# AERO 321 Term Project Report

**Fall 2021**

AEROSPACE ENGINEERING
TEXAS A&M UNIVERSITY

**Submitted By:**



| | |
|---|---|
| **Chenliang Zhang** | **UIN: 827008031** |
| **Daniel Duhon** | **UIN: 827004077** |
| **Russtam Wafayee** | **UIN: 626006337** |
| **Steven Mai** | **UIN: 826007930** |

# Contents

# 1. Problem Statement

A manufacturer of a small twin-engine turboprop aircraft contacted our engineering firm for a simple analysis of their aircrafts flying qualities. Our firm is a team of 4 engineers which doesn't possess any CFD (computational fluid dynamics) software, tables from AAA, or empirical equations from DATCOM. The following information is given:

1. The vehicle will cruise at Mach numbers below 0.3 and the lifting surfaces can be assumed to be rectangular (no sweep or taper). The wing aspect ratio will be high.
2. The estimated weight of the vehicle is 12,000 lb.
3. A stability augmentation system is not planned for the vehicle.
4. Constant horsepower propulsive system.
5. Weight and Balance Table (shown in results section)

## 1.1 Requirements

We are required to perform a trim analysis, modal analysis, and determine the flying qualities of the aircraft at the given cruise speed and altitude. Because our engineering firm doesn't have CFD or information from AAA or DATCOM we will conduct our analysis with non empirically derived equations.

## 1.2 Scope of Analysis

The scope of our analysis of the manufacturers aircraft will be brief and a good predictor of the flight dynamics for it. Our analysis will be less accurate than using CFD, wind tunnel testing, or data from AAA or DATCOM but will be a good surface level analysis.

# 2. Problem Formulation

## 2.1 Assumptions and Knowns

Assumptions:

1. Rectangular wing (no sweep or taper ratio = 1), high aspect ratio
2. Standard atmosphere
3. Zero Sideslip, straight and level flight
4. Assume $C_{D_u}$ is zero

Knowns

Flight Altitude: $10,000\ ft$

Air Density: $0.001755 \frac{slugs}{ft^3}$

Temperature: $483.03\ ^{\circ}R$

Speed of Sound, a: $1077.233\ ft/s$

Speed of air flow: $U_0 = 278\ ft/s$

## 2.2 Analysis Outline

### 2.2.1 Moment of Inertias

$I_{yy} = 20,399.534\ slugs \cdot ft^2$

### 2.2.2 Trim Analysis

Under trim condition, 3 relations can be obtained:

$C_{L_{Trim}} q_\infty S_w = W$ & $C_{D_{Trim}} = C_{D_{Parasite}} + \frac{(C_{L_{Trim}})^2}{\pi AR_w e_{Eff}}$ & $C_{M_{Trim}} = 0$

For calculation of $C_{L_{\alpha wf}}$, two equations are utilized:

$C_{L_{\alpha wf}} = K_{wf} C_{L_{\alpha w}}$ & $K_{wf} = 1 + 0.025(\frac{d_f}{b}) - 0.25(\frac{d_f}{b})^2$

Downwash gradient at subsonic field can be expressed as:

$\frac{d\varepsilon}{d\alpha_w} = \frac{C_{L_{\alpha w}}}{\pi eAR}$ (at wing a.c.; 1 at wing trailing edge)

$\frac{d\varepsilon}{d\alpha_w} = \frac{2C_{L_{\alpha w}}}{\pi eAR}$ (at at infinity behind the wing)

Lift coefficient derivatives with respect to α & $\delta_E$ & $i_H$and lift coefficient at $\alpha = \delta_E = 0$:

$C_{L_\alpha} = C_{L_{\alpha_{WF}}} + C_{L_{\alpha_H}} \eta_H \frac{S_H}{S_W}(1 - \frac{d\varepsilon}{d\alpha})$

$C_{L_{\delta_E}} = C_{L_{\alpha_H}} \eta_H \alpha_\delta \frac{S_H}{S_W}$

$C_{L_{i_H}} = C_{L_{\alpha_H}} \eta_H \frac{S_H}{S_W}$

$C_{L_{\alpha=0,\delta E=0}} = C_{L_{Trim}} - C_{L_\alpha}\alpha - C_{L_{\delta_E}}\delta_E - C_{L_{i_H}} i_H$

For some distance parameters:

$\Delta\overline{X}_{AC_H} = \frac{X_{AC_H} - X_{CG}}{\overline{C}_w}$ & $\Delta X_{AC_f} = X_{AC_f} - X_{CG}$

