EigenValue_Project_PartIV

April 12, 2024

[ ]:
```python
#import packages
import scipy.linalg as scilin
import numpy as np
import json
import pandas as pd
import os
import matplotlib.pyplot as plt
```

[ ]:
```python
#Functions Section

def EigenPrint_TwoMat(A,B):
    C = np.matmul(np.linalg.inv(B),A)
    eigen_vals,eigen_vects = scilin.eig(C)
    id_list = eigen_vals.argsort()[::-1]
    eigen_vals = eigen_vals[id_list]
    eigen_vects = eigen_vects[:,id_list]
    for i in range(len(eigen_vals)):
        print(f'Eigen Value: {eigen_vals[i]}')
    for j in range(len(eigen_vects)):
        print(f'Eigenvector: {eigen_vects[j]}')

def directory_check(directory_name):
    if not os.path.exists(directory_name):
        os.makedirs(directory_name)
        print(f"Directory '{directory_name}' created.")
    else:
        print(f"Directory '{directory_name}' already exists.")
```

[ ]:
```python
#Read in the data from the JSON file
filename_load = "6917_new.json"
base_name = os.path.basename(filename_load).split('.')[0]
directory_check(base_name)
Output_File_Long = base_name +'/'+base_name +"_Eigen_Long.txt"
Output_File_Lat = base_name +'/'+base_name +"_Eigen_Lat.txt"
Output_File_Long_mat = base_name +'/'+base_name +'_Matrices_Long.txt'
Output_File_Lat_mat = base_name +'/'+base_name +'_Matrices_Lat.txt'
J_string = open(filename_load).read()
J_vals = json.loads(J_string)
```

```python
#################  Aircraft Properties  ##################################

#Get the moment information of aircraft
I_xx = J_vals['aircraft']['Ixx[slug-ft^2]']
I_yy = J_vals['aircraft']['Iyy[slug-ft^2]']
I_zz = J_vals['aircraft']['Izz[slug-ft^2]']
I_xy = J_vals['aircraft']['Ixy[slug-ft^2]']
I_xz = J_vals['aircraft']['Ixz[slug-ft^2]']

#Name
#Plane_name = J_vals['aircraft']['name']

#Wing Information
Wing_Area = J_vals['aircraft']['wing_area[ft^2]']
Wing_Span = J_vals['aircraft']['wing_span[ft]']
Wing_MeanChord = Wing_Area/Wing_Span

#aircraft weight
Weight = J_vals['aircraft']['weight[lbf]']

#Launch Energy
#Launch_Energy = J_vals['aircraft']['launch_kinetic_energy[ft-lbf]']

#################  Air Properties  ########################################

#density
Air_Density = J_vals['analysis']['density[slugs/ft^3]']

#################  Aerodynamic Properties  #################################

#CL values
CL_0 = J_vals['aerodynamics']['CL']['0']
CL_alpha = J_vals['aerodynamics']['CL']['alpha']
CL_qbar = J_vals['aerodynamics']['CL']['qbar']
CL_alpha_hat = J_vals['aerodynamics']['CL']['alpha_hat']

#CY values
CY_beta = J_vals['aerodynamics']['CS']['beta']
CY_pbar = J_vals['aerodynamics']['CS']['pbar']
CY_rbar = J_vals['aerodynamics']['CS']['rbar']

#CD values
CD_L0 = J_vals['aerodynamics']['CD']['L0']
CD_L1 = J_vals['aerodynamics']['CD']['L']
CD_L2 = J_vals['aerodynamics']['CD']['L2']
CD_0 = CD_L0 + CD_L1*CL_0+CD_L2*CL_0**2
```

```python
CD_alpha = CD_L1*CL_alpha + 2*CD_L2*CL_0*CL_alpha
CD_qbar = J_vals['aerodynamics']['CD']['qbar']

#Cl Values
Cl_beta = J_vals['aerodynamics']['Cl']['beta']
Cl_pbar = J_vals['aerodynamics']['Cl']['pbar']
Cl_rbar = J_vals['aerodynamics']['Cl']['rbar']

#Cm Values
Cm_0 = J_vals['aerodynamics']['Cm']['0']
Cm_alpha = J_vals['aerodynamics']['Cm']['alpha']
Cm_qbar = J_vals['aerodynamics']['Cm']['qbar']
Cm_alpha_hat = J_vals['aerodynamics']['Cm']['alpha_hat']

#Cn values
Cn_beta = J_vals['aerodynamics']['Cn']['beta']
Cn_pbar = J_vals['aerodynamics']['Cn']['pbar']
Cn_rbar = J_vals['aerodynamics']['Cn']['rbar']

#################  Solved Variables ############################################

#Gravity at location
g = 32.17 #gravity at logan elevation used for design

#Solve for the inital velocity given the launch conditions
#V_0 = np.sqrt(2*Launch_Energy*g/Weight) #Need to check if this is correct,␣
↪don't do this, but we can do this later

#Get V_0 from the CL
V_0 = np.sqrt((Weight)/(0.5*Wing_Area*Air_Density*CL_0))
#V_0 = J_vals['initial']['airspeed[ft/s]']
#CW of aircraft
CW = Weight/(0.5*Wing_Area*Air_Density*V_0**2)

print(f'Velocity: {V_0}')
```

```
Directory '6917_new' already exists.
Velocity: 11.573374411266089
```

