LineWidth', 1.1)
1342 % R/C Max line
1343 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)], ...
1344       [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', ...
1345       'LineWidth', 1.5, 'LineStyle', '-.', 'Marker', 'o', 'MarkerSize', 3.5, 'MarkerFaceColor', 'r')
1346 % V_best
1347 plot([V_Best_9 V_Best_9], [ROC_max_6_9 ROC_max_1_9], 'Color', "blue", 'LineWidth', 1.5)
1348 % ROC_Best
1349 plot([0 V_Best_9], [ROC_Best_9 ROC_Best_9], '--', 'Color', "#A020F0", 'LineWidth', 1.3)
1350 % V_stall lines
1351 plot([V_stall_2_9 V_stall_2_9], [0 ROC_2_9(92)], '-.', 'Color', "#6600cc", 'LineWidth', 1.1)
1352 plot([V_stall_3_9 V_stall_3_9], [0 ROC_3_9(109)], '-.', 'Color', "#6600cc", 'LineWidth', 1.1)
1353 plot([V_stall_4_9 V_stall_4_9], [0 ROC_4_9(134)], '-.', 'Color', "#6600cc", 'LineWidth', 1.1)
1354 plot([V_stall_5_9 V_stall_5_9], [0 ROC_5_9(154)], '-.', 'Color', "#6600cc", 'LineWidth', 1.1)
1355 plot([V_stall_6_9 V_stall_6_9], [0 ROC_6_9(160)], '-.', 'Color', "#6600cc", 'LineWidth', 1.1)
1356 % M_crit line
1357 plot([Mcrit_2 Mcrit_2], [0 ROC_2_9(270)], '-.', 'Color', "#008888", 'LineWidth', 1.3)
1358 plot([Mcrit_3 Mcrit_3], [0 ROC_3_9(261)], '-.', 'Color', "#008888", 'LineWidth', 1.3)
1359 plot([Mcrit_4 Mcrit_4], [0 ROC_4_9(249)], '-.', 'Color', "#008888", 'LineWidth', 1.3)
1360 plot([Mcrit_5 Mcrit_5], [0 ROC_5_9(242)], '-.', 'Color', "#008888", 'LineWidth', 1.3)
1361 plot([Mcrit_6 Mcrit_6], [0 ROC_6_9(240)], '-.', 'Color', "#008888", 'LineWidth', 1.3)
1362 text(260, 41.5, 'Best Speed for Climb = 294 m/s', 'Interpreter', 'latex', 'FontSize', 15)

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1363 text(195,39.5,'Best (R/C) = 38.4 m/s','Interpreter','latex','FontSize',15)
1364 hold off
1365 xlabel("Velocity (m/s)","Interpreter','latex','FontSize',17)
1366 ylabel("Rate of Climb (m/s)","Interpreter','latex','FontSize',17)
1367 leg1 = legend("0.5 Km","3 Km","5.5 Km","8.5 Km","10.5 Km","11.5 Km","$V_{crit}$","$V_{stall}$", ...
1368     "$ (R/C)_{max}$","Best Speed For Climb","Best (R/C)","Interpreter','latex','Location','west', ...
1369     'FontSize',16);
1370 title(leg1,'Legend')
1371 ylim([5 50])
1372 xlim([50 325])
1373 xticks(45:15:325)
1374 ax = gca;
1375 ax.TickDir = 'out';
1376 ax.TickLength = [0.005 0.005];
1377 grid on
1378 set(gcf, 'Position', get(0,'ScreenSize'));
1379 set(gca, 'Box', 'on');
1380 ax = gca;
1381 ax.TickDir = 'out';
1382 ax.FontSize = 20;
1383 ax.TickLength = [0.005 0.005];
1384 %% Plot R/C Max at 0.8 WTO
1385 hold on
1386 title("\textbf{Rate of Climb Plot $(R/C)_{max}$ for 0.8 $W_{TO}$ and Various Altitudes}", ...
1387     "Interpreter","latex","FontSize',30)
1388 plot(V,ROC_1_8,'Color','magenta','LineWidth',1.2)
1389 plot(V,ROC_2_8,'Color','blue','LineWidth',1.2)
1390 plot(V,ROC_3_8,'Color','#D95319','LineWidth',1.2)
1391 plot(V,ROC_4_8,'Color','#EDB120','LineWidth',1.2)
1392 plot(V,ROC_5_8,'Color','green','LineWidth',1.2)
1393 plot(V,ROC_6_8,'Color','#4DBEEE','LineWidth',1.2)
1394 % M_crit for legend
1395 plot([Mcrit_1 Mcrit_1],[0 ROC_1_8(278)],'-','Color','#008888','LineWidth',1.3)
1396 % V_stall for legend
1397 plot([V_stall_1_9 V_stall_1_9],[0 ROC_1_8(80)],'-','Color','#6600cc','LineWidth',1.1)
1398 % R/C Max line
1399 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)], ...
1400     [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', ...
1401     'LineWidth',1.5,'LineStyle','-','Marker','o','MarkerSize',3.5,'MarkerFaceColor','r')
1402 % V_best
1403 plot([V_Best_8 V_Best_8],[ROC_max_6_8 ROC_max_1_8], 'Color','blue','LineWidth',1.5)
1404 % ROC_Best
1405 plot([0 V_Best_8],[ROC_Best_8 ROC_Best_8], '--','Color','#A020F0','LineWidth',1.3)
1406 % V_stall lines
1407 plot([V_stall_2_9 V_stall_2_9],[0 ROC_2_8(93)],'-','Color','#6600cc','LineWidth',1.1)
1408 plot([V_stall_3_9 V_stall_3_9],[0 ROC_3_8(110)],'-','Color','#6600cc','LineWidth',1.1)
1409 plot([V_stall_4_9 V_stall_4_9],[0 ROC_4_8(134)],'-','Color','#6600cc','LineWidth',1.1)
1410 plot([V_stall_5_9 V_stall_5_9],[0 ROC_5_8(155)],'-','Color','#6600cc','LineWidth',1.1)
1411 plot([V_stall_6_9 V_stall_6_9],[0 ROC_6_8(161)],'-','Color','#6600cc','LineWidth',1.1)
1412 % M_crit line
1413 plot([Mcrit_2 Mcrit_2],[0 ROC_2_8(270)],'-','Color','#008888','LineWidth',1.3)
1414 plot([Mcrit_3 Mcrit_3],[0 ROC_3_8(261)],'-','Color','#008888','LineWidth',1.3)
1415 plot([Mcrit_4 Mcrit_4],[0 ROC_4_8(248)],'-','Color','#008888','LineWidth',1.3)
1416 plot([Mcrit_5 Mcrit_5],[0 ROC_5_8(242)],'-','Color','#008888','LineWidth',1.3)
1417 plot([Mcrit_6 Mcrit_6],[0 ROC_6_8(240)],'-','Color','#008888','LineWidth',1.3)
1418 text(260,47,'Best Speed for Climb = 293 m/s','Interpreter','latex','FontSize',20)
1419 text(195,45,'Best (R/C) = 44.1 m/s','Interpreter','latex','FontSize',15)
1420 hold off
1421 xlabel("Velocity (m/s)","Interpreter','latex','FontSize',25)
1422 ylabel("Rate of Climb (m/s)","Interpreter','latex','FontSize',25)
1423 leg1 = legend("0.5 Km","3 Km","5.5 Km","8.5 Km","10.5 Km","11.5 Km","$V_{crit}$","$V_{stall}$", ...
1424     "$ (R/C)_{max}$","Best Speed For Climb","Best (R/C)","Interpreter','latex','Location','west', ...
1425     'FontSize',20);
1426 title(leg1,'Legend')
1427 ylim([15 50])

```

```

1428 xlim([75 325])
1429 xticks(45:15:325)
1430 ax = gca;
1431 ax.TickDir = 'out';
1432 ax.TickLength = [0.005 0.005];
1433 grid on
1434 set(gcf, 'Position', get(0,'ScreenSize'));
1435 set(gca, 'Box', 'on');
1436 ax = gca;
1437 ax.TickDir = 'out';
1438 ax.FontSize = 20;
1439 ax.TickLength = [0.005 0.005];
1440 %% %% h v/s R/C Max Calculation
1441 alt = [500 3000 5500 8500 10500 11500];
1442 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];
1443 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];
1444 x = 0:0.5:50;
1445 m1 = -1*h_abs_9/ROC_max_0_9;
1446 y1 = m1*x + h_abs_9;
1447 m2 = -1*h_abs_8/ROC_max_0_8;
1448 y2 = m2*x + h_abs_8;
1449 %% Service Ceiling 0.9 WTO
1450 rho1 = ((-0.5 + ((V_Best_9*t_sl)/(0.9*WTO))) + sqrt(((0.5-(V_Best_9*t_sl)/(0.9*WTO)))^2 - ...
1451         (4*k*V_Best_9^2*CDo)))/(((V_Best_9^3)*S*CDo)/(0.9*WTO));
1452 rho2 = ((-0.5 + ((V_Best_9*t_sl)/(0.9*WTO))) - sqrt(((0.5-(V_Best_9*t_sl)/(0.9*WTO)))^2 - ...
1453         (4*k*V_Best_9^2*CDo)))/(((V_Best_9^3)*S*CDo)/(0.9*WTO));
1454 %% Service Ceiling 0.8 WTO
1455 rho1 = ((-0.5 + ((V_Best_9*t_sl)/(0.8*WTO))) + sqrt(((0.5-(V_Best_9*t_sl)/(0.8*WTO)))^2 - ...
1456         (4*k*V_Best_9^2*CDo)))/(((V_Best_9^3)*S*CDo)/(0.8*WTO));
1457 rho2 = ((-0.5 + ((V_Best_9*t_sl)/(0.8*WTO))) - sqrt(((0.5-(V_Best_9*t_sl)/(0.8*WTO)))^2 - ...
1458         (4*k*V_Best_9^2*CDo)))/(((V_Best_9^3)*S*CDo)/(0.8*WTO));
1459 %% h v/s R/C Max Plot 0.9 WTO
1460 hold on
1461 title("\textbf{Rate of Climb Plot $(R/C)_{\{max\}}$ for 0.9 $W_{\{TO\}}$ and Various Altitudes}", ...
1462       "Interpreter", "latex", 'FontSize', 30)
1463 plot(x, y1, 'Color', "red", 'LineWidth', 1.3)
1464 plot([2.5 0], [h_abs_9 h_abs_9], '-.', 'Color', "#FFA500", 'LineWidth', 1.3)
1465 plot([0.5 0.5], [0 13707.1], '-.', 'Color', "blue", 'LineWidth', 1.3)
1466 plot([42.5 42.5], [0 1000], '-.', 'Color', "magenta", 'LineWidth', 1.3)
1467 plot([2.5 0], [13707.1 13707.1], '-.', 'Color', "blue", 'LineWidth', 1.3)
1468 text(3, h_abs_9+200, 'Absolute Ceiling = 13870 m (Rate of Climb at Absolute Ceiling = 0 m/s)', ...
1469      'Interpreter', 'latex', 'FontSize', 20)
1470 text(3, 13700, 'Service Ceiling = 13707.1 m', 'Interpreter', 'latex', 'FontSize', 20)
1471 text(42.5, 1200, 'Rate of Climb at SL = 42.58 m/s', 'Interpreter', 'latex', 'FontSize', 20, 'Rotation', 90)
1472 text(1.5, 3000, 'Rate of Climb at Service Ceiling = 0.5 m/s', 'Interpreter', 'latex', ...
1473      'FontSize', 20, 'Rotation', 90)
1474 hold off
1475 ylabel("Altitude (m)", 'Interpreter', 'latex', 'FontSize', 25)
1476 xlabel("Rate of Climb (m/s)", 'Interpreter', 'latex', 'FontSize', 25)
1477 xlim([0 45])
1478 ylim([0 15000])
1479 yticks(0:1000:15000)
1480 xticks(2.5:2.5:45)
1481 ax = gca;
1482 ax.TickDir = 'out';
1483 ax.TickLength = [0.005 0.005];
1484 grid on
1485 set(gcf, 'Position', get(0,'ScreenSize'));
1486 set(gca, 'Box', 'on');
1487 ax = gca;
1488 ax.TickDir = 'out';
1489 ax.FontSize = 20;
1490 ax.TickLength = [0.005 0.005];
1491 %% h v/s R/C Max Plot 0.8 WTO
1492 hold on

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1493 title("\textbf{Rate of Climb Plot  $(R/C)_{\max}$  for 0.8  $SW_{TO}$  and Various Altitudes}"), ...
1494     "Interpreter","latex",'FontSize',30)
1495 plot(x,y2,'Color',"red",'LineWidth',1.3)
1496 plot([2.5 0],[h_abs_8 h_abs_8],'-','Color',"#FFA500",'LineWidth',1.3)
1497 plot([0.5 0.5],[0 14468.7],'-','Color',"blue",'LineWidth',1.3)
1498 plot([48.3 48.3],[0 1000],'-','Color',"magenta",'LineWidth',1.3)
1499 plot([2.5 0],[14468.7 14468.7],'-','Color',"blue",'LineWidth',1.3)
1500 text(4,h_abs_8+200,'Absolute Ceiling = 13870 m (Rate of Climb at Absolute Ceiling = 0 m/s)', ...
1501     'Interpreter','latex','FontSize',20)
1502 text(4,14300,'Service Ceiling = 14468.7 m','Interpreter','latex','FontSize',20)
1503 text(48.3,1200,'Rate of Climb at SL = 48.32 m/s','Interpreter','latex', ...
1504     'FontSize',20,'Rotation',90)
1505 text(1.5,3000,'Rate of Climb at Service Ceiling = 0.5 m/s','Interpreter','latex', ...
1506     'FontSize',20,'Rotation',90)
1507 hold off
1508 ylabel("Altitude (m)","Interpreter','latex','FontSize',25)
1509 xlabel("Rate of Climb (m/s)","Interpreter','latex','FontSize',25)
1510 xlim([0 50])
1511 ylim([0 16000])
1512 yticks(0:1000:16000)
1513 xticks(2.5:2.5:50)
1514 ax = gca;
1515 ax.TickDir = 'out';
1516 ax.TickLength = [0.005 0.005];
1517 grid on
1518 set(gcf, 'Position', get(0,'ScreenSize'));
1519 set(gca,'Box','on');
1520 ax = gca;
1521 ax.TickDir = 'out';
1522 ax.FontSize = 20;
1523 ax.TickLength = [0.005 0.005];
1524 %% Variation of Thrust with Altitude for 0.9 WTO
1525 sigma = rho(1:1501)./Rho_SL;
1526 Thrust = Tasl*1000.*sigma;
1527 hold on
1528 title("\textbf{Variation of Thrust with Altitude for 0.9  $SW_{TO}$ "}), ...
1529     "Interpreter","latex",'FontSize',30)
1530 plot(height(1:1501),Thrust,'Color',"blue",'LineWidth',1.5)
1531 xlabel("Altitude (m)","Interpreter','latex','FontSize',20)
1532 ylabel("Thrust (N)","Interpreter','latex','FontSize',20)
1533 hold off
1534 xlim([0 15000])
1535 xticks(0:1500:15000)
1536 ax = gca;
1537 ax.TickDir = 'out';
1538 ax.TickLength = [0.005 0.005];
1539 grid on
1540 set(gcf, 'Position', get(0,'ScreenSize'));
1541 set(gca,'Box','on');
1542 ax = gca;
1543 ax.TickDir = 'out';
1544 ax.FontSize = 20;
1545 ax.TickLength = [0.005 0.005];
1546 %% Variation of TSFC with Altitude for 0.9 WTO
1547 Theta = T./T_SL;
1548 TSFC = 47.5*sqrt(Theta);
1549 hold on
1550 title("\textbf{Variation of Thrust Specific Fuel Consumption (TSFC) with Altitude for 0.9  $SW_{TO}$ "}), ...
1551     "Interpreter","latex",'FontSize',30)
1552 plot(height,TSFC,'Color',"blue",'LineWidth',1.5)
1553 xlabel("Altitude (m)","Interpreter','latex','FontSize',25)
1554 ylabel("Thrust Specific Fuel Consumption (TSFC) ( $\frac{\text{kg}}{\text{hr kN}}$ )"), ...
1555     'Interpreter','latex','FontSize',25)
1556 hold off
1557 xlim([0 15000])