$X_{AC_{WF}} = X_{AC_w} + \Delta X_{AC_f}$ & $\Delta\overline{X}_{AC_{WF}} = \frac{X_{CG} - X_{AC_{WF}}}{\overline{C}_w}$

Under trim condition:

$T_{trim} = D_{trim} = C_{D_{trim}} S_w q_\infty$

$\overline{Z}_T = \frac{Z_T}{\overline{c}_w}$

$C_{M_T} = C_p = \frac{T_{trim}}{q_\infty S_w}\overline{Z}_T$

Pitching moment coefficient derivatives with respect to α & $\delta E$ & $i_H$ and pitching moment coefficient at $\alpha = \delta E = 0$

$$C_{M_\alpha} = C_{L_{\alpha_{WF}}} \Delta\overline{X}_{AC_{WF}} - C_{L_{\alpha_H}} \eta_H (\frac{S_H}{S_W} \Delta\overline{X}_{AC_H})(1 - \frac{d\varepsilon}{d\alpha})$$

$$C_{M_{i_H}} = - C_{L_{\alpha_H}} \eta_H (\frac{S_H}{S_W} \Delta\overline{X}_{AC_H})$$

$$C_{M_{\delta_E}} = - C_{L_{\alpha_H}} \eta_H \alpha_\delta (\frac{S_H}{S_W} \Delta\overline{X}_{AC_H})$$

$$C_{M_{\alpha=0,\delta E=0}} = C_P - C_{M_\alpha} \alpha - C_{M_{\delta_E}} \delta E - C_{M_{i_H}} i_H$$

The Neutral Point can be calculated using the following equation:

$$\overline{X}_{NP} = \frac{C_{L_{\alpha_{wf}}} \overline{X}_{AC_{wf}} + C_{L_{\alpha_H}} \eta_H \frac{S_H}{S_W} \overline{X}_{AC_H} (1 - \frac{d\varepsilon}{d\alpha})}{C_{L_\alpha}}$$

From the Neutral Point locating and the location of the C.G., we can compute the Static Margin:

$$SM = \overline{X}_{cg} - \overline{X}_{NP}$$

$$X_{CG} = 2.798\ ft$$

$$\overline{X}_{CG} = X_{CG}/\overline{c}_W = 0.430$$

Mach number can be calculated from:

$$M = \frac{U_0}{a} = \frac{278\ ft/s}{1077.233\ ft/s} = 0.258$$

**Table 1:**

| Parameter | Equation | Value |
|---|---|---|
| $q_\infty$ at u=278 ft/s and h = 10,000 ft | $q_\infty = 0.5\rho_\infty u^2$ | 67.81 $\frac{lbf}{ft^2}$ |
| Aspect ratio of wing | $AR_w = \frac{b_w^2}{S_w}$ | 10 |
| Wingspan (for rectangular wing) | $b_w = \frac{S_w}{c_w}$ | 65 ft |
| $C_{L_0}$ (Trim) | $C_{L_0} = C_{L_{Trim}} = \frac{W}{q_\infty S_W}$ | 0.419 |
| $C_{D_0}$ (Trim) | $C_{D_0} = C_{D_{Trim}} = C_{D_{Parasite}} + \frac{(C_{L_{Trim}})^2}{\pi AR_w e_{Eff}}$ | 0.0469 |
| $C_{M_0}$ (Trim,Aero) | $C_{M_0} = C_{M_{Trim}} = 0$ | 0 |