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1558 xticks(0:1500:15000)
1559 ax = gca;
1560 ax.TickDir = 'out';
1561 ax.TickLength = [0.005 0.005];
1562 grid on
1563 set(gcf, 'Position', get(0,'ScreenSize'));
1564 set(gca, 'Box', 'on');
1565 ax = gca;
1566 ax.TickDir = 'out';
1567 ax.FontSize = 20;
1568 ax.TickLength = [0.005 0.005];
1569 %% Time to Climb and Fuel to Climb using for loop
1570 h = 11500;
1571 H = 0:10:11500;
1572 del_h = 10;
1573 W = [];
1574 V_crit_9 = 0.895*a(1:1150);
1575 W(1) = 0.9*WTO;
1576 tc=0;
1577 TC = [];
1578 TC(1) = 0;
1579 DEL_W = [];
1580 Del_W = 0;
1581 DEL_W(1) = 0;
1582 Sing = [];
1583 roc = [];
1584 for i = 1:1150
1585     if V_Best_9 ≥ V_crit_9(i)
1586         q_SL = 0.5*1.225*(V_crit_9(i)^2);
1587     else
1588         q_SL = 0.5*1.225*(V_Best_9^2);
1589     end
1590     hi = (i)*del_h;
1591     sigma = (1-(hi/44300))^(1/0.235);
1592     q = sigma*q_SL;
1593     theta = (288.16 - (0.0065*hi))/288.16;
1594     TSFC = TSFC_SL*9.81*sqrt(theta)/(3600*1000);
1595     Cl = W(i)/(q*S);
1596     Cd = CDo + (k*(Cl^2));
1597     D = q*S*Cd;
1598     sing = ((t_sl*sigma)-D)/(W(i));
1599     if V_Best_9 ≥ V_crit_9(i)
1600         ROC = V_crit_9(i)*sing;
1601     else
1602         ROC = V_Best_9*sing;
1603     end
1604     del_t = del_h/ROC;
1605     del_W = (t_sl*sigma)*TSFC*del_t;
1606     W(i+1) = W(i) - del_W;
1607     tc = tc + del_t;
1608     TC = [TC tc];
1609     Del_W = Del_W+del_W;
1610     DEL_W = [DEL_W Del_W];
1611     Sing = [Sing sing];
1612     roc = [roc ROC];
1613 end
1614 tc = tc/60;
1615 TC = TC./60;
1616 %% Time to climb PLOTS
1617 %% SUBPLOT 1
1618 hold on
1619 title("\textbf{Variation of Altitude with Time ($\Sigma\Delta t_i$) for 0.9 $W_{TO}$}", ...
1620     "Interpreter","latex",'FontSize',30)
1621 plot(TC,H,'Color','blue','LineWidth',1.5)
1622 ylabel("Altitude (m)","Interpreter','latex','FontSize',25)

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1623 xlabel("Time ( $\Sigma \Delta t_i$ ) (in minutes)", 'Interpreter', 'latex', 'FontSize', 25)
1624 yticks(0:1000:12000)
1625 xticks(1:12)
1626 hold off
1627 ax = gca;
1628 ax.TickDir = 'out';
1629 ax.TickLength = [0.005 0.005];
1630 grid on
1631 set(gcf, 'Position', get(0, 'ScreenSize'));
1632 set(gca, 'Box', 'on');
1633 ax = gca;
1634 ax.TickDir = 'out';
1635 ax.FontSize = 20;
1636 ax.TickLength = [0.005 0.005];
1637 %% SUBPLOT 2
1638 hold on
1639 title("\textbf{Variation of Weight ( $W_i$ ) with Altitude for 0.9  $W_{TO}$ }", ...
1640       "Interpreter", "latex", 'FontSize', 30)
1641 plot(H, W, 'Color', "blue", 'LineWidth', 1.5)
1642 xlabel("Altitude (m)", 'Interpreter', 'latex', 'FontSize', 25)
1643 ylabel("Weight ( $W_i$ ) (N)", 'Interpreter', 'latex', 'FontSize', 25)
1644 xticks(0:1000:12000)
1645 hold off
1646 ax = gca;
1647 ax.TickDir = 'out';
1648 ax.TickLength = [0.005 0.005];
1649 grid on
1650 set(gcf, 'Position', get(0, 'ScreenSize'));
1651 set(gca, 'Box', 'on');
1652 ax = gca;
1653 ax.TickDir = 'out';
1654 ax.FontSize = 20;
1655 ax.TickLength = [0.005 0.005];
1656 %% SUBPLOT 3
1657 hold on
1658 title("\textbf{Variation of Change in Weight (  $\Sigma \Delta W_{fi}$  ) with Altitude for 0.9  $W_{TO}$ }", ...
1659       "Interpreter", "latex", 'FontSize', 30)
1660 plot(H, DELW, 'Color', "blue", 'LineWidth', 1.5)
1661 xlabel("Altitude (m)", 'Interpreter', 'latex', 'FontSize', 25)
1662 ylabel("Change in Weight (  $\Sigma \Delta W_{fi}$  ) (N)", 'Interpreter', 'latex', 'FontSize', 25)
1663 hold off
1664 ax = gca;
1665 ax.TickDir = 'out';
1666 ax.TickLength = [0.005 0.005];
1667 grid on
1668 set(gcf, 'Position', get(0, 'ScreenSize'));
1669 set(gca, 'Box', 'on');
1670 ax = gca;
1671 ax.TickDir = 'out';
1672 ax.FontSize = 20;
1673 ax.TickLength = [0.005 0.005];
1674 %% SUBPLOT 4
1675 hold on
1676 title("\textbf{Variation of sin  $\gamma_i$  with Altitude for 0.9  $W_{TO}$ }", ...
1677       "Interpreter", "latex", 'FontSize', 30)
1678 plot(H(1:end-1), Sing, 'Color', "blue", 'LineWidth', 1.5)
1679 xlabel("Altitude (m)", 'Interpreter', 'latex', 'FontSize', 25)
1680 ylabel("sin  $\gamma_i$ ", 'Interpreter', 'latex', 'FontSize', 25)
1681 hold off
1682 ax = gca;
1683 ax.TickDir = 'out';
1684 ax.TickLength = [0.005 0.005];
1685 grid on
1686 set(gcf, 'Position', get(0, 'ScreenSize'));
1687 set(gca, 'Box', 'on');

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1688 ax = gca;
1689 ax.TickDir = 'out';
1690 ax.FontSize = 20;
1691 ax.TickLength = [0.005 0.005];
1692 %% SUBPLOT 5
1693 hold on
1694 title("\textbf{Variation of R/C with Altitude for 0.9 $W_{TO}$}", "Interpreter", "latex", 'FontSize', 30)
1695 plot(H(1:end-1), roc, 'Color', "blue", 'LineWidth', 1.5)
1696 xlabel("Altitude (m)", 'Interpreter', 'latex', 'FontSize', 25)
1697 ylabel("Rate of Climb (R/C) (m/s)", 'Interpreter', 'latex', 'FontSize', 25)
1698 hold off
1699 ax = gca;
1700 ax.TickDir = 'out';
1701 ax.TickLength = [0.005 0.005];
1702 grid on
1703 set(gcf, 'Position', get(0, 'ScreenSize'));
1704 set(gca, 'Box', 'on');
1705 ax = gca;
1706 ax.TickDir = 'out';
1707 ax.FontSize = 20;
1708 ax.TickLength = [0.005 0.005];
1709 %% PLOT 4
1710 sigma_5km = rho(501)/1.225;
1711 %% Omega - V PLOT
1712 % Calculations subplot 1
1713 V = 0:10:700;
1714 n = 0:0.25:2.5;
1715 V_stall_1.9_turn = sqrt(n)*sqrt(0.9*WTO/(0.5*1.225*sigma_1*S*CLmax));
1716 omega_1.9 = [];
1717 Omega_stall_1.9 = [];
1718 R = 0:2.5:100;
1719 vr = [];
1720 for i = 1:11
1721     Omega = ((9.81.*sqrt((n(i).^2)-1))./V)*180/pi;
1722     omegastall = ((9.81.*sqrt((n(i).^2)-1))./V_stall_1.9_turn(i))*180/pi;
1723     omega_1.9 = [omega_1.9 Omega];
1724     Omega_stall_1.9 = [Omega_stall_1.9 omegastall];
1725 end
1726 Omega_R_1.9 = [];
1727 for i = 1:40
1728     for j = 1:10
1729         Omega = ((9.81.*sqrt((n(j).^2)-1))./V)*180/pi;
1730         Omega_R_1.9 = [Omega_R_1.9 Omega];
1731         v = Omega*R(i);
1732         vr = [vr v];
1733     end
1734 end
1735 v1 = sqrt(((t_sl*sigma_1)+sqrt(((t_sl*sigma_1)^2)-(4*A_1*B_1.9*n.^2)))./(2*A_1));
1736 v2 = sqrt(((t_sl*sigma_1)-sqrt(((t_sl*sigma_1)^2)-(4*A_1*B_1.9*n.^2)))./(2*A_1));
1737 om1 = ((9.81*sqrt((n.^2)-1))./v1)*180/pi;
1738 om2 = ((9.81*sqrt((n.^2)-1))./v2)*180/pi;
1739 %% Plot 0.5 Km and 0.9 WTO
1740 title("\textbf{Turn Performance for 0.9 $W_{TO}$ and Altitude 0.5 Km}", ...
1741     "Interpreter", "latex", 'FontSize', 30)
1742 xlabel("Mach Number (M)", 'Interpreter', 'latex', 'FontSize', 25)
1743 ylabel("Turn Rate ($\omega$) ($^\circ$/s)", 'Interpreter', 'latex', 'FontSize', 25)
1744 hold on
1745 grid on
1746 % radius of turn lines
1747 plot(vr(711:1420)./a(500), Omega_R_1.9(711:1420), 'Color', "cyan", 'LineWidth', 0.0001)
1748 plot(vr(1421:2130)./a(500), Omega_R_1.9(1421:2130), 'Color', "cyan", 'LineWidth', 0.0001)
1749 plot(vr(2131:2840)./a(500), Omega_R_1.9(2131:2840), 'Color', "cyan", 'LineWidth', 0.0001)
1750 plot(vr(2841:3550)./a(500), Omega_R_1.9(2841:3550), 'Color', "cyan", 'LineWidth', 0.0001)
1751 plot(vr(3551:4260)./a(500), Omega_R_1.9(3551:4260), 'Color', "cyan", 'LineWidth', 0.0001)
1752 plot(vr(4261:4970)./a(500), Omega_R_1.9(4261:4970), 'Color', "cyan", 'LineWidth', 0.0001)

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1753 plot(vr(4971:5680)./a(500),Omega_R_1_9(4971:5680),'Color','cyan','LineWidth',0.0001)
1754 plot(vr(5681:6390)./a(500),Omega_R_1_9(5681:6390),'Color','cyan','LineWidth',0.0001)
1755 plot(vr(6391:7100)./a(500),Omega_R_1_9(6391:7100),'Color','cyan','LineWidth',0.0001)
1756 plot(vr(7101:7810)./a(500),Omega_R_1_9(7101:7810),'Color','cyan','LineWidth',0.0001)
1757 plot(vr(7811:8522)./a(500),Omega_R_1_9(7811:8522),'Color','cyan','LineWidth',0.0001)
1758 % load factor lines
1759 plot(V./a(500),omega_1_9(356:426),'Color','red','LineWidth',0.0001)
1760 plot(V./a(500),omega_1_9(427:497),'Color','red','LineWidth',0.0001)
1761 plot(V./a(500),omega_1_9(498:568),'Color','red','LineWidth',0.0001)
1762 plot(V./a(500),omega_1_9(569:639),'Color','red','LineWidth',0.0001)
1763 plot(V./a(500),omega_1_9(640:710),'Color','red','LineWidth',0.0001)
1764 plot(V./a(500),omega_1_9(711:781),'Color','red','LineWidth',3)
1765 % Stall Boundary
1766 plot(V_stall_1_9_turn(5:end)./a(500),Omega_stall_1_9(5:end),'Color','blue','LineWidth',1.3)
1767 % Propulsive Boundary
1768 plot(v1(5:11)./a(500),om1(5:11),'Color','magenta','LineWidth',1.3)
1769 plot(v2(5:11)./a(500),om2(5:11),'Color','magenta','LineWidth',1.3)
1770 % Text and Markers
1771 plot(0.50839,7.9029,'Color','black','LineWidth',1.5,'LineStyle','-','Marker','o', ...
1772      'MarkerSize',3.5,'MarkerFaceColor','r')
1773 text(0.51,8.5,'Corner Speed','Interpreter','latex','FontSize',20,'Rotation',15)
1774 text(0.075,80,'Maximum Load Factor ($n_{max}$) = 2.5','Interpreter','latex', ...
1775      'Color','red','FontSize',20,'Rotation',-73)
1776 text(0.4,12,'Sustained Turn Rate (STR)','Interpreter','latex','Color','magenta', ...
1777      'FontSize',20,'Rotation',13)
1778 text(0.38,2,'$C_{L_{max}}$ Limit','Interpreter','latex','Color','blue', ...
1779      'FontSize',20,'Rotation',0)
1780 % Radius of Turn
1781 text(0.48,65,'Radius of Turn = 2.5 m','Interpreter','latex','Color','#8282ff', ...
1782      'FontSize',20,'Rotation',45)
1783 text(0.78,52,'Radius of Turn = 5 m','Interpreter','latex','Color','#8282ff', ...
1784      'FontSize',20,'Rotation',28)
1785 text(0.9,40,'Radius of Turn = 7.5 m','Interpreter','latex','Color','#8282ff', ...
1786      'FontSize',20,'Rotation',20)
1787 text(0.9,30,'Radius of Turn = 10 m','Interpreter','latex','Color','#8282ff', ...
1788      'FontSize',20,'Rotation',15)
1789 xlim([0 1.4])
1790 ylim([0 100])
1791 xticks(0.1:0.1:1.4)
1792 hold off
1793 set(gcf,'Position',get(0,'ScreenSize'));
1794 set(gca,'Box','on');
1795 ax = gca;
1796 ax.TickDir = 'out';
1797 ax.FontSize = 20;
1798 ax.TickLength = [0.005 0.005];
1799 %% Plot 5 Km and 0.9 WTO
1800 % Calculations subplot 2
1801 V = 0:10:700;
1802 n = 0:0.25:2.5;
1803 V_stall_2_9_turn = sqrt(n)*sqrt(0.9*WTO/(0.5*1.225*sigma_5km*S*CLmax));
1804 omega_2_9 = [];
1805 Omega_stall_2_9 = [];
1806 R = 0:2.5:100;
1807 vr = [];
1808 for i = 1:11
1809     Omega = ((9.81.*sqrt((n(i).^2)-1))./V)*180/pi;
1810     omegastall = ((9.81.*sqrt((n(i).^2)-1))./V_stall_2_9_turn(i))*180/pi;
1811     omega_2_9 = [omega_2_9 Omega];
1812     Omega_stall_2_9 = [Omega_stall_2_9 omegastall];
1813 end
1814 Omega_R_2_9 = [];
1815 for i = 1:40
1816     for j = 1:10
1817         Omega = ((9.81.*sqrt((n(j).^2)-1))./V)*180/pi;

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1818     Omega_R_2_9 =[Omega_R_2_9 Omega];
1819     v = Omega*R(i);
1820     vr =[vr v];
1821     end
1822 end
1823 v1 = sqrt(((t_sl*sigma_5km)+sqrt(((t_sl*sigma_5km)^2)-(4*A_2*B_2_9*n.^2)))/(2*A_2));
1824 v2 = sqrt(((t_sl*sigma_5km)-sqrt(((t_sl*sigma_5km)^2)-(4*A_2*B_2_9*n.^2)))/(2*A_2));
1825 om1 = ((9.81*sqrt((n.^2)-1))./v1)*180/pi;
1826 om2 = ((9.81*sqrt((n.^2)-1))./v2)*180/pi;
1827 %% Plot 5 Km and 0.9 WTO
1828 title("\textbf{Turn Performance for 0.9 $W_{TO}$ and Altitude 5 Km}", ...
1829     "Interpreter","latex",'FontSize',30)
1830 xlabel("Mach Number (M)","Interpreter",'latex','FontSize',25)
1831 ylabel("Turn Rate ($\omega$) ($^\circ$/s)","Interpreter",'latex','FontSize',25)
1832 hold on
1833 grid on
1834 % radius of turn lines
1835 plot(vr(711:1420)./a(500),Omega_R_2_9(711:1420),'Color',"cyan",'LineWidth',0.0001)
1836 plot(vr(1421:2130)./a(500),Omega_R_2_9(1421:2130),'Color',"cyan",'LineWidth',0.0001)
1837 plot(vr(2131:2840)./a(500),Omega_R_2_9(2131:2840),'Color',"cyan",'LineWidth',0.0001)
1838 plot(vr(2841:3550)./a(500),Omega_R_2_9(2841:3550),'Color',"cyan",'LineWidth',0.0001)
1839 plot(vr(3551:4260)./a(500),Omega_R_2_9(3551:4260),'Color',"cyan",'LineWidth',0.0001)
1840 plot(vr(4261:4970)./a(500),Omega_R_2_9(4261:4970),'Color',"cyan",'LineWidth',0.0001)
1841 plot(vr(4971:5680)./a(500),Omega_R_2_9(4971:5680),'Color',"cyan",'LineWidth',0.0001)
1842 plot(vr(5681:6390)./a(500),Omega_R_2_9(5681:6390),'Color',"cyan",'LineWidth',0.0001)
1843 plot(vr(6391:7100)./a(500),Omega_R_2_9(6391:7100),'Color',"cyan",'LineWidth',0.0001)
1844 plot(vr(7101:7810)./a(500),Omega_R_2_9(7101:7810),'Color',"cyan",'LineWidth',0.0001)
1845 plot(vr(7811:8522)./a(500),Omega_R_2_9(7811:8522),'Color',"cyan",'LineWidth',0.0001)
1846 plot(vr(8523:9230)./a(500),Omega_R_2_9(8523:9230),'Color',"cyan",'LineWidth',0.0001)
1847 plot(vr(9231:9940)./a(500),Omega_R_2_9(9231:9940),'Color',"cyan",'LineWidth',0.0001)
1848 % load factor lines
1849 plot(V./a(500),omega_2_9(356:426),'Color',"red",'LineWidth',0.0001)
1850 plot(V./a(500),omega_2_9(427:497),'Color',"red",'LineWidth',0.0001)
1851 plot(V./a(500),omega_2_9(498:568),'Color',"red",'LineWidth',0.0001)
1852 plot(V./a(500),omega_2_9(569:639),'Color',"red",'LineWidth',0.0001)
1853 plot(V./a(500),omega_2_9(640:710),'Color',"red",'LineWidth',0.0001)
1854 plot(V./a(500),omega_2_9(711:781),'Color',"red",'LineWidth',3)
1855 % Stall Boundary
1856 plot(V_stall_2_9_turn(5:end)./a(500),Omega_stall_2_9(5:end),'Color',"blue",'LineWidth',1.3)
1857 % Propulsive Boundary
1858 plot(v1(5:11)./a(500),om1(5:11),'Color',"magenta",'LineWidth',1.3)
1859 plot(v2(5:11)./a(500),om2(5:11),'Color',"magenta",'LineWidth',1.3)
1860 % Text and Markers
1861 plot(0.640189,6.27538,'Color',"black",'LineWidth',1.5,'LineStyle','-.', ...
1862     'Marker','o','MarkerSize',3.5,'MarkerFaceColor','r')
1863 text(0.65,7.5,'Corner Speed','Interpreter','latex','FontSize',20,'Rotation',5)
1864 text(0.075,80,'Maximum Load Factor ($n_{\max}$) = 2.5','Interpreter','latex', ...
1865     'Color',"red",'FontSize',20,'Rotation',-78)
1866 text(0.48,10,'Sustained Turn Rate (STR)','Interpreter','latex','Color', ...
1867     'magenta','FontSize',20,'Rotation',7)
1868 text(0.28,2,'$C_{L_{\max}}$ Limit','Interpreter','latex','Color',"blue", ...
1869     'FontSize',20,'Rotation',0)
1870 % Radius of Turn
1871 text(0.48,65,'Radius of Turn = 2.5 m','Interpreter','latex','Color',"#8282ff", ...
1872     'FontSize',20,'Rotation',45)
1873 text(0.78,52,'Radius of Turn = 5 m','Interpreter','latex','Color',"#8282ff", ...
1874     'FontSize',20,'Rotation',28)
1875 text(0.9,40,'Radius of Turn = 7.5 m','Interpreter','latex','Color',"#8282ff", ...
1876     'FontSize',20,'Rotation',20)
1877 text(0.9,30,'Radius of Turn = 10 m','Interpreter','latex','Color',"#8282ff", ...
1878     'FontSize',20,'Rotation',15)
1879 xlim([0 1.4])
1880 ylim([0 100])
1881 xticks(0.1:0.1:1.4)
1882 hold off

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1883 set(gcf, 'Position', get(0,'ScreenSize'));
1884 set(gca, 'Box', 'on');
1885 ax = gca;
1886 ax.TickDir = 'out';
1887 ax.FontSize = 20;
1888 ax.TickLength = [0.005 0.005];
1889 %% Plot 0.5 Km and 0.8 WTO
1890 % Calculations subplot 3
1891 V = 0:10:700;
1892 n = 0:0.25:2.5;
1893 V_stall_1.8_turn = sqrt(n)*sqrt(0.8*WTO/(0.5*1.225*sigma_1*S*CLmax));
1894 omega_1.8 = [];
1895 Omega_stall_1.8 = [];
1896 R = 0:2.5:100;
1897 vr = [];
1898 for i = 1:11
1899     Omega = ((9.81.*sqrt((n(i).^2)-1))./V)*180/pi;
1900     omegastall = ((9.81.*sqrt((n(i).^2)-1))./V_stall_1.8_turn(i))*180/pi;
1901     omega_1.8 = [omega_1.8 Omega];
1902     Omega_stall_1.8 = [Omega_stall_1.8 omegastall];
1903 end
1904 Omega_R_1.8 = [];
1905 for i = 1:40
1906     for j = 1:10
1907         Omega = ((9.81.*sqrt((n(j).^2)-1))./V)*180/pi;
1908         Omega_R_1.8 = [Omega_R_1.8 Omega];
1909         v = Omega*R(i);
1910         vr = [vr v];
1911     end
1912 end
1913 v1 = sqrt(((t_sl*sigma_1)+sqrt(((t_sl*sigma_1)^2)-(4*A_1*B_1.8*n.^2)))./(2*A_1));
1914 v2 = sqrt(((t_sl*sigma_1)-sqrt(((t_sl*sigma_1)^2)-(4*A_1*B_1.8*n.^2)))./(2*A_1));
1915 om1 = ((9.81*sqrt((n.^2)-1))./v1)*180/pi;
1916 om2 = ((9.81*sqrt((n.^2)-1))./v2)*180/pi;
1917 %% Plot 0.5 Km and 0.8 WTO
1918 title("\textbf{Turn Performance for 0.8 $W_{TO}$ and Altitude 0.5 Km}", ...
1919     "Interpreter", "latex", 'FontSize', 30)
1920 xlabel("Mach Number (M)", 'Interpreter', 'latex', 'FontSize', 25)
1921 ylabel("Turn Rate ($\omega$) ($^\circ/s$)", 'Interpreter', 'latex', 'FontSize', 25)
1922 hold on
1923 grid on
1924 % radius of turn lines
1925 plot(vr(711:1420)./a(500), Omega_R_1.8(711:1420), 'Color', "cyan", 'LineWidth', 0.0001)
1926 plot(vr(1421:2130)./a(500), Omega_R_1.8(1421:2130), 'Color', "cyan", 'LineWidth', 0.0001)
1927 plot(vr(2131:2840)./a(500), Omega_R_1.8(2131:2840), 'Color', "cyan", 'LineWidth', 0.0001)
1928 plot(vr(2841:3550)./a(500), Omega_R_1.8(2841:3550), 'Color', "cyan", 'LineWidth', 0.0001)
1929 plot(vr(3551:4260)./a(500), Omega_R_1.8(3551:4260), 'Color', "cyan", 'LineWidth', 0.0001)
1930 plot(vr(4261:4970)./a(500), Omega_R_1.8(4261:4970), 'Color', "cyan", 'LineWidth', 0.0001)
1931 plot(vr(4971:5680)./a(500), Omega_R_1.8(4971:5680), 'Color', "cyan", 'LineWidth', 0.0001)
1932 plot(vr(5681:6390)./a(500), Omega_R_1.8(5681:6390), 'Color', "cyan", 'LineWidth', 0.0001)
1933 plot(vr(6391:7100)./a(500), Omega_R_1.8(6391:7100), 'Color', "cyan", 'LineWidth', 0.0001)
1934 plot(vr(7101:7810)./a(500), Omega_R_1.8(7101:7810), 'Color', "cyan", 'LineWidth', 0.0001)
1935 plot(vr(7811:8522)./a(500), Omega_R_1.8(7811:8522), 'Color', "cyan", 'LineWidth', 0.0001)
1936 % load factor lines
1937 plot(V./a(500), omega_1.8(356:426), 'Color', "red", 'LineWidth', 0.0001)
1938 plot(V./a(500), omega_1.8(427:497), 'Color', "red", 'LineWidth', 0.0001)
1939 plot(V./a(500), omega_1.8(498:568), 'Color', "red", 'LineWidth', 0.0001)
1940 plot(V./a(500), omega_1.8(569:639), 'Color', "red", 'LineWidth', 0.0001)
1941 plot(V./a(500), omega_1.8(640:710), 'Color', "red", 'LineWidth', 0.0001)
1942 plot(V./a(500), omega_1.8(711:781), 'Color', "red", 'LineWidth', 3)
1943 % Stall Boundary
1944 plot(V_stall_1.8_turn(5:end)./a(500), Omega_stall_1.8(5:end), 'Color', "blue", 'LineWidth', 1.3)
1945 % Propulsive Boundary
1946 plot(v1(5:11)./a(500), om1(5:11), 'Color', "magenta", 'LineWidth', 1.3)
1947 plot(v2(5:11)./a(500), om2(5:11), 'Color', "magenta", 'LineWidth', 1.3)

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1948 % Text and Markers
1949 plot(0.47926,8.38229,'Color','black','LineWidth',1.5,'LineStyle','-.', ...
1950 'Marker','o','MarkerSize',3.5,'MarkerFaceColor','r')
1951 text(0.48,10,'Corner Speed','Interpreter','latex','FontSize',20,'Rotation',5)
1952 text(0.075,80,'Maximum Load Factor ($n_{\max}$) = 2.5','Interpreter','latex', ...
1953 'Color','red','FontSize',20,'Rotation',-78)
1954 text(0.35,13,'Sustained Turn Rate (STR)','Interpreter','latex','Color','magenta', ...
1955 'FontSize',20,'Rotation',15)
1956 text(0.35,2,'$C_{L_{\max}}$ Limit','Interpreter','latex','Color','blue', ...
1957 'FontSize',20,'Rotation',0)
1958 % Radius of Turn
1959 text(0.48,65,'Radius of Turn = 2.5 m','Interpreter','latex','Color','#8282ff', ...
1960 'FontSize',20,'Rotation',45)
1961 text(0.78,52,'Radius of Turn = 5 m','Interpreter','latex','Color','#8282ff', ...
1962 'FontSize',20,'Rotation',28)
1963 text(0.9,40,'Radius of Turn = 7.5 m','Interpreter','latex','Color','#8282ff', ...
1964 'FontSize',20,'Rotation',20)
1965 text(0.9,30,'Radius of Turn = 10 m','Interpreter','latex','Color','#8282ff', ...
1966 'FontSize',20,'Rotation',15)
1967 xlim([0 1.4])
1968 ylim([0 100])
1969 xticks(0.1:0.1:1.4)
1970 hold off
1971 set(gcf, 'Position', get(0,'ScreenSize'));
1972 set(gca, 'Box', 'on');
1973 ax = gca;
1974 ax.FontSize = 20;
1975 ax.TickDir = 'out';
1976 ax.TickLength = [0.005 0.005];
1977 %% Plot 5 Km and 0.8 WTO
1978 % Calculations subplot 2
1979 V = 0:10:700;
1980 n = 0:0.25:2.5;
1981 V_stall_2.8_turn = sqrt(n)*sqrt(0.8*WTO/(0.5*1.225*sigma_5km*S*CLmax));
1982 omega_2.8 = [];
1983 Omega_stall_2.8 = [];
1984 R = 0:2.5:100;
1985 vr = [];
1986 for i = 1:11
1987     Omega = ((9.81.*sqrt((n(i).^2)-1))./V)*180/pi;
1988     omegastall = ((9.81.*sqrt((n(i).^2)-1))./V_stall_2.8_turn(i))*180/pi;
1989     omega_2.8 = [omega_2.8 Omega];
1990     Omega_stall_2.8 = [Omega_stall_2.8 omegastall];
1991 end
1992 Omega_R_2.8 = [];
1993 for i = 1:40
1994     for j = 1:10
1995         Omega = ((9.81.*sqrt((n(j).^2)-1))./V)*180/pi;
1996         Omega_R_2.8 = [Omega_R_2.8 Omega];
1997         v = Omega*R(i);
1998         vr = [vr v];
1999     end
2000 end
2001 v1 = sqrt(((t_sl*sigma_5km)+sqrt(((t_sl*sigma_5km)^2)-(4*A_2*B_2.8*n.^2)))./(2*A_2));
2002 v2 = sqrt(((t_sl*sigma_5km)-sqrt(((t_sl*sigma_5km)^2)-(4*A_2*B_2.8*n.^2)))./(2*A_2));
2003 om1 = ((9.81*sqrt((n.^2)-1))./v1)*180/pi;
2004 om2 = ((9.81*sqrt((n.^2)-1))./v2)*180/pi;
2005 %% Plot 5 Km and 0.8 WTO
2006 title("\textbf{Turn Performance for 0.8 $W_{TO}$ and Altitude 5 Km}", ...
2007 'Interpreter','latex','FontSize',30)
2008 xlabel("Mach Number (M)", 'Interpreter','latex','FontSize',25)
2009 ylabel("Turn Rate ($\omega$) ($^\circ$/s)", 'Interpreter','latex','FontSize',25)
2010 hold on
2011 grid on
2012 % radius of turn lines