| | | |
|---|---|---|
| $\frac{d\epsilon}{d\alpha}$ | $\frac{2C_{L_{\alpha w}}}{\pi\, e\, AR}$ | 0.3247 |
| $C_{L_{\alpha_{wf}}}$ | $C_{L_{\alpha_w}}[1 + 0.025(\frac{df}{b}) - 0.25(\frac{df}{b})^2]$ | 5.1 |
| $C_{L_\alpha}$ | $C_{L_\alpha} = C_{L_{\alpha_{wf}}} + C_{L_{\alpha_H}}\eta_H \frac{S_H}{S_w}(1 - \frac{d\epsilon}{d\alpha})$ | 5.687 |
| $C_{D_\alpha}$ | $C_{D_\alpha} = \frac{2}{\pi}(C_{L_{\alpha w}}\frac{C_{L_w}}{AR_w e_w} + C_{L_{\alpha H}}\frac{C_{L_H}}{AR_H e_H}\eta_H \frac{S_H}{S_W}(1 - \frac{d\varepsilon}{d\alpha}))$ | |
| $C_{L_{\delta_E}}$ | $C_{L_{\delta_E}} = C_{L_{\alpha_H}}\eta_H \alpha_\delta \frac{S_H}{S_W}$ | 0.478 |
| $C_{L_{i_h}}$ | $C_{L_{i_H}} = C_{L_{\alpha_H}}\eta_H \frac{S_H}{S_W}$ | 0.869 |
| $\Delta\bar{X}_{AC_H}$ | $\frac{X_{AC_H} - X_{CG}}{\bar{c}_w}$ | 3.97 |
| $\Delta X_{AC_f}$ | $X_{AC_f} - X_{CG}$ | -1.59 ft |
| $X_{AC_{wf}}$ | $X_{AC_w} + \Delta X_{AC_f}$ | 0.035 ft |
| $\Delta\bar{X}_{AC_{w\&f}}$ | $\frac{X_{CG} - X_{AC_{wf}}}{\bar{c}_w}$ | 0.424 |
| $C_{M_\alpha}$ | $C_{M_\alpha} = C_{L_{\alpha_{wf}}}\Delta\bar{X}_{AC_{w\&f}} - C_{L_{\alpha_H}}\eta_H(\frac{S_H}{S_W}\Delta\bar{X}_{AC_H})(1 - \frac{d\epsilon}{d\alpha})$ | -0.731 |
| $C_{M_{i_H}}$ | $C_{M_{i_H}} = - C_{L_{\alpha_H}}\eta_H(\frac{S_H}{S_W}\Delta\bar{X}_{AC_H})$ | -3.45 |
| $C_{M_{\delta_E}}$ | $C_{M_{\delta_E}} = - C_{L_{\alpha_H}}\eta_H \alpha_\delta(\frac{S_H}{S_W}\Delta\bar{X}_{AC_H})$ | -1.89 |

| | | |
|---|---|---|
| $C_L\vert_{\alpha=\delta_E=0}$ | $C_L\vert_{\alpha=\delta_E=0} = C_{L_{Trim}} - C_{L_\alpha}\alpha - C_{L_{i_H}} - C_{L_{\delta_E}}\delta_E$ | 0.493 |
| $T_{trim}$ | $T_{trim} = D_{trim} = C_{D_{tim}} S_w q_\infty$ | 1294.8 lbf |
| $\bar{Z}_T$ | $\bar{Z}_T = \frac{Z_T}{\bar{c}_W}$ | 0.4354 |
| $C_{M_T}$ | $\frac{T_{trim}}{q_\infty S_W}\bar{Z}_T$ | 0.0196 |
| $C_M\vert_{\alpha=\delta_E=0}$ | $C_M\vert_{\alpha=\delta_E=0} = C_{M_T} - C_{M_\alpha}\alpha - C_{M_{i_H}} i_H - C_{M_{\delta_E}}\delta_E$ | -0.255 |
| $i_H$ Recommended | Need $C_M\vert_{\alpha=\delta_E=0}$ to be negative and $C_L\vert_{\alpha=\delta_E=0}$ to be positive | $i_H \approx - 0.0872\, ra$<br>$i_H \approx - 5\, deg$ |
| Trim aoa | $\alpha_{trim} = \frac{(C_{L_{trim}} - C_L\vert_{\alpha=\delta_E=0} - C_{L_{i_H}} i_H)\, C_{M_{\delta_E}} + (C_M\vert_{\alpha=\delta_E=0} + C_{M_{i_H}} i_H)\, C_{L_{\delta_E}}}{C_{L_\alpha} C_{M_{\delta_E}} - C_{M_\alpha} C_{L_{\delta_E}}}$ | $\alpha_{trim} = - 0.00209\, r$<br>$\alpha_{trim} = - 0.115\, deg$ |
| Trim elevator angle | $\delta_E(trim) = \frac{(C_{L_{trim}} - C_L\vert_{\alpha=\delta_E=0} - C_{L_{i_H}} i_H)\, C_{M_{\delta_E}} + (C_M\vert_{\alpha=\delta_E=0} + C_{M_{i_H}} i_H)\, C_{L_{\delta_E}}}{C_{L_\alpha} C_{M_{\delta_E}} - C_{M_\alpha} C_{L_{\delta_E}}}$ | $\delta_{Etrim} = 0.0250\, rad$<br>$\delta_{Etrim} = 1.43\, deg$ |
| Static margin (SM) | $SM = \frac{C_{M_\alpha}}{-C_{L_\alpha}}$ | 0.125 |