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2013 plot(vr(711:1420)./a(500),Omega_R_2.8(711:1420),'Color',"cyan",'LineWidth',0.0001)
2014 plot(vr(1421:2130)./a(500),Omega_R_2.8(1421:2130),'Color',"cyan",'LineWidth',0.0001)
2015 plot(vr(2131:2840)./a(500),Omega_R_2.8(2131:2840),'Color',"cyan",'LineWidth',0.0001)
2016 plot(vr(2841:3550)./a(500),Omega_R_2.8(2841:3550),'Color',"cyan",'LineWidth',0.0001)
2017 plot(vr(3551:4260)./a(500),Omega_R_2.8(3551:4260),'Color',"cyan",'LineWidth',0.0001)
2018 plot(vr(4261:4970)./a(500),Omega_R_2.8(4261:4970),'Color',"cyan",'LineWidth',0.0001)
2019 plot(vr(4971:5680)./a(500),Omega_R_2.8(4971:5680),'Color',"cyan",'LineWidth',0.0001)
2020 plot(vr(5681:6390)./a(500),Omega_R_2.8(5681:6390),'Color',"cyan",'LineWidth',0.0001)
2021 plot(vr(6391:7100)./a(500),Omega_R_2.8(6391:7100),'Color',"cyan",'LineWidth',0.0001)
2022 plot(vr(7101:7810)./a(500),Omega_R_2.8(7101:7810),'Color',"cyan",'LineWidth',0.0001)
2023 plot(vr(7811:8522)./a(500),Omega_R_2.8(7811:8522),'Color',"cyan",'LineWidth',0.0001)
2024 plot(vr(8523:9230)./a(500),Omega_R_2.9(8523:9230),'Color',"cyan",'LineWidth',0.0001)
2025 plot(vr(9231:9940)./a(500),Omega_R_2.9(9231:9940),'Color',"cyan",'LineWidth',0.0001)
2026 % load factor lines
2027 plot(V./a(500),omega_2.8(356:426),'Color',"red",'LineWidth',0.0001)
2028 plot(V./a(500),omega_2.8(427:497),'Color',"red",'LineWidth',0.0001)
2029 plot(V./a(500),omega_2.8(498:568),'Color',"red",'LineWidth',0.0001)
2030 plot(V./a(500),omega_2.8(569:639),'Color',"red",'LineWidth',0.0001)
2031 plot(V./a(500),omega_2.8(640:710),'Color',"red",'LineWidth',0.0001)
2032 plot(V./a(500),omega_2.8(711:781),'Color',"red",'LineWidth',3)
2033 % Stall Boundary
2034 plot(V_stall_2.8_turn(5:end)./a(500),Omega_stall_2.8(5:end),'Color',"blue",'LineWidth',1.3)
2035 % Propulsive Boundary
2036 plot(v1(5:11)./a(500),om1(5:11),'Color',"magenta",'LineWidth',1.3)
2037 plot(v2(5:11)./a(500),om2(5:11),'Color',"magenta",'LineWidth',1.3)
2038 % Text and Markers
2039 plot(0.603576,6.6505,'Color',"black",'LineWidth',1.5,'LineStyle','-.', ...
2040      'Marker','o','MarkerSize',3.5,'MarkerFaceColor','r')
2041 text(0.6,8,'Corner Speed','Interpreter','latex','FontSize',20,'Rotation',5)
2042 text(0.075,83,'Maximum Load Factor ($n_{max}$) = 2.5','Interpreter','latex', ...
2043      'Color',"red",'FontSize',20,'Rotation',-81)
2044 text(0.48,10,'Sustained Turn Rate (STR)','Interpreter','latex','Color', ...
2045      "magenta",'FontSize',20,'Rotation',7)
2046 text(0.27,2,'$C_{L_{max}}$ Limit','Interpreter','latex','Color',"blue", ...
2047      'FontSize',20,'Rotation',0)
2048 % Radius of Turn
2049 text(0.48,65,'Radius of Turn = 2.5 m','Interpreter','latex','Color',"#8282ff", ...
2050      'FontSize',20,'Rotation',45)
2051 text(0.78,52,'Radius of Turn = 5 m','Interpreter','latex','Color',"#8282ff", ...
2052      'FontSize',20,'Rotation',28)
2053 text(0.9,40,'Radius of Turn = 7.5 m','Interpreter','latex','Color',"#8282ff", ...
2054      'FontSize',20,'Rotation',20)
2055 text(0.9,30,'Radius of Turn = 10 m','Interpreter','latex','Color',"#8282ff", ...
2056      'FontSize',20,'Rotation',15)
2057 xlim([0 1.4])
2058 ylim([0 100])
2059 xticks(0.1:0.1:1.4)
2060 hold off
2061 set(gcf,'Position',get(0,'ScreenSize'));
2062 set(gca,'Box','on');
2063 ax = gca;
2064 ax.FontSize = 20;
2065 ax.TickDir = 'out';
2066 ax.TickLength = [0.005 0.005];
2067 %% n - V PLOT
2068 %% Plot 0.5 Km and 0.9 WTO
2069 % Calculations
2070 n_stall = 0:0.05:5;
2071 V = 0:10:508;
2072 n = sqrt((0.5*1.225*sigma_1*S.*(V.^2)/(k*(0.9*WTO)).*((t_sl*sigma_1)/ ...
2073      (0.9*WTO)))-(0.5*S*1.225*sigma_1.*(V.^2).*CDo)/(0.9*WTO));
2074 V_stall_1.9_turn = sqrt(n_stall)*sqrt(0.9*WTO/(0.5*1.225*sigma_1*S*CLmax));
2075 n_max = 0.5*1.225*sigma_1*S.*(V.^2).*CLmax/(0.9*WTO);
2076 phi = atand(sqrt(n.^2-1));
2077 [~,index] = max(n);

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2078 title("\textbf{Turn Performance for 0.9 $W_{TO}$ and Altitude 0.5 Km}", ...
2079     "Interpreter","latex",'FontSize',30)
2080 xlabel("Velocity ($V_{\infty}$) (m/s)",'Interpreter','latex','FontSize',25)
2081 yyaxis left
2082 yticks(0:0.5:6)
2083 ylabel("Load Factor (n)",'Interpreter','latex','FontSize',25)
2084 grid on
2085 hold on
2086 plot(V,n,'Color',"blue",'LineWidth',1.3)
2087 plot(V_stall_1.9_turn(1:75),n_stall(1:75),'Color',"red",'LineWidth',1.3,'LineStyle','-')
2088 plot([0 550],[2.5 2.5],'Color',"#FFA500",'LineWidth',1.3,'LineStyle','-')
2089 plot(162.961,2.5,'Color',"black",'LineWidth',1.5,'LineStyle','-','...',
2090     'Marker','o','MarkerSize',3.5,'MarkerFaceColor','r')
2091 plot(V(index),max(n),'Color',"black",'LineWidth',1.5,'LineStyle','-','...',
2092     'Marker','o','MarkerSize',3.5,'MarkerFaceColor','r')
2093 text(168,2.58,'Corner Speed','Interpreter','latex','FontSize',20,'Rotation',0)
2094 text(250,5.15,'Maximum load factor (from propulsive boundary) = 5.04', ...
2095     'Interpreter','latex','FontSize',20,'Rotation',0,'Color',"blue")
2096 text(20,2.6,'Structural limit n = 2.5','Interpreter','latex','FontSize',20, ...
2097     'Rotation',0,'Color',"#FFA500")
2098 text(290,4.6,'Bank Angle Boundary ($\phi_{\max}$)','Interpreter','latex', ...
2099     'FontSize',20,'Rotation',0,'Color',"green")
2100 text(85,0.8,'Stall Boundary ($C_{L_{\max}}$)','Interpreter','latex', ...
2101     'FontSize',20,'Rotation',51,'Color',"red")
2102 yyaxis right
2103 plot(V(32:end),phi(32:end),'Color',"green",'LineWidth',1.3)
2104 ylabel("Bank Angle ($\phi$)",'Interpreter','latex','FontSize',25)
2105 ylim([0 100])
2106 hold off
2107 xlim([0 550])
2108 xticks(50:50:550)
2109 yticks(10:10:100)
2110 ax = gca;
2111 ax.YAxis(1).Color = 'k';
2112 ax.YAxis(2).Color = 'k';
2113 set(gcf, 'Position', get(0,'ScreenSize'));
2114 ax.FontSize = 20;
2115 set(gca,'Box','on');
2116 ax = gca;
2117 ax.TickDir = 'out';
2118 ax.TickLength = [0.005 0.005];
2119 %% Plot 5 Km and 0.9 WTO
2120 % Calculations
2121 n_stall = 0:0.05:5;
2122 V = 0:10:508;
2123 n = sqrt((0.5*1.225*sigma_5km*S.*(V.^2)/(k*(0.9*WTO)))*((t_sl*sigma_5km)/ ...
2124     (0.9*WTO))-((0.5*S*1.225*sigma_5km.*(V.^2).*CDo)./(0.9*WTO)));
2125 V_stall_2.9_turn = sqrt(n_stall)*sqrt(0.9*WTO/(0.5*1.225*sigma_5km*S*CLmax));
2126 n_max = 0.5*1.225*sigma_5km*S.*(V.^2).*CLmax./(0.9*WTO);
2127 phi = atand(sqrt(n.^2-1));
2128 [~,index] = max(n);
2129 title("\textbf{Turn Performance for 0.9 $W_{TO}$ and Altitude 5 Km}", ...
2130     "Interpreter","latex",'FontSize',30)
2131 xlabel("Velocity ($V_{\infty}$) (m/s)",'Interpreter','latex','FontSize',25)
2132 yyaxis left
2133 yticks(0:0.5:6)
2134 ylabel("Load Factor (n)",'Interpreter','latex','FontSize',25)
2135 grid on
2136 hold on
2137 plot(V,n,'Color',"blue",'LineWidth',1.3)
2138 plot(V_stall_2.9_turn(1:51),n_stall(1:51),'Color',"red",'LineWidth',1.3,'LineStyle','-')
2139 plot([0 550],[2.5 2.5],'Color',"#FFA500",'LineWidth',1.3,'LineStyle','-')
2140 plot(205.225,2.5,'Color',"black",'LineWidth',1.5,'LineStyle','-','...',
2141     'Marker','o','MarkerSize',3.5,'MarkerFaceColor','r')
2142 plot(V(index),max(n),'Color',"black",'LineWidth',1.5,'LineStyle','-','...',

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2143     'MarkerSize',3.5,'MarkerFaceColor','r')
2144 text(160,2.59,'Corner Speed','Interpreter','latex','FontSize',20,'Rotation',0)
2145 text(250,3.25,'Maximum load factor (from propulsive boundary) = 3.18', ...
2146     'Interpreter','latex','FontSize',20,'Rotation',0,'Color','blue')
2147 text(40,2.6,'Structural limit n = 2.5','Interpreter','latex','FontSize',20, ...
2148     'Rotation',0,'Color','FFA500')
2149 text(300,2.4,'Bank Angle Boundary ( $\phi_{\max}$ )','Interpreter','latex', ...
2150     'FontSize',20,'Rotation',0,'Color','green')
2151 text(100,0.8,'Stall Boundary ( $C_{L_{\max}}$ )','Interpreter','latex', ...
2152     'FontSize',20,'Rotation',55,'Color','red')
2153 yyaxis right
2154 plot(V(32:end),phi(32:end),'Color','green','LineWidth',1.3)
2155 ylabel('Bank Angle ( $\phi^{\circ}$ )','Interpreter','latex','FontSize',25)
2156 ylim([0 100])
2157 hold off
2158 xlim([0 550])
2159 xticks(50:50:550)
2160 yticks(10:10:100)
2161 ax = gca;
2162 ax.YAxis(1).Color = 'k';
2163 ax.YAxis(2).Color = 'k';
2164 set(gcf, 'Position', get(0,'ScreenSize'))
2165 ax.FontSize = 20;
2166 set(gca, 'Box', 'on');
2167 ax = gca;
2168 ax.TickDir = 'out';
2169 ax.TickLength = [0.005 0.005];
2170 %% Plot 0.5 Km and 0.8 WTO
2171 % Calculations
2172 n_stall = 0:0.05:5;
2173 V = 0:10:508;
2174 n = sqrt((0.5*1.225*sigma_1*S.*(V.^2)/(k*(0.8*WTO)).*((t_sl*sigma_1)/ ...
2175     (0.8*WTO))-((0.5*S*1.225*sigma_1.*(V.^2).*CDo)/(0.8*WTO)));
2176 V_stall_1.8_turn = sqrt(n_stall)*sqrt(0.8*WTO/(0.5*1.225*sigma_1*S*CLmax));
2177 n_max = 0.5*1.225*sigma_1*S.*(V.^2).*CLmax./(0.8*WTO);
2178 phi = atan(sqrt(n.^2-1));
2179 [~,index] = max(n);
2180 title('\textbf{Turn Performance for 0.8 $W_{TO}$ and Altitude 0.5 Km}','Interpreter','latex','FontSize',30)
2181 xlabel('Velocity ( $V_{\infty}$ ) (m/s)','Interpreter','latex','FontSize',25)
2182 yyaxis left
2183 yticks(0:0.5:6)
2184 ylabel('Load Factor (n)','Interpreter','latex','FontSize',25)
2185 grid on
2186 hold on
2187 plot(V,n,'Color','blue','LineWidth',1.3)
2188 plot(V_stall_1.8_turn(1:85),n_stall(1:85),'Color','red','LineWidth',1.3,'LineStyle','--')
2189 plot([0 550],[2.5 2.5],'Color','FFA500','LineWidth',1.3,'LineStyle','--')
2190 plot(153.642,2.5,'Color','black','LineWidth',1.5,'LineStyle','-','Marker','o', ...
2191     'MarkerSize',3.5,'MarkerFaceColor','r')
2192 plot(V(index),max(n),'Color','black','LineWidth',1.5,'LineStyle','-',' ...
2193     'Marker','o','MarkerSize',3.5,'MarkerFaceColor','r')
2194 text(158,2.58,'Corner Speed','Interpreter','latex','FontSize',20,'Rotation',0)
2195 text(250,5.8,'Maximum load factor (from propulsive boundary) = 5.67', ...
2196     'Interpreter','latex','FontSize',20,'Rotation',0,'Color','blue')
2197 text(7,2.6,'Structural limit n = 2.5','Interpreter','latex','FontSize',20, ...
2198     'Rotation',0,'Color','FFA500')
2199 text(300,4.6,'Bank Angle Boundary ( $\phi_{\max}$ )','Interpreter','latex', ...
2200     'FontSize',20,'Rotation',0,'Color','green')
2201 text(80,0.8,'Stall Boundary ( $C_{L_{\max}}$ )','Interpreter','latex', ...
2202     'FontSize',20,'Rotation',52,'Color','red')
2203 yyaxis right
2204 plot(V(32:end),phi(32:end),'Color','green','LineWidth',1.3)
2205 ylabel('Bank Angle ( $\phi^{\circ}$ )','Interpreter','latex','FontSize',25)
2206 ylim([0 100])
2207 hold off

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```

2208 xlim([0 550])
2209 xticks(50:50:550)
2210 yticks(10:10:100)
2211 ax = gca;
2212 ax.YAxis(1).Color = 'k';
2213 ax.YAxis(2).Color = 'k';
2214 set(gcf, 'Position', get(0,'ScreenSize'));
2215 ax.FontSize = 20;
2216 set(gca, 'Box', 'on');
2217 ax = gca;
2218 ax.TickDir = 'out';
2219 ax.TickLength = [0.005 0.005];
2220 %% Plot 5 Km and 0.8 WTO
2221 % Calculations
2222 n_stall = 0:0.05:5;
2223 V = 0:10:508;
2224 n = sqrt((0.5*1.225*sigma_5km*S.*(V.^2)/(k*(0.8*WTO)).*((t_sl*sigma_5km)/ ...
2225 (0.8*WTO)) - ((0.5*S*1.225*sigma_5km.*(V.^2).*CDo)/(0.8*WTO))));
2226 V_stall_2.8_turn = sqrt(n_stall)*sqrt(0.8*WTO/(0.5*1.225*sigma_5km*S*CLmax));
2227 n_max = 0.5*1.225*sigma_5km*S.*(V.^2).*CLmax./(0.9*WTO);
2228 phi = atand(sqrt(n.^2-1));
2229 [~,index] = max(n);
2230 title("\textbf{Turn Performance for 0.8 $W_{TO}$ and Altitude 5 Km}", ...
2231 'Interpreter','latex','FontSize',30)
2232 xlabel("Velocity ($V_{\infty}$) (m/s)", 'Interpreter','latex','FontSize',25)
2233 yyaxis left
2234 yticks(0:0.5:6)
2235 ylabel("Load Factor (n)", 'Interpreter','latex','FontSize',25)
2236 grid on
2237 hold on
2238 plot(V,n,'Color','blue','LineWidth',1.3)
2239 plot(V_stall_2.8_turn(1:54),n_stall(1:54),'Color','red','LineWidth',1.3,'LineStyle','-')
2240 plot([0 550],[2.5 2.5],'Color','#FFA500','LineWidth',1.3,'LineStyle','-')
2241 plot(193.488,2.5,'Color','black','LineWidth',1.5,'LineStyle','-','Marker','o', ...
2242 'MarkerSize',3.5,'MarkerFaceColor','r')
2243 plot(V(index),max(n),'Color','black','LineWidth',1.5,'LineStyle','-',' ...
2244 'Marker','o','MarkerSize',3.5,'MarkerFaceColor','r')
2245 text(200,2.55,'Corner Speed','Interpreter','latex','FontSize',20,'Rotation',0)
2246 text(275,3.7,'Maximum load factor (from propulsive boundary) = 3.57', ...
2247 'Interpreter','latex','FontSize',20,'Rotation',0,'Color','blue')
2248 text(40,2.6,'Structural limit n = 2.5','Interpreter','latex','FontSize',20, ...
2249 'Rotation',0,'Color','#FFA500')
2250 text(300,2.8,'Bank Angle Boundary ($\phi_{\max}$)', 'Interpreter','latex', ...
2251 'FontSize',20,'Rotation',0,'Color','green')
2252 text(105,0.8,'Stall Boundary ($C_{L_{\max}}$)', 'Interpreter','latex', ...
2253 'FontSize',20,'Rotation',57,'Color','red')
2254 yyaxis right
2255 plot(V(32:end),phi(32:end),'Color','green','LineWidth',1.3)
2256 ylabel("Bank Angle ($\phi^{\circ}$)", 'Interpreter','latex','FontSize',25)
2257 ylim([0 100])
2258 hold off
2259 xlim([0 550])
2260 xticks(50:50:550)
2261 yticks(10:10:100)
2262 ax = gca;
2263 ax.YAxis(1).Color = 'k';
2264 ax.YAxis(2).Color = 'k';
2265 set(gcf, 'Position', get(0,'ScreenSize'));
2266 ax.FontSize = 20;
2267 set(gca, 'Box', 'on');
2268 ax = gca;
2269 ax.TickDir = 'out';
2270 ax.TickLength = [0.005 0.005];
2271 %% Combined Plot for 0.9 WTO
2272 % Calculations

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2273 n_stall = 0:0.05:5;
2274 V = 0:10:508;
2275 n = sqrt((0.5*1.225*sigma_1*S.*(V.^2)/(k*(0.9*WTO))).*(((t_sl*sigma_1)/ ...
2276 (0.9*WTO))-((0.5*S*1.225*sigma_1.*(V.^2).*CDo)./(0.9*WTO))));
2277 V_stall_1.9_turn = sqrt(n_stall)*sqrt(0.9*WTO/(0.5*1.225*sigma_1*S*CLmax));
2278 n_max = 0.5*1.225*sigma_1*S.*(V.^2).*CLmax./(0.9*WTO);
2279 phi = atand(sqrt(n.^2-1));
2280 [~,index] = max(n);
2281 hold on
2282 plot(V,n,'Color','blue','LineWidth',1.3)
2283 plot(V_stall_1.9_turn(1:75),n_stall(1:75),'Color','red','LineWidth',1.3,'LineStyle','--')
2284 plot([0 550],[2.5 2.5],'Color','#FFA500','LineWidth',1.3,'LineStyle','--')
2285 plot(V(index),max(n),'Color','black','LineWidth',1.5,'LineStyle','-.',' ...
2286 'Marker','o','MarkerSize',3.5,'MarkerFaceColor','r')
2287 text(168,2.58,'Corner Speed','Interpreter','latex','FontSize',20,'Rotation',0)
2288 text(200,5.15,['Maximum load factor (from propulsive boundary of Altitude 0.5 Km) ' ...
2289 '= 5.04'],'Interpreter','latex','FontSize',20,'Rotation',0,'Color','blue')
2290
2291 % Calculations
2292 n_stall = 0:0.05:5;
2293 V = 0:10:508;
2294 n = sqrt((0.5*1.225*sigma_5km*S.*(V.^2)/(k*(0.9*WTO))).*(((t_sl*sigma_5km)/ ...
2295 (0.9*WTO))-((0.5*S*1.225*sigma_2.*(V.^2).*CDo)./(0.9*WTO))));
2296 V_stall_2.9_turn = sqrt(n_stall)*sqrt(0.9*WTO/(0.5*1.225*sigma_5km*S*CLmax));
2297 n_max = 0.5*1.225*sigma_5km*S.*(V.^2).*CLmax./(0.9*WTO);
2298 phi = atand(sqrt(n.^2-1));
2299 [~,index] = max(n);
2300 title("\textbf{Turn Performance for 0.9 $W_{TO}$ and Altitudes 0.5 and 5 Km}", ...
2301 'Interpreter','latex','FontSize',30)
2302 xlabel("Velocity ($V_{\infty}$) (m/s)","Interpreter','latex','FontSize',25)
2303 yticks(0:0.5:6)
2304 ylabel("Load Factor (n)","Interpreter','latex','FontSize',25)
2305 grid on
2306 plot(V,n,'Color','blue','LineWidth',1.3)
2307 plot(V_stall_2.9_turn(1:51),n_stall(1:51),'Color','red','LineWidth',1.3,'LineStyle','--')
2308 plot([0 550],[2.5 2.5],'Color','#FFA500','LineWidth',1.3,'LineStyle','--')
2309 plot(205.225,2.5,'Color','black','LineWidth',1.5,'LineStyle','-.','Marker','o', ...
2310 'MarkerSize',3.5,'MarkerFaceColor','r')
2311 plot(162.961,2.5,'Color','black','LineWidth',1.5,'LineStyle','-.','Marker','o', ...
2312 'MarkerSize',3.5,'MarkerFaceColor','r')
2313 plot(V(index),max(n),'Color','black','LineWidth',1.5,'LineStyle','-.','Marker','o', ...
2314 'MarkerSize',3.5,'MarkerFaceColor','r')
2315 text(195,3.3,'Maximum load factor (from propulsive boundary of Altitude 5 Km) = 3.18', ...
2316 'Interpreter','latex','FontSize',20,'Rotation',0,'Color','blue')
2317 text(10,2.6,'Structural limit n = 2.5','Interpreter','latex','FontSize',20, ...
2318 'Rotation',0,'Color','#FFA500')
2319 text(105,0.8,'Stall Boundary ($C_{L_{max}}$)','Interpreter','latex','FontSize',20, ...
2320 'Rotation',40,'Color','red')
2321 hold off
2322 xlim([0 530])
2323 xticks(50:50:550)
2324 set(gcf,'Position',get(0,'ScreenSize'));
2325 set(gca,'Box','on');
2326 ax = gca;
2327 ax.FontSize = 20;
2328 ax.TickDir = 'out';
2329 ax.TickLength = [0.005 0.005];
2330 %% Combined Plot for 0.8 WTO
2331 % Calculations
2332 n_stall = 0:0.05:5;
2333 V = 0:10:508;
2334 n = sqrt((0.5*1.225*sigma_1*S.*(V.^2)/(k*(0.8*WTO))).*(((t_sl*sigma_1)/ ...
2335 (0.8*WTO))-((0.5*S*1.225*sigma_1.*(V.^2).*CDo)./(0.8*WTO))));
2336 V_stall_1.8_turn = sqrt(n_stall)*sqrt(0.8*WTO/(0.5*1.225*sigma_1*S*CLmax));
2337 n_max = 0.5*1.225*sigma_1*S.*(V.^2).*CLmax./(0.8*WTO);

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2338 phi = atand(sqrt(n.^2-1));
2339 [~,index] = max(n);
2340 hold on
2341 plot(V,n,'Color','blue','LineWidth',1.3)
2342 plot(V_stall_1.8_turn(1:85),n_stall(1:85),'Color','red','LineWidth',1.3,'LineStyle','-')
2343 plot([0 550],[2.5 2.5],'Color','#FFA500','LineWidth',1.3,'LineStyle','-')
2344 plot(V(index),max(n),'Color','black','LineWidth',1.5,'LineStyle','-','Marker','o', ...
2345     'MarkerSize',3.5,'MarkerFaceColor','r')
2346 text(275,5.8,'Maximum load factor (from propulsive boundary) = 5.67','Interpreter','latex', ...
2347     'FontSize',20,'Rotation',0,'Color','blue')
2348 % Calculations
2349 n_stall = 0:0.05:5;
2350 V = 0:10:508;
2351 n = sqrt((0.5*1.225*sigma_5km*S.*(V.^2)/(k*(0.8*WTO)))*((t_sl*sigma_5km)/ ...
2352     (0.8*WTO)) - ((0.5*S*1.225*sigma_5km.*(V.^2).*CDo)/(0.8*WTO)));
2353 V_stall_2.8_turn = sqrt(n_stall)*sqrt(0.8*WTO/(0.5*1.225*sigma_5km*S*CLmax));
2354 n_max = 0.5*1.225*sigma_5km*S.*(V.^2).*CLmax./(0.9*WTO);
2355 phi = atand(sqrt(n.^2-1));
2356 [~,index] = max(n);
2357 title("\textbf{Turn Performance for 0.8 $W_{TO}$ and Altitudes 0.5 and 5 Km}", ...
2358     "Interpreter","latex",'FontSize',30)
2359 xlabel("Velocity ($V_{\infty}$) (m/s)","Interpreter','latex','FontSize',25)
2360 yticks(0:0.5:6)
2361 ylabel("Load Factor (n)","Interpreter','latex','FontSize',25)
2362 grid on
2363 plot(V,n,'Color','blue','LineWidth',1.3)
2364 plot(V_stall_2.8_turn(1:54),n_stall(1:54),'Color','red','LineWidth',1.3,'LineStyle','-')
2365 plot([0 550],[2.5 2.5],'Color','#FFA500','LineWidth',1.3,'LineStyle','-')
2366 plot(193.488,2.5,'Color','black','LineWidth',1.5,'LineStyle','-','Marker','o', ...
2367     'MarkerSize',3.5,'MarkerFaceColor','r')
2368 plot(153.642,2.5,'Color','black','LineWidth',1.5,'LineStyle','-','Marker','o', ...
2369     'MarkerSize',3.5,'MarkerFaceColor','r')
2370 plot(V(index),max(n),'Color','black','LineWidth',1.5,'LineStyle','-','Marker','o', ...
2371     'MarkerSize',3.5,'MarkerFaceColor','r')
2372 text(200,2.6,'Corner Speed','Interpreter','latex','FontSize',20,'Rotation',0)
2373 text(210,3.7,'Maximum load factor (from propulsive boundary) = 3.57', ...
2374     'Interpreter','latex','FontSize',20,'Rotation',0,'Color','blue')
2375 text(10,2.6,'Structural limit n = 2.5','Interpreter','latex','FontSize',20, ...
2376     'Rotation',0,'Color','#FFA500')
2377 text(105,0.8,'Stall Boundary ($C_{L_{max}}$)','Interpreter','latex','FontSize',20, ...
2378     'Rotation',45,'Color','red')
2379 hold off
2380 xlim([0 530])
2381 xticks(50:50:550)
2382 set(gcf,'Position',get(0,'ScreenSize'));
2383 set(gca,'Box','on');
2384 ax = gca;
2385 ax.FontSize = 20;
2386 ax.TickDir = 'out';
2387 ax.TickLength = [0.005 0.005];
2388 %% PLOT 5
2389 % Calculation
2390 T = t_sl*sigma_1;
2391 V_stall_1.9 = ((2*0.9*WTO)/(1.225*sigma_1*S*(1.15+1.15)))^0.5;
2392 V_stall_1.8 = ((2*0.8*WTO)/(1.225*sigma_1*S*(1.15+1.15)))^0.5;
2393 V_lo_9 = 1.2*V_stall_1.9;
2394 V_lo_8 = 1.2*V_stall_1.8;
2395 CDp = CDo+CDo.Flap + CDo.Land.Gear;
2396 Cl_gr = CLmax + CLmax.HLD.part;
2397 Cl_climb = 0.9*Cl_gr;
2398 Cl_ge = 0.12;
2399 Cdi = k*Cl_ge^2;
2400 Cdi_c = k*Cl_ge^2;
2401 CD_TO = CDp+Cdi;
2402 CD_climb = CDp+Cdi_c;

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2403 D_9 = 0.5*1.225*sigma_1*V_lo_9^2*S*CD_TO;
2404 D_9_c = 0.5*1.225*sigma_1*(V_lo_9^2)*S*CD_climb;
2405 D_8 = 0.5*1.225*sigma_1*V_lo_8^2*S*CD_TO;
2406 D_8_c = 0.5*1.225*sigma_1*V_lo_8^2*S*CD_climb;
2407 % Distance for Rotation
2408 sr_9 = 3*V_lo_9;
2409 sr_8 = 3*V_lo_8;
2410 % Calculation
2411 sing_9 = (T-D_9_c)/(0.9*WTO);
2412 g_9 = asind(sing_9);
2413 sing_8 = (T-D_8_c)/(0.8*WTO);
2414 g_8 = asind(sing_8);
2415 % Distance to Climb
2416 s_c_9 = 10.7/tand(g_9);
2417 s_c_8 = 10.7/tand(g_8);
2418 % Time for Rotation
2419 t_r = 3;
2420 % Time to Climb
2421 t_c_9 = 10.7/(V_lo_9*tand(g_9));
2422 t_c_8 = 10.7/(V_lo_8*tand(g_8));
2423 %% AEO for 0.9 WTO
2424 T = t_sl*sigma_1;
2425 Vstall = ((2*0.9*WTO)/(1.225*sigma_1*S*(1.15+1.15)))^0.5;
2426 Vr = 1.2*Vstall;
2427 v = zeros([500 1]);
2428 a = zeros([500 1]);
2429 s = zeros([500 1]);
2430 t = zeros([500 1]);
2431 del_v = zeros([500 1]);
2432 del_s = zeros([500 1]);
2433 q = zeros([500 1]);
2434 D = zeros([500 1]);
2435 L = zeros([500 1]);
2436 i = 1;
2437 while v(i) ≤ Vr % loop to find T/O parameters
2438     q(i) = 0.5*1.225*v(i)^2;
2439     L(i) = q(i)*S*0.12;
2440     D(i) = q(i)*S*CD_TO;
2441     a(i) = ((T - D(i) - mu*((0.9*WTO)-L(i)))*g)/(0.9*WTO);
2442     del_v(i) = a(i)*0.25;
2443     del_s(i) = v(i)*0.25 + 0.5*a(i)*0.25^2;
2444     v(i+1) = v(i) + del_v(i);
2445     s(i+1) = s(i) + del_s(i);
2446     t(i+1) = t(i) + 0.25;
2447     i = i+1;
2448 end
2449 S_9 = s(182)+sr_9+s_c_9;
2450 T_9 = t_r + t_c_9 + t(182);
2451 %% AEO for 0.8 WTO
2452 T = t_sl*sigma_1;
2453 Vstall = ((2*0.8*WTO)/(1.225*sigma_1*S*(1.15+1.15)))^0.5;
2454 Vr = 1.2*Vstall;
2455 v = zeros([500 1]);
2456 a = zeros([500 1]);
2457 s = zeros([500 1]);
2458 t = zeros([500 1]);
2459 del_v = zeros([500 1]);
2460 del_s = zeros([500 1]);
2461 q = zeros([500 1]);
2462 D = zeros([500 1]);
2463 L = zeros([500 1]);
2464 i = 1;
2465 while v(i) ≤ Vr % loop to find T/O parameters
2466     q(i) = 0.5*1.225*v(i)^2;
2467     L(i) = q(i)*S*0.12;