**2.2.3 Non Dimensional and Dimensional Stability / Control Derivatives**

**Table 2:**

| Stability Derivative | Equation Used | Value (Units) |
|---|---|---|
| $C_{D_M}$ | $C_{D_M} = \frac{M_0}{1-M_0^2} C_{D_0}$ | 0.01296 |
| $C_{D_u}$ | $C_{D_u} = \frac{C_{D_M}}{a_0}$ | $0.00001203 \approx 0$ |
| $C_{L_M}$ | $C_{L_M} = \frac{M_0}{1-M_0^2} C_{L_0}$ | 0.116 |

| | | |
|---|---|---|
| $C_{L_u}$ | $C_{L_u} = \frac{C_{L_M}}{a_0}$ | .0001077 |
| $C_{M_u}$ | $C_{M_u} = \frac{M_u I_{yy}}{q_\infty S_W \bar{c}_W} - \frac{2}{U_0} C_{M_0}, C_{M_0} = 0, M_u = 0$ | 0 |
| $C_{T_u}$ | $C_{T_u} = - 3(C_{D_0} + C_{L_0} tan(\Theta_0)), \Theta_0 = 5º$ | -0.243 |
| $X_u$ | $X_u = \frac{-(C_{D_u} + \frac{2}{U_0} C_{D_0}) q_\infty S_W}{m}$ | -0.02592 $\frac{ft}{rad \cdot s}$ |
| $Z_u$ | $Z_u = \frac{-(C_{L_u} + \frac{2}{U_0} C_{L_0}) q_\infty S_W}{m}$ | $0.359 \frac{ft}{rad \cdot s}$ |
| $X_{P_u}$ | $\frac{dT}{dU}$/m | $- 0.000388 \frac{ft}{rad \cdot s}$ |
| $Z_\alpha$ | $Z_\alpha = \frac{-(C_{L_\alpha} + C_{D_0}) q_\infty S_W}{m}$ | $- 451.0828$ |
| $X_\alpha$ | $X_\alpha = \frac{-(C_{D_\alpha} + C_{L_0}) q_\infty S_W}{m}$ | -32.031 |
| $M_\alpha$ | $M_\alpha = \frac{C_{M_\alpha} q_\infty S_W \bar{c}_w}{I_{yy}}$ | -6.2821 |
| $M_u$ | $M_u = \frac{(C_{M_u} + \frac{2}{U_0} C_{M_0}) q_\infty S_W \bar{c}_w}{I_{yy}}$ | 0 |
| $M_{\alpha_{dot}}$ | $M_{\alpha_{dot}} = \frac{C_{M_{\alpha dot}} q_\infty S_W \bar{c}_w}{I_{yy}}$ | 0.0649 |
| $C_{M_{\alpha dot}}$ | $- (C_{L_{\alpha H}} \frac{d\varepsilon}{d\alpha} \frac{(X_{ACW} - X_{ACH})(X_{CG} - X_{ACH})}{U_0 \bar{c}_w} \eta_H \frac{S_H}{S_W}$ | 0.007112 |
| $M_q$ | $M_q = \frac{C_{M_q} q_\infty S_W \bar{c}_w}{I_{yy}}$ | -0.06925 |
| $C_{M_q}$ | $C_{M_q} = - \frac{C_{L_{\alpha H}} (X_{CG} - X_{ACH})^2}{U_0 \bar{c}_w} \frac{S_H}{S_W} \eta_H$ | -0.007586 |

**2.2.4 Modal Analysis**

$$\begin{bmatrix} \dot{u} \\ \dot{\alpha} \\ \dot{q} \\ \dot{\theta} \end{bmatrix} = \begin{bmatrix} X_u & X_\alpha & 0 & -g \\ Z_u / U_0 & Z_\alpha / U_0 & 1 & 0 \\ M_u + M_{\dot{\alpha}} Z_u / U_0 & M_\alpha + (M_{\dot{\alpha}} Z_\alpha / U_0) & M_q + M_{\dot{\alpha}} & 0 \\ 0 & 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} u \\ \alpha \\ q \\ \theta \end{bmatrix} + \begin{bmatrix} X_{\delta_E} \\ Z_{\delta_E} / U_0 \\ M_{\delta_E} + (M_{\dot{\alpha}} Z_{\delta_E} / U_0) \\ 0 \end{bmatrix} \delta_E$$