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2468     D(i) = q(i)*S*CD_TO;
2469     a(i) = ((T - D(i) - mu*((0.8*WTO)-L(i)))*g)/(0.8*WTO);
2470     del_v(i) = a(i)*0.25;
2471     del_s(i) = v(i)*0.25 + 0.5*a(i)*0.25^2;
2472     v(i+1) = v(i) + del_v(i);
2473     s(i+1) = s(i) + del_s(i);
2474     t(i+1) = t(i) + 0.25;
2475     i = i+1;
2476 end
2477 S_8 = s(151)+sr_8+s_c_8;
2478 T_8 = t_r + t_c_8 + t(151);
2479 %% OEI for 0.9 WTO
2480 %% ASDR for 0.9 WTO and 0.5 km
2481 T = t_sl*sigma_1;
2482 Vstall = ((2*0.9*WTO)/(1.225*sigma_1*S*(1.15+1.15)))^0.5;
2483 Vr = 1.2*Vstall;
2484 v_asdr_9 = zeros([400 8]);
2485 a = zeros([400 8]);
2486 s_asdr_9 = zeros([400 8]);
2487 t_asdr_9 = zeros([400 8]);
2488 del_v = zeros([400 8]);
2489 del_s = zeros([400 8]);
2490 q = zeros([400 8]);
2491 D = zeros([400 8]);
2492 L = zeros([400 8]);
2493 x = 0.65;
2494 z = 1;
2495 condition = true;
2496 % loop
2497 while condition == true
2498     i = 1;
2499     while v_asdr_9(i,z) ≤ x*Vr % loop to find T/O parameters till failure
2500         q(i,z) = 0.5*1.225*sigma_1*v_asdr_9(i,z)^2;
2501         L(i,z) = q(i,z)*S*0.12;
2502         D(i,z) = q(i,z)*S*CD_TO;
2503         a(i,z) = ((T - D(i,z) - mu*((0.9*WTO)-L(i,z)))*g)/(0.9*WTO);
2504         del_v(i,z) = a(i,z)*0.25;
2505         del_s(i,z) = v_asdr_9(i,z)*0.25 + 0.5*a(i,z)*0.25^2;
2506         v_asdr_9(i+1,z) = v_asdr_9(i,z) + del_v(i,z);
2507         s_asdr_9(i+1,z) = s_asdr_9(i,z) + del_s(i,z);
2508         t_asdr_9(i+1,z) = t_asdr_9(i,z) + 0.25;
2509         i = i+1;
2510     end
2511     j = i;
2512     v_asdr_9(j) = x*Vr;
2513     s_asdr_9(j) = s_asdr_9(i);
2514     q(j) = q(i);
2515     L(j) = L(i);
2516     D(j) = D(i);
2517     t_asdr_9(j) = t_asdr_9(i);
2518     while j < i + 12 % loop to find T/O paramters during decision phase
2519         q(j,z) = 0.5*1.225*v_asdr_9(j,z)^2;
2520         L(j,z) = q(j,z)*S*0.12;
2521         D(j,z) = q(j,z)*S*CD_TO;
2522         a(j,z) = ((0.75*T - D(i,z) - mu*((0.9*WTO)-L(i,z)))*g)/(0.9*WTO);
2523         del_v(j,z) = a(j,z)*0.25;
2524         del_s(j,z) = v_asdr_9(j,z)*0.25 + 0.5*a(j,z)*0.25^2;
2525         v_asdr_9(j+1,z) = v_asdr_9(j,z) + del_v(j,z);
2526         s_asdr_9(j+1,z) = s_asdr_9(j) + del_s(j,z);
2527         t_asdr_9(j+1,z) = t_asdr_9(j,z) + 0.25;
2528         j = j+1;
2529     end
2530     k = j;
2531     v_asdr_9(k) = x*Vr;
2532     s_asdr_9(k) = s_asdr_9(j);

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2533     q(k) = q(j);
2534     L(k) = L(j);
2535     D(k) = D(j);
2536     t_asdr_9(k) = t_asdr_9(j);
2537     while v_asdr_9(k,z) ≥ 0 % loop to find T/O parameters during deceleration phase
2538         q(k,z) = 0.5*1.225*sigma_1*v_asdr_9(k,z)^2;
2539         L(k,z) = q(k,z)*S*0.12;
2540         D(k,z) = q(k,z)*S*CD_TO;
2541         a(k,z) = -2.4525;
2542         del_v(k,z) = a(k,z)*0.25;
2543         del_s(k,z) = v_asdr_9(k,z)*0.25 + 0.5*a(k,z)*0.25^2;
2544         v_asdr_9(k+1,z) = v_asdr_9(k,z) + del_v(k,z);
2545         s_asdr_9(k+1,z) = s_asdr_9(k,z) + del_s(k,z);
2546         t_asdr_9(k+1,z) = t_asdr_9(k,z) + 0.25;
2547         k = k+1;
2548     end
2549     if x<1
2550         x = x + 0.05;
2551     else
2552         condition = false;
2553     end
2554     z = z + 1;
2555 end
2556 %% TODR for 0.9 WTO and 0.5 km
2557 % Initialisation
2558 T = t_sl*sigma_1;
2559 Vstall = ((2*WTO*0.9)/(1.225*sigma_1*S*(1.15+1.15)))^0.5;
2560 Vr = 1.2*Vstall;
2561 a = zeros([400 8]);
2562 s_todr_9 = zeros([400 8]);
2563 v_todr_9 = zeros([400 8]);
2564 t_todr_9 = zeros([400 8]);
2565 del_v = zeros([400 8]);
2566 del_s = zeros([400 8]);
2567 q = zeros([400 8]);
2568 D = zeros([400 8]);
2569 L = zeros([400 8]);
2570 x = 0.65;
2571 z = 1;
2572 condition = true;
2573 % Loop
2574 while condition == true
2575     i = 1;
2576     while v_todr_9(i,z) ≤ x*Vr % loop to find T/O parameters till failure
2577         q(i,z) = 0.5*1.225*sigma_1*v_todr_9(i,z)^2;
2578         L(i,z) = q(i,z)*S*0.12;
2579         D(i,z) = q(i,z)*S*CD_TO;
2580         a(i,z) = ((T - D(i,z) - mu*((0.9*WTO)-L(i,z)))*g)/(0.9*WTO);
2581         del_v(i,z) = a(i,z)*0.25;
2582         del_s(i,z) = v_todr_9(i,z)*0.25 + 0.5*a(i,z)*0.25^2;
2583         v_todr_9(i+1,z) = v_todr_9(i,z) + del_v(i,z);
2584         s_todr_9(i+1,z) = s_todr_9(i,z) + del_s(i,z);
2585         t_todr_9(i+1,z) = t_todr_9(i,z) + 0.25;
2586         i = i+1;
2587     end
2588     j = i;
2589     v_todr_9(j,z) = x*Vr;
2590     s_todr_9(j,z) = s_todr_9(i,z);
2591     q(j,z) = q(i,z);
2592     L(j,z) = L(i,z);
2593     D(j,z) = D(i,z);
2594     t_todr_9(j,z) = t_todr_9(i,z);
2595     while v_todr_9(j,z) ≤ Vr % loop to find T/O parameters after failure
2596         q(j,z) = 0.5*1.225*sigma_1*v_todr_9(j,z)^2;
2597         L(j,z) = q(j,z)*S*0.12;

```

```

2598     D(j,z) = q(j,z)*S*CD_TO;
2599     a(j,z) = ((0.75*T - D(j,z) - mu*((0.9*WTO)-L(j,z)))*g)/(0.9*WTO);
2600     del_v(j,z) = a(j,z)*0.25;
2601     del_s(j,z) = v_todr_9(j,z)*0.25 + 0.5*a(j,z)*0.25^2;
2602     v_todr_9(j+1,z) = v_todr_9(j,z) + del_v(j,z);
2603     s_todr_9(j+1,z) = s_todr_9(j,z) + del_s(j,z);
2604     t_todr_9(j+1,z) = t_todr_9(j,z) + 0.25;
2605     j = j+1;
2606 end
2607 if x < 1
2608     x = x + 0.05;
2609 else
2610     condition = false;
2611 end
2612 z = z + 1;
2613 end
2614 %% BFL for 0.5 Km
2615 V_f = [0.65*Vr 0.70*Vr 0.75*Vr 0.80*Vr 0.85*Vr 0.90*Vr 0.95*Vr Vr];
2616 S_TODR_9 = [2.4541e03 2.4143e03 2.3654e03 2.2973e03 2.2472e03 2.1709e03 2.0903e03 2.0050e03];
2617 S_ASDR_9 = [1.6634e+03 2.0008e03 2.2562e03 2.4803e03 2.6988e03 2.9116e03 3.1185e03 3.3414e03];
2618 hold on
2619 title("\textbf{Balanced Field Length for a Take-Off Altitude of 0.5 km and 0.9 $W_{TO}$}", ...
2620     "Interpreter","latex",'FontSize',30)
2621 P = InterX([V_f;S_ASDR_9],[V_f;S_TODR_9]);
2622 plot(V_f,S_ASDR_9,'Color',"blue",'LineWidth',1.3,'LineStyle','-')
2623 plot(V_f,S_TODR_9,'Color',"magenta",'LineWidth',1.3,'LineStyle','-')
2624 plot([P(1) P(1)],[1400 P(2)],'Color',"green",'LineWidth',1.3,'LineStyle','--')
2625 plot([0 P(1)],[P(2) P(2)],'Color',"green",'LineWidth',1.3,'LineStyle','--')
2626 plot(P(1),P(2),'Color',"black",'LineWidth',1.5,'LineStyle','-','Marker','o', ...
2627     'MarkerSize',3.5,'MarkerFaceColor','r')
2628 text(P(1)+0.5,1500,'Decision Speed = 67.23 m/s','Interpreter','latex', ...
2629     'FontSize',20,'Rotation',90)
2630 text(56,P(2)-50,'BFL = 2339.95 m','Interpreter','latex','FontSize',20,'Rotation',0)
2631 hold off
2632 grid on
2633 set(gcf,'Position',get(0,'ScreenSize'));
2634 leg1 = legend("ASDR","TODR",'Interpreter','latex','Location','northwest','FontSize',20);
2635 xlabel("Velocity (m/s)",'Interpreter','latex','FontSize',25)
2636 ylabel("Distance (m)",'Interpreter','latex','FontSize',25)
2637 title(leg1,'Legend')
2638 set(gca,'Box','on');
2639 ax = gca;
2640 xticks(55:2.5:95)
2641 ylim([1400 3400])
2642 xlim([55 95])
2643 ax.FontSize = 20;
2644 ax.TickDir = 'out';
2645 ax.TickLength = [0.005 0.005];
2646 %% ASDR for 1.5 km
2647 sigma_15 = sigma(151);
2648 T = t_sl*sigma_15;
2649 Vstall = ((2*0.9*WTO)/(1.225*sigma_15*S*(1.15+1.15)))^0.5;
2650 Vr = 1.2*Vstall;
2651 v_asdr_9 = zeros([400 8]);
2652 a = zeros([400 8]);
2653 s_asdr_9 = zeros([400 8]);
2654 t_asdr_9 = zeros([400 8]);
2655 del_v = zeros([400 8]);
2656 del_s = zeros([400 8]);
2657 q = zeros([400 8]);
2658 D = zeros([400 8]);
2659 L = zeros([400 8]);
2660 x = 0.65;
2661 z = 1;
2662 condition = true;

```

```

2663 % loop
2664 while condition == true
2665     i = 1;
2666     while v_asdr_9(i,z) ≤ x*Vr % loop to find T/O parameters till failure
2667         q(i,z) = 0.5*1.225*sigma_15*v_asdr_9(i,z)^2;
2668         L(i,z) = q(i,z)*S*0.12;
2669         D(i,z) = q(i,z)*S*CD_TO;
2670         a(i,z) = ((T - D(i,z) - mu*((0.9*WTO)-L(i,z)))*g)/(0.9*WTO);
2671         del_v(i,z) = a(i,z)*0.25;
2672         del_s(i,z) = v_asdr_9(i,z)*0.25 + 0.5*a(i,z)*0.25^2;
2673         v_asdr_9(i+1,z) = v_asdr_9(i,z) + del_v(i,z);
2674         s_asdr_9(i+1,z) = s_asdr_9(i,z) + del_s(i,z);
2675         t_asdr_9(i+1,z) = t_asdr_9(i,z) + 0.25;
2676         i = i+1;
2677     end
2678     j = i;
2679     v_asdr_9(j) = x*Vr;
2680     s_asdr_9(j) = s_asdr_9(i);
2681     q(j) = q(i);
2682     L(j) = L(i);
2683     D(j) = D(i);
2684     t_asdr_9(j) = t_asdr_9(i);
2685     while j < i + 12 % loop to find T/O paramters during decision phase
2686         q(j,z) = 0.5*1.225*sigma_15*v_asdr_9(j,z)^2;
2687         L(j,z) = q(j,z)*S*0.12;
2688         D(j,z) = q(j,z)*S*CD_TO;
2689         a(j,z) = ((0.75*T - D(i,z) - mu*((0.9*WTO)-L(i,z)))*g)/(0.9*WTO);
2690         del_v(j,z) = a(j,z)*0.25;
2691         del_s(j,z) = v_asdr_9(j,z)*0.25 + 0.5*a(j,z)*0.25^2;
2692         v_asdr_9(j+1,z) = v_asdr_9(j,z) + del_v(j,z);
2693         s_asdr_9(j+1,z) = s_asdr_9(j) + del_s(j,z);
2694         t_asdr_9(j+1,z) = t_asdr_9(j,z) + 0.25;
2695         j = j+1;
2696     end
2697     k = j;
2698     v_asdr_9(k) = x*Vr;
2699     s_asdr_9(k) = s_asdr_9(j);
2700     q(k) = q(j);
2701     L(k) = L(j);
2702     D(k) = D(j);
2703     t_asdr_9(k) = t_asdr_9(j);
2704     while v_asdr_9(k,z) ≥ 0 % loop to find T/O parameters during deceleration phase
2705         q(k,z) = 0.5*1.225*sigma_15*v_asdr_9(k,z)^2;
2706         L(k,z) = q(k,z)*S*0.12;
2707         D(k,z) = q(k,z)*S*CD_TO;
2708         a(k,z) = -2.4525;
2709         del_v(k,z) = a(k,z)*0.25;
2710         del_s(k,z) = v_asdr_9(k,z)*0.25 + 0.5*a(k,z)*0.25^2;
2711         v_asdr_9(k+1,z) = v_asdr_9(k,z) + del_v(k,z);
2712         s_asdr_9(k+1,z) = s_asdr_9(k,z) + del_s(k,z);
2713         t_asdr_9(k+1,z) = t_asdr_9(k,z) + 0.25;
2714         k = k+1;
2715     end
2716     if x<1
2717         x = x + 0.05;
2718     else
2719         condition = false;
2720     end
2721     z = z + 1;
2722 end
2723 %% TODR for 0.9 WTO and 1.5 km
2724 % Initialisation
2725 % Initialisation
2726 T = t_sl*sigma_15;
2727 Vstall = ((2*WTO*0.9)/(1.225*sigma_15*S*(1.15+1.15)))^0.5;

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```

2728 Vr = 1.2*Vstall;
2729 a = zeros([400 8]);
2730 s_todr_9 = zeros([400 8]);
2731 v_todr_9 = zeros([400 8]);
2732 t_todr_9 = zeros([400 8]);
2733 del_v = zeros([400 8]);
2734 del_s = zeros([400 8]);
2735 q = zeros([400 8]);
2736 D = zeros([400 8]);
2737 L = zeros([400 8]);
2738 x = 0.65;
2739 z = 1;
2740 condition = true;
2741 % Loop
2742 while condition == true
2743     i = 1;
2744     while v_todr_9(i,z) ≤ x*Vr % loop to find T/O parameters till failure
2745         q(i,z) = 0.5*1.225*sigma_15*v_todr_9(i,z)^2;
2746         L(i,z) = q(i,z)*S*0.12;
2747         D(i,z) = q(i,z)*S*CD_TO;
2748         a(i,z) = ((T - D(i,z) - mu*((0.9*WTO)-L(i,z)))*g)/(0.9*WTO);
2749         del_v(i,z) = a(i,z)*0.25;
2750         del_s(i,z) = v_todr_9(i,z)*0.25 + 0.5*a(i,z)*0.25^2;
2751         v_todr_9(i+1,z) = v_todr_9(i,z) + del_v(i,z);
2752         s_todr_9(i+1,z) = s_todr_9(i,z) + del_s(i,z);
2753         t_todr_9(i+1,z) = t_todr_9(i,z) + 0.25;
2754         i = i+1;
2755     end
2756     j = i;
2757     v_todr_9(j,z) = x*Vr;
2758     s_todr_9(j,z) = s_todr_9(i,z);
2759     q(j,z) = q(i,z);
2760     L(j,z) = L(i,z);
2761     D(j,z) = D(i,z);
2762     t_todr_9(j,z) = t_todr_9(i,z);
2763     while v_todr_9(j,z) ≤ Vr % loop to find T/O parameters after failure
2764         q(j,z) = 0.5*1.225*sigma_15*v_todr_9(j,z)^2;
2765         L(j,z) = q(j,z)*S*0.12;
2766         D(j,z) = q(j,z)*S*CD_TO;
2767         a(j,z) = ((0.75*T - D(j,z) - mu*((0.9*WTO)-L(j,z)))*g)/(0.9*WTO);
2768         del_v(j,z) = a(j,z)*0.25;
2769         del_s(j,z) = v_todr_9(j,z)*0.25 + 0.5*a(j,z)*0.25^2;
2770         v_todr_9(j+1,z) = v_todr_9(j,z) + del_v(j,z);
2771         s_todr_9(j+1,z) = s_todr_9(j,z) + del_s(j,z);
2772         t_todr_9(j+1,z) = t_todr_9(j,z) + 0.25;
2773         j = j+1;
2774     end
2775     if x < 1
2776         x = x + 0.05;
2777     else
2778         condition = false;
2779     end
2780     z = z + 1;
2781 end
2782 %% AEO for 0.9 WTO and 1.5 km
2783 % Initialisation
2784 T = t_sl*sigma_15;
2785 Vstall = ((2*0.9*WTO)/(1.225*sigma_15*S*(1.15+1.15)))^0.5;
2786 Vr = 1.2*Vstall;
2787 D_9 = 0.5*1.225*sigma_15*Vr^2*S*CD_TO;
2788 D_9_c = 0.5*1.225*sigma_15*(Vr^2)*S*CD_climb;
2789 % Distance for Rotation
2790 sr_9_15 = 3*Vr;
2791 % Calculation
2792 sing_9_15 = (T-D_9_c)/(0.9*WTO);

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2793 g_9_15 = asind(sing_9_15);
2794 % Distance to Climb
2795 s_c_9_15 = 10.7/tand(g_9_15);
2796 % Time for Rotation
2797 t_r = 3;
2798 % Time to Climb
2799 t_c_9_15 = 10.7/(Vr*tand(g_9));
2800 T = t_sl*sigma_1;
2801 v = zeros([500 1]);
2802 a = zeros([500 1]);
2803 s = zeros([500 1]);
2804 t = zeros([500 1]);
2805 del_v = zeros([500 1]);
2806 del_s = zeros([500 1]);
2807 q = zeros([500 1]);
2808 D = zeros([500 1]);
2809 L = zeros([500 1]);
2810 i = 1;
2811 while v(i) ≤ Vr % loop to find T/O parameters
2812     q(i) = 0.5*1.225*v(i)^2;
2813     L(i) = q(i)*S*0.12;
2814     D(i) = q(i)*S*CD_TO;
2815     a(i) = ((T - D(i) - mu*((0.8*WTO)-L(i)))*g)/(0.8*WTO);
2816     del_v(i) = a(i)*0.25;
2817     del_s(i) = v(i)*0.25 + 0.5*a(i)*0.25^2;
2818     v(i+1) = v(i) + del_v(i);
2819     s(i+1) = s(i) + del_s(i);
2820     t(i+1) = t(i) + 0.25;
2821     i = i+1;
2822 end
2823 S_9_15 = s(151)+sr_9_15+s_c_9_15;
2824 T_9_15 = t(151)+t_r+t_c_9_15;
2825 %% BFL for 1.5 Km
2826 V_f = [0.65*Vr 0.70*Vr 0.75*Vr 0.80*Vr 0.85*Vr 0.90*Vr 0.95*Vr Vr];
2827 S_TODR_9 = [3.0536e03 2.9912e03 2.9253e03 2.8372e03 2.7623e03 2.6602e03 2.5674e03 2.4648e03];
2828 S_ASDR_9 = [1.9319e+03 2.3120e03 2.5865e03 2.8272e03 3.0819e03 3.3260e03 3.5592e03 3.7814e03];
2829 hold on
2830 title("\textbf{Balanced Field Length for a Take-Off Altitude of 1.5 km and 0.9 $W_{TO}$", ...
2831     "Interpreter", "latex", 'FontSize', 30)
2832 P = InterX([V_f; S_ASDR_9], [V_f; S_TODR_9]);
2833 plot(V_f, S_ASDR_9, 'Color', "blue", 'LineWidth', 1.3, 'LineStyle', '-')
2834 plot(V_f, S_TODR_9, 'Color', "magenta", 'LineWidth', 1.3, 'LineStyle', '-')
2835 plot([P(1) P(1)], [1400 P(2)], 'Color', "green", 'LineWidth', 1.3, 'LineStyle', '--')
2836 plot([0 P(1)], [P(2) P(2)], 'Color', "green", 'LineWidth', 1.3, 'LineStyle', '--')
2837 plot(P(1), P(2), 'Color', "black", 'LineWidth', 1.5, 'LineStyle', '-.', ...
2838     'Marker', 'o', 'MarkerSize', 3.5, 'MarkerFaceColor', 'r')
2839 text(P(1)+0.5, 1900, 'Decision Speed = 73.63 m/s', 'Interpreter', ...
2840     'latex', 'FontSize', 20, 'Rotation', 90)
2841 text(56, P(2)-50, 'BFL = 2834.93 m', 'Interpreter', 'latex', 'FontSize', 20, 'Rotation', 0)
2842 hold off
2843 grid on
2844 set(gcf, 'Position', get(0, 'ScreenSize'));
2845 leg1 = legend("ASDR", "TODR", 'Interpreter', 'latex', 'Location', 'northwest', 'FontSize', 20);
2846 xlabel("Velocity (m/s)", 'Interpreter', 'latex', 'FontSize', 25)
2847 ylabel("Distance (m)", 'Interpreter', 'latex', 'FontSize', 25)
2848 title(leg1, 'Legend')
2849 set(gca, 'Box', 'on');
2850 ax = gca;
2851 xticks(57.5:2.5:95)
2852 ylim([1800 4000])
2853 xlim([55 95])
2854 ax.FontSize = 20;
2855 ax.TickDir = 'out';
2856 ax.TickLength = [0.005 0.005];
2857 %% Landing Distance

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2858 V_stall_8 = sqrt(2*0.8*WTO/((CLmax+CLmax_HLD_full)*S*rho_1));
2859 V_stall_6 = sqrt(2*0.6*WTO/((CLmax+CLmax_HLD_full)*S*rho_1));
2860 V_a_8 = 1.3*V_stall_8;
2861 V_a_6 = 1.3*V_stall_6;
2862 gamma = 3*pi/180;
2863 s_1_8 = 15.2/tan(gamma);
2864 s_1_6 = 15.2/tan(gamma);
2865 s_2_8 = 0.1248*(V_stall_8^2)*gamma;
2866 s_2_6 = 0.1248*(V_stall_6^2)*gamma;
2867 s_3_8 = 3*V_a_8;
2868 s_3_6 = 3*V_a_6;
2869 s_4_8 = V_a_8^2/(2*2.5);
2870 s_4_6 = V_a_6^2/(2*2.5);
2871 s_8 = s_1_8 + s_2_8 + s_3_8 + s_4_8;
2872 s_6 = s_1_6 + s_2_6 + s_3_6 + s_4_6;
2873 %% PLOT 6 Payload v/s Range
2874 MTOW = (WEmpty*1000)+(0.95*WFuel*1000)+(0.95*WPayLoad*1000);
2875 TSFC = (47.5*9.81*(Theta(1201)^0.5))/(3600*1000);
2876 % Weights
2877 WA = MTOW - (0.05*WFuel*1000);
2878 WB = MTOW - (0.93*WFuel*1000);
2879 MTOW = (WEmpty*1000)+(1.3*0.95*WFuel*1000)+(0.95*WPayLoad*1000);
2880 WE = MTOW - (0.05*WFuel*1000);
2881 WC = MTOW - (1.23*WFuel*1000);
2882 WF = (MTOW - ((1/3)*(0.95*WPayLoad*1000))) - (0.05*WFuel*1000);
2883 WG = (MTOW - ((1/3)*(0.95*WPayLoad*1000))) - (1.23*WFuel*1000);
2884 WH = (MTOW - ((2/3)*(0.95*WPayLoad*1000))) - (0.05*WFuel*1000);
2885 WI = (MTOW - ((2/3)*(0.95*WPayLoad*1000))) - (1.23*WFuel*1000);
2886 WO = (MTOW - ((0.95*WPayLoad*1000))) - (0.05*WFuel*1000);
2887 WD = (MTOW - ((0.95*WPayLoad*1000))) - (1.23*WFuel*1000);
2888
2889 WPLA = 0.95*WPayLoad*1000;
2890 WPLE = (0.95*WPayLoad*1000) - (0.3*0.95*WFuel*1000);
2891 WPLF = (2/3)*WPLE;
2892 WPLH = (1/3)*WPLE;
2893 WPLO = 0;
2894 % Cruise Calculation
2895 CL_Cruise = sqrt(CDo/k);
2896 % V_Cruise = sqrt(((2*MTOW)/(rho(1201)*S))*(1/CL_Cruise));
2897 CD_Cruise = 2*CDo;
2898 V_crit = a(1201)*Mcrit_orig;
2899 V_Cruise = V_crit;
2900 % Ranges
2901 R_1 = ((2/TSFC)*sqrt(2/(rho(1201)*S))*(3/4)*(1/(3*k*(CDo^3)))^(1/4)* ...
2902     (sqrt(WA) - sqrt(WB)))/1000;
2903 R_2 = ((2/TSFC)*sqrt(2/(rho(1201)*S))*(3/4)*(1/(3*k*(CDo^3)))^(1/4)* ...
2904     (sqrt(WE) - sqrt(WC)))/1000;
2905 R_3 = ((2/TSFC)*sqrt(2/(rho(1201)*S))*(3/4)*(1/(3*k*(CDo^3)))^(1/4)* ...
2906     (sqrt(WF) - sqrt(WG)))/1000;
2907 R_4 = ((2/TSFC)*sqrt(2/(rho(1201)*S))*(3/4)*(1/(3*k*(CDo^3)))^(1/4)* ...
2908     (sqrt(WH) - sqrt(WI)))/1000;
2909 R_5 = ((2/TSFC)*sqrt(2/(rho(1201)*S))*(3/4)*(1/(3*k*(CDo^3)))^(1/4)* ...
2910     (sqrt(WO) - sqrt(WD)))/1000;
2911 % Breguet Ranges
2912 R_1_B = ((V_Cruise/TSFC)*(CL_Cruise/CD_Cruise)*log(WA/WB))/1000;
2913 R_2_B = ((V_Cruise/TSFC)*(CL_Cruise/CD_Cruise)*log(WE/WC))/1000;
2914 R_3_B = ((V_Cruise/TSFC)*(CL_Cruise/CD_Cruise)*log(WF/WG))/1000;
2915 R_4_B = ((V_Cruise/TSFC)*(CL_Cruise/CD_Cruise)*log(WH/WI))/1000;
2916 R_5_B = ((V_Cruise/TSFC)*(CL_Cruise/CD_Cruise)*log(WO/WD))/1000;
2917
2918 %% Plotting Payload v/s Range
2919 hold on
2920 title("\textbf{Payload v/s Range Diagram for a Cruise Altitude of 12 km}", ...
2921     "Interpreter","latex",'FontSize',30)
2922 xlim([0 4.5e4])