And this matrix can be written as the form:

$X_{dot} = AX + BU$ (through this form we can obtain matrix A and B)

And eigenvalues and eigenvectors matrix can be obtained through:

$AM = M\Lambda$

$M^{-1}AM = \Lambda$

M: matrix of eigenvectors

Λ: diagonal matrix of eigenvalues

Characteristic equation: $det(sI - A) = 0$which can be used to solve for s and get matrixΛ

Then using matrix relations to solve for M

**A matrix**

| | | | |
|---|---|---|---|
| -0.02459 | -32.031 | 0 | -32.174 |
| 0.001291 | -1.6226 | 1 | 0 |
| 0.000083844 | -6.3874 | -0.00435 | 0 |
| 0 | 0 | 1 | 0 |

**Eigenvectors**

| **Vector 1** | **Vector 2** | **Vector 3** | **Vector 4** |
|---|---|---|---|
| 0.9929 | 0.9929 | 1 | 1 |
| 0.0249-0.0323i | 0.0249+0.0323i | 0 | 0 |
| 0.0982+0.0331i | 0.0982-0.0331i | 0.0013-0.0001i | 0.0013+0.0001i |
| -0.0003-0.0412i | -0.0003+0.0412i | -0.0005-0.0064i | -0.0005+0.0064i |

**Eigenvalues**

| | |
|---|---|
| Value 1 | -0.8184+2.3784i |
| Value 2 | -0.8184-2.3784i |
| Value 3 | -0.0073+0.2063i |
| Value 4 | -0.0073-0.2063i |

**Table 3**

| Mode | eigenvalues | eigenvectors |
|---|---|---|
| Phugoid | $-0.0073 \pm 0.2063j$ | $[1]$<br>$[0]$<br>$[0.0013 \mp 0.2063j]$<br>$[-0.0005 \mp 0.0064j]$ |
| Short Period | $-0.8184 \pm 2.3784j$ | $[0.9929]$<br>$[0.0249 \mp 0.0323j]$<br>$[0.0982 \pm 0.0331j]$<br>$[-0.0003 \mp 0.0412j]$ |

### 2.2.5 Modal Characteristics

Characteristic equation: $det(sI - A) = 0$

$sI - A =$

$$\begin{pmatrix} s & 0 & 0 & 0 \\ 0 & s & 0 & 0 \\ 0 & 0 & s & 0 \\ 0 & 0 & 0 & s \end{pmatrix} - \begin{pmatrix} -0.02459 & -32.031 & 0 & -32.174 \\ 0.001291 & -1.6226 & 1 & 0 \\ 0.000083844 & -6.3874 & -0.00435 & 0 \\ 0 & 0 & 1 & 0 \end{pmatrix} = \begin{pmatrix} s+0.02459 & 32.031 & 0 & 32.174 \\ -0.001291 & s+1.6226 & -1 & 0 \\ -0.000084 & 6.3874 & s+0.00435 & 0 \\ 0 & 0 & -1 & s \end{pmatrix}$$

$det(sI - A) = s^4 + 1.651s^3 + 6.475s^2 + 0.1628s - 0.2609 = 0$

Our characteristic equation:
$s^4 + 1.651s^3 + 6.475s^2 + 0.1628s - 0.2609 = 0$

$s^2 + 2\varsigma\omega_n s + \omega_n^2 = 0$

Natural frequency: $\omega_n$

Damping ratio: $\varsigma$

Then s values are solved from Characteristic equation:

$$s = \eta \pm j\omega = -\varsigma\omega_n \pm j\omega_n\sqrt{1-\varsigma^2}$$

Damped frequency: $\omega = \omega_n\sqrt{1-\varsigma^2}$

Period of oscillation: $t_p = \frac{2\pi}{\omega}$

time -to-half: $t_{half} = \frac{log_{natural}2}{|\eta|}$

Cycles-to-half: $\frac{t_{half}}{t_p}$

Time constant: $\frac{1}{|\eta|}$

**Table 4**

| Mode | Natural Frequency (rad/s) | Damping Ratio | Damped Frequency (rad/s) | Time-to-half (s) | Cycles-to-half | Time constant (s) |
|---|---|---|---|---|---|---|
| Phugoid | 0.206 | 0.035 | 0.2063 | 94.9517 | 3.1176 | 136.9863 |
| Short Period | 2.515 | 0.325 | 2.3784 | 0.8470 | 0.3390 | 1.2219 |