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2923 ylim([0 16e5])
2924 xlabel("Range (km)", 'Interpreter', 'latex', 'FontSize', 25)
2925 ylabel("Payload (N)", 'Interpreter', 'latex', 'FontSize', 25)
2926 % Lines
2927 plot([0 R_1], [WPLA WPLA], 'Color', "blue", 'LineWidth', 1.3, 'LineStyle', '-')
2928 plot([0 R_2], [WPLE WPLE], 'Color', "magenta", 'LineWidth', 1.3, 'LineStyle', '--')
2929 plot([0 R_3], [WPLF WPLF], 'Color', "magenta", 'LineWidth', 1.3, 'LineStyle', '--')
2930 plot([0 R_4], [WPLH WPLH], 'Color', "magenta", 'LineWidth', 1.3, 'LineStyle', '--')
2931 plot([0 R_5], [WPLO WPLO], 'Color', "magenta", 'LineWidth', 1.3, 'LineStyle', '--')
2932 plot([R_1 R_2], [WPLA WPLE], 'Color', "blue", 'LineWidth', 1.3, 'LineStyle', '-')
2933 plot([R_2 R_3], [WPLE WPLF], 'Color', "blue", 'LineWidth', 1.3, 'LineStyle', '-')
2934 plot([R_3 R_4], [WPLF WPLH], 'Color', "blue", 'LineWidth', 1.3, 'LineStyle', '-')
2935 plot([R_4 R_5], [WPLH WPLO], 'Color', "blue", 'LineWidth', 1.3, 'LineStyle', '-')
2936 % Text
2937 text(R_1+1000, WPLA+100, 'B', 'Interpreter', 'latex', 'FontSize', 20)
2938 text(R_2+1000, WPLE+100, 'C', 'Interpreter', 'latex', 'FontSize', 20)
2939 text(R_3+1000, WPLF+100, 'G', 'Interpreter', 'latex', 'FontSize', 20)
2940 text(R_4+1000, WPLH+100, 'I', 'Interpreter', 'latex', 'FontSize', 20)
2941 text(R_5+100, WPLO+50000, 'D', 'Interpreter', 'latex', 'FontSize', 20)
2942 text(1000, WPLA+50000, 'A', 'Interpreter', 'latex', 'FontSize', 20)
2943 text(1000, WPLE+50000, 'E', 'Interpreter', 'latex', 'FontSize', 20)
2944 text(1000, WPLF+50000, 'F', 'Interpreter', 'latex', 'FontSize', 20)
2945 text(1000, WPLH+50000, 'H', 'Interpreter', 'latex', 'FontSize', 20)
2946 text(1000, WPLO+50000, 'O', 'Interpreter', 'latex', 'FontSize', 20)
2947 xticks(0.5e4:0.5e4:6e4)
2948 % Markers
2949 plot(R_1, WPLA, 'Color', "black", 'LineWidth', 1.5, 'LineStyle', '-.', ...
2950      'Marker', 'o', 'MarkerSize', 3.5, 'MarkerFaceColor', 'r')
2951 plot(R_2, WPLE, 'Color', "black", 'LineWidth', 1.5, 'LineStyle', '-.', ...
2952      'Marker', 'o', 'MarkerSize', 3.5, 'MarkerFaceColor', 'r')
2953 plot(R_3, WPLF, 'Color', "black", 'LineWidth', 1.5, 'LineStyle', '-.', ...
2954      'Marker', 'o', 'MarkerSize', 3.5, 'MarkerFaceColor', 'r')
2955 plot(R_4, WPLH, 'Color', "black", 'LineWidth', 1.5, 'LineStyle', '-.', ...
2956      'Marker', 'o', 'MarkerSize', 3.5, 'MarkerFaceColor', 'r')
2957 plot(R_5, WPLO, 'Color', "black", 'LineWidth', 1.5, 'LineStyle', '-.', ...
2958      'Marker', 'o', 'MarkerSize', 3.5, 'MarkerFaceColor', 'r')
2959 plot(0, WPLA, 'Color', "black", 'LineWidth', 1.5, 'LineStyle', '-.', ...
2960      'Marker', 'o', 'MarkerSize', 3.5, 'MarkerFaceColor', 'r')
2961 plot(0, WPLE, 'Color', "black", 'LineWidth', 1.5, 'LineStyle', '-.', ...
2962      'Marker', 'o', 'MarkerSize', 3.5, 'MarkerFaceColor', 'r')
2963 plot(0, WPLF, 'Color', "black", 'LineWidth', 1.5, 'LineStyle', '-.', ...
2964      'Marker', 'o', 'MarkerSize', 3.5, 'MarkerFaceColor', 'r')
2965 plot(0, WPLH, 'Color', "black", 'LineWidth', 1.5, 'LineStyle', '-.', ...
2966      'Marker', 'o', 'MarkerSize', 3.5, 'MarkerFaceColor', 'r')
2967 plot(0, WPLO, 'Color', "black", 'LineWidth', 1.5, 'LineStyle', '-.', ...
2968      'Marker', 'o', 'MarkerSize', 3.5, 'MarkerFaceColor', 'r')
2969 grid on
2970 hold off
2971 set(gcf, 'Position', get(0, 'ScreenSize'));
2972 set(gca, 'Box', 'on');
2973 ax = gca;
2974 ax.FontSize = 20;
2975 ax.TickDir = 'out';
2976 %% Plotting Payload v/s Breguet Range
2977 hold on
2978 title("\textbf{Payload v/s Breguet Range Diagram for a Cruise Altitude" + ...
2979      " of 12 km}", 'Interpreter', 'latex', 'FontSize', 30)
2980 xlim([0 4.5e4])
2981 ylim([0 16e5])
2982 xlabel("Range (km)", 'Interpreter', 'latex', 'FontSize', 25)
2983 ylabel("Payload (N)", 'Interpreter', 'latex', 'FontSize', 25)
2984 % Lines
2985 plot([0 R_1-B], [WPLA WPLA], 'Color', "blue", 'LineWidth', 1.3, 'LineStyle', '-')
2986 plot([0 R_2-B], [WPLE WPLE], 'Color', "magenta", 'LineWidth', 1.3, 'LineStyle', '--')
2987 plot([0 R_3-B], [WPLF WPLF], 'Color', "magenta", 'LineWidth', 1.3, 'LineStyle', '--')

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2988 plot([0 R_4_B],[WPLH WPLH], 'Color','magenta','LineWidth',1.3,'LineStyle','--')
2989 plot([0 R_5_B],[WPLO WPLO], 'Color','magenta','LineWidth',1.3,'LineStyle','--')
2990 plot([R_1_B R_2_B],[WPLA WPLE], 'Color','blue','LineWidth',1.3,'LineStyle','-')
2991 plot([R_2_B R_3_B],[WPLE WPLF], 'Color','blue','LineWidth',1.3,'LineStyle','-')
2992 plot([R_3_B R_4_B],[WPLF WPLH], 'Color','blue','LineWidth',1.3,'LineStyle','-')
2993 plot([R_4_B R_5_B],[WPLH WPLO], 'Color','blue','LineWidth',1.3,'LineStyle','-')
2994 % Text
2995 text(R_1_B+1000,WPLA+100,'B','Interpreter','latex','FontSize',20)
2996 text(R_2_B+1000,WPLE+100,'C','Interpreter','latex','FontSize',20)
2997 text(R_3_B+1000,WPLF+100,'G','Interpreter','latex','FontSize',20)
2998 text(R_4_B+1000,WPLH+100,'I','Interpreter','latex','FontSize',20)
2999 text(R_5_B+100,WPLO+50000,'D','Interpreter','latex','FontSize',20)
3000 text(1000,WPLA+50000,'A','Interpreter','latex','FontSize',20)
3001 text(1000,WPLE+50000,'E','Interpreter','latex','FontSize',20)
3002 text(1000,WPLF+50000,'F','Interpreter','latex','FontSize',20)
3003 text(1000,WPLH+50000,'H','Interpreter','latex','FontSize',20)
3004 text(1000,WPLO+50000,'O','Interpreter','latex','FontSize',20)
3005 xticks(0.5e4:0.5e4:8e4)
3006 % Markers
3007 plot(R_1_B,WPLA,'Color','black','LineWidth',1.5,'LineStyle','-.', ...
3008      'Marker','o','MarkerSize',3.5,'MarkerFaceColor','r')
3009 plot(R_2_B,WPLE,'Color','black','LineWidth',1.5,'LineStyle','-.', ...
3010      'Marker','o','MarkerSize',3.5,'MarkerFaceColor','r')
3011 plot(R_3_B,WPLF,'Color','black','LineWidth',1.5,'LineStyle','-.', ...
3012      'Marker','o','MarkerSize',3.5,'MarkerFaceColor','r')
3013 plot(R_4_B,WPLH,'Color','black','LineWidth',1.5,'LineStyle','-.', ...
3014      'Marker','o','MarkerSize',3.5,'MarkerFaceColor','r')
3015 plot(R_5_B,WPLO,'Color','black','LineWidth',1.5,'LineStyle','-.', ...
3016      'Marker','o','MarkerSize',3.5,'MarkerFaceColor','r')
3017 plot(0,WPLA,'Color','black','LineWidth',1.5,'LineStyle','-.', ...
3018      'Marker','o','MarkerSize',3.5,'MarkerFaceColor','r')
3019 plot(0,WPLE,'Color','black','LineWidth',1.5,'LineStyle','-.', ...
3020      'Marker','o','MarkerSize',3.5,'MarkerFaceColor','r')
3021 plot(0,WPLF,'Color','black','LineWidth',1.5,'LineStyle','-.', ...
3022      'Marker','o','MarkerSize',3.5,'MarkerFaceColor','r')
3023 plot(0,WPLH,'Color','black','LineWidth',1.5,'LineStyle','-.', ...
3024      'Marker','o','MarkerSize',3.5,'MarkerFaceColor','r')
3025 plot(0,WPLO,'Color','black','LineWidth',1.5,'LineStyle','-.', ...
3026      'Marker','o','MarkerSize',3.5,'MarkerFaceColor','r')
3027 grid on
3028 hold off
3029 set(gcf, 'Position', get(0,'ScreenSize'));
3030 set(gca,'Box','on');
3031 ax = gca;
3032 ax.FontSize = 20;
3033 ax.TickDir = 'out';
3034 %% Combined Plot
3035 hold on
3036 title("\textbf{Combined Payload v/s Range Diagram for a Cruise " + ...
3037       "Altitude of 12 km}","Interpreter","latex","FontSize",30)
3038 xlim([0 4.5e4])
3039 ylim([0 16e5])
3040 xlabel("Range (km)","Interpreter','latex','FontSize',25)
3041 ylabel("Payload (N)","Interpreter','latex','FontSize',25)
3042 % Lines
3043 plot([0 R_1],[WPLA WPLA], 'Color','blue','LineWidth',1.3,'LineStyle','-')
3044 plot([R_1_B R_2_B],[WPLA WPLE], 'Color','magenta','LineWidth',1.3,'LineStyle','-')
3045 plot([R_1 R_2],[WPLA WPLE], 'Color','blue','LineWidth',1.3,'LineStyle','-')
3046 plot([R_2 R_3],[WPLE WPLF], 'Color','blue','LineWidth',1.3,'LineStyle','-')
3047 plot([R_3 R_4],[WPLF WPLH], 'Color','blue','LineWidth',1.3,'LineStyle','-')
3048 plot([R_4 R_5],[WPLH WPLO], 'Color','blue','LineWidth',1.3,'LineStyle','-')
3049 plot([0 R_2],[WPLE WPLE], 'Color','green','LineWidth',1.3,'LineStyle','--')
3050 plot([0 R_3],[WPLF WPLF], 'Color','green','LineWidth',1.3,'LineStyle','--')
3051 plot([0 R_4],[WPLH WPLH], 'Color','green','LineWidth',1.3,'LineStyle','--')
3052 plot([0 R_5],[WPLO WPLO], 'Color','green','LineWidth',1.3,'LineStyle','--')

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3053 % Markers
3054 plot(R_1,WPLA,'Color','black','LineWidth',1.5,'LineStyle','-.', ...
3055       'Marker','o','MarkerSize',3.5,'MarkerFaceColor','r')
3056 plot(R_2,WPLE,'Color','black','LineWidth',1.5,'LineStyle','-.', ...
3057       'Marker','o','MarkerSize',3.5,'MarkerFaceColor','r')
3058 plot(R_3,WPLF,'Color','black','LineWidth',1.5,'LineStyle','-.', ...
3059       'Marker','o','MarkerSize',3.5,'MarkerFaceColor','r')
3060 plot(R_4,WPLH,'Color','black','LineWidth',1.5,'LineStyle','-.', ...
3061       'Marker','o','MarkerSize',3.5,'MarkerFaceColor','r')
3062 plot(R_5,WPLO,'Color','black','LineWidth',1.5,'LineStyle','-.', ...
3063       'Marker','o','MarkerSize',3.5,'MarkerFaceColor','r')
3064 plot(0,WPLA,'Color','black','LineWidth',1.5,'LineStyle','-.', ...
3065       'Marker','o','MarkerSize',3.5,'MarkerFaceColor','r')
3066 plot(0,WPLE,'Color','black','LineWidth',1.5,'LineStyle','-.', ...
3067       'Marker','o','MarkerSize',3.5,'MarkerFaceColor','r')
3068 plot(0,WPLF,'Color','black','LineWidth',1.5,'LineStyle','-.', ...
3069       'Marker','o','MarkerSize',3.5,'MarkerFaceColor','r')
3070 plot(0,WPLH,'Color','black','LineWidth',1.5,'LineStyle','-.', ...
3071       'Marker','o','MarkerSize',3.5,'MarkerFaceColor','r')
3072 plot(0,WPLO,'Color','black','LineWidth',1.5,'LineStyle','-.', ...
3073       'Marker','o','MarkerSize',3.5,'MarkerFaceColor','r')
3074 grid on
3075 % Text
3076 text(R_1+1000,WPLA+50000,'$B_1$', 'Interpreter','latex','FontSize',20)
3077 text(R_2+1000,WPLE+50000,'$C_1$', 'Interpreter','latex','FontSize',20)
3078 text(R_3+1000,WPLF+50000,'$G_1$', 'Interpreter','latex','FontSize',20)
3079 text(R_4+1000,WPLH+50000,'$I_1$', 'Interpreter','latex','FontSize',20)
3080 text(R_5+100,WPLO+50000,'$D_1$', 'Interpreter','latex','FontSize',20)
3081
3082 text(1000,WPLA+50000,'A','Interpreter','latex','FontSize',20)
3083 text(1000,WPLE+50000,'E','Interpreter','latex','FontSize',20)
3084 text(1000,WPLF+50000,'F','Interpreter','latex','FontSize',20)
3085 text(1000,WPLH+50000,'H','Interpreter','latex','FontSize',20)
3086 text(1000,WPLO+50000,'O','Interpreter','latex','FontSize',20)
3087
3088 text(R_1_B+1000,WPLA+50000,'$B_2$', 'Interpreter','latex','FontSize',20)
3089 text(R_2_B+1000,WPLE+50000,'$C_2$', 'Interpreter','latex','FontSize',20)
3090 text(R_3_B+1000,WPLF+50000,'$G_2$', 'Interpreter','latex','FontSize',20)
3091 text(R_4_B+1000,WPLH+50000,'$I_2$', 'Interpreter','latex','FontSize',20)
3092 text(R_5_B+100,WPLO+50000,'$D_2$', 'Interpreter','latex','FontSize',20)
3093 % Plotting Payload v/s Breguet Range
3094 hold on
3095 % Lines
3096 plot([0 R_1_B],[WPLA WPLA],'Color','magenta','LineWidth',1.3,'LineStyle','-')
3097 plot([R_2_B R_3_B],[WPLE WPLF],'Color','magenta','LineWidth',1.3,'LineStyle','-')
3098 plot([R_3_B R_4_B],[WPLF WPLH],'Color','magenta','LineWidth',1.3,'LineStyle','-')
3099 plot([R_4_B R_5_B],[WPLH WPLO],'Color','magenta','LineWidth',1.3,'LineStyle','-')
3100 % Markers
3101 plot(R_1_B,WPLA,'Color','black','LineWidth',1.5,'LineStyle','-.', ...
3102       'Marker','o','MarkerSize',3.5,'MarkerFaceColor','r')
3103 plot(R_2_B,WPLE,'Color','black','LineWidth',1.5,'LineStyle','-.', ...
3104       'Marker','o','MarkerSize',3.5,'MarkerFaceColor','r')
3105 plot(R_3_B,WPLF,'Color','black','LineWidth',1.5,'LineStyle','-.', ...
3106       'Marker','o','MarkerSize',3.5,'MarkerFaceColor','r')
3107 plot(R_4_B,WPLH,'Color','black','LineWidth',1.5,'LineStyle','-.', ...
3108       'Marker','o','MarkerSize',3.5,'MarkerFaceColor','r')
3109 plot(R_5_B,WPLO,'Color','black','LineWidth',1.5,'LineStyle','-.', ...
3110       'Marker','o','MarkerSize',3.5,'MarkerFaceColor','r')
3111 plot(0,WPLA,'Color','black','LineWidth',1.5,'LineStyle','-.', ...
3112       'Marker','o','MarkerSize',3.5,'MarkerFaceColor','r')
3113 plot(0,WPLE,'Color','black','LineWidth',1.5,'LineStyle','-.', ...
3114       'Marker','o','MarkerSize',3.5,'MarkerFaceColor','r')
3115 plot(0,WPLF,'Color','black','LineWidth',1.5,'LineStyle','-.', ...
3116       'Marker','o','MarkerSize',3.5,'MarkerFaceColor','r')
3117 plot(0,WPLH,'Color','black','LineWidth',1.5,'LineStyle','-.', ...

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3118         'Marker', 'o', 'MarkerSize', 3.5, 'MarkerFaceColor', 'r')
3119 plot(0, WPLO, 'Color', "black", 'LineWidth', 1.5, 'LineStyle', '-.', ...
3120      'Marker', 'o', 'MarkerSize', 3.5, 'MarkerFaceColor', 'r')
3121 grid on
3122 hold off
3123 xticks(0.5e4:0.5e4:8e4)
3124 set(gcf, 'Position', get(0, 'ScreenSize'));
3125 set(gca, 'Box', 'on');
3126 ax = gca;
3127 ax.FontSize = 20;
3128 ax.TickDir = 'out';
3129 ax.TickLength = [0.005 0.005];
3130 leg1 = legend("Range", "Breguet Range", 'Interpreter', 'latex', 'Location', ...
3131             'northeast', 'FontSize', 20);
3132 title(leg1, 'Legend')

```