### 2.2.6 Flying Qualities

**Table 5**

| Parameter | Value (units) | FQ level |
|---|---|---|
| Phugoid damping ratio | 0.035 | Level 2 |
| Short Period damping ratio | 0.325 | Level 2 |
| Short Period Natural Frequency | 2.515 | Level 1 |

Weight and Balance Table

| **Component** | **Weight (lbs.)** | **Mass (slugs)** | **Distance from leading edge (ft.)** | **Assumption** | **Iyy** $slugs \cdot ft^2$ | **Moment** $lbs \cdot ft$ |
|---|---|---|---|---|---|---|
| Fuselage | 1000 | 31.0809970783863 | 4.325 | Thin Cylinder Radius 3.5 ft, length 41 ft. | 5030.50470359089 | 4325 |
| Wing | 1550 | 48.1755454714987 | 1.2 | Thin flat plate, width 6.5 ft | 169.618066347568 | 1860 |
| H-Tail | 165 | 5.12836451793374 | 28.625 | Point Mass | 4202.13380757755 | 4723.125 |
| V-Tail | 200 | 6.21619941567726 | 30.325 | Point Mass | 5716.45194877852 | 6065 |
| Fuel Tanks | 150 | 4.66214956175794 | 1.2 | Thin rod, length 8ft. | 24.864797662709 | 180 |
| Engines | 800 | 24.864797662709 | -2.175 | Point Mass | 117.626033443153 | -1740 |
| Props | 350 | 10.8783489774352 | -4.175 | Point Mass | 189.616421644806 | -1461.25 |
| Main Gear | 250 | 7.77024926959657 | 7.325 | Point Mass | 416.917580965997 | 1831.25 |
| Nose Gear | 150 | 4.66214956175794 | -10.175 | Point Mass | 482.675257972276 | -1526.25 |
| Instruments | 200 | 6.21619941567726 | -2.975 | Point Mass | 55.0172499533785 | -595 |
| Furnishings and Baggage | 1075 | 33.4120718592652 | -0.525 | Thin rod, length 16.5 ft | 758.03638030708 | -564.375 |
| Pilots (2) | 340 | 10.5675390066513 | -7.175 | Point Mass | 544.02351277429 | -2439.5 |
| Hydraulic Fluid | 40 | 1.24323988313545 | -0.675 | Neglect | 0 | -27 |
| Fuel | 2500 | 77.7024926959657 | 1.2 | Thin rod, length 8ft. | 414.413294378484 | 3000 |
| Passengers (19) | 3230 | 100.391620563188 | 6.175 | Thin rod, length 16.5 ft | 2277.63489152732 | 19945.25 |
| Total | 12000 | 372.971964940635 | 2.798 | | 20399.533946924 | 33576.25 |

# 3. Results Discussion

### 3.1 Limitations of our Calculations

Our analysis was conducted using non-empirical methods and with no CFD. This will greatly limit the accuracy of our analysis, but these calculations are a good indicator of how the aircraft will perform at cruise. In order to increase the accuracy of these results, we suggest wind tunnel testing or CFD.

### 3.2 Meaning of Results

In order to determine if an aircraft is statically stable $M_{\alpha} < 0$. In the case of this aircraft $M_{\alpha}$ is -6.821 which means this aircraft is statically stable. This is a good thing because the aircraft will have a tendency to stay trimmed when cruising. For dynamic stability $M_{q} + M_{\alpha dot} < 0$. In our case, $M_{q} + M_{\alpha dot} = - 0.00435$ which means the aircraft will be dynamically stable. This means that if the aircraft is perturbed when it is in equilibrium it will return to a stable state which is a good flight characteristic. The damping ratios of the phugoid and short period are greater than 1 which means the aircraft is overdamped. This is preferred because the system will slowly move towards equilibrium which is preferred for a civilian aircraft. The flying quality level of the aircraft is between 1 and 2 which suggests that the pilot will have to put a little more effort into flying which isn't necessarily a bad thing or a good thing. Our engineers recommend an incidence tail angle of -5 degrees in order to keep the pitching moment coefficient negative and the lift coefficient positive. We want the pitching moment coefficient to be negative in order to keep the aircraft statically stable. The lifting coefficient must be positive for an aircraft if you want to fly. A negative lift coefficient is desirable for cars with aerodynamic surfaces.