[ ]:
```python
#Solving for all the Base Components found in eqs. 10.70-10.76 to then put into␣
↪the matrices in 10.77 and 10.78, all variable must be unitless

#10.70 -10.72 not required because we don't know these variables and this is a␣
↪glider

#10.73
R_gx = (g*Wing_MeanChord)/(2*V_0**2)
```

```
R_gy = (g*Wing_Span)/(2*V_0**2)
#10.74
R_rhox = (4*Weight/g)/(Air_Density*Wing_Area*Wing_MeanChord)
R_rhoy = (4*Weight/g)/(Air_Density*Wing_Area*Wing_Span)
#10.75
R_xx = (8*I_xx)/(Air_Density*Wing_Area*Wing_Span**3)
R_yy = (8*I_yy)/(Air_Density*Wing_Area*Wing_MeanChord**3)
R_zz = (8*I_zz)/(Air_Density*Wing_Area*Wing_Span**3)
R_xz = (8*I_xz)/(Air_Density*Wing_Area*Wing_Span**3)
#10.76
#Not required since there is no thrust given this aircraft is a glider
```

[ ]:

```
#Generating the Matrices, going for the nondimensional form, Longitudinal␣
 ↪Equations
#10.77 B mat is the LHS matrix, A mat is the RHS matrix
A_mat_long = np.zeros([6,6])
B_mat_long = np.identity(6)

#Variables that could be changed, but assumed to be zero
CD_mu = 0
CL_mu_hat = 0
Cm_mu_hat = 0
CD_alpha_hat = 0
alpha_deg = 0
alpha_rad = alpha_deg*np.pi/180
#Fill in the A Matrix given what is known
    #Single Row
A_mat_long[0,0] = -2*CD_0 #+ CT_V*np.cos(alpha_rad)
A_mat_long[0,1] = CL_0-CD_alpha
A_mat_long[0,2] = -CD_qbar
A_mat_long[0,5] = -R_rhox*R_gx*np.cos(alpha_rad)
    #Second Row
A_mat_long[1,0] = -2*CL_0 #+ CT_V*np.sin(alpha_rad)
A_mat_long[1,1] = -CL_alpha-CD_0  #Variable is not correct currently, CD_0 is␣
 ↪not correct
A_mat_long[1,2] = -CL_qbar+R_rhox
A_mat_long[1,5] = -R_rhox*R_gx*np.sin(alpha_rad)
    #Third Row
A_mat_long[2,0] = 2*Cm_0
A_mat_long[2,1] = Cm_alpha
A_mat_long[2,2] = Cm_qbar
    #Fourth Row
A_mat_long[3,0] = np.cos(alpha_rad)
A_mat_long[3,1] = np.sin(alpha_rad)
A_mat_long[3,5] = -np.sin(alpha_rad)
    #Fifth Row
A_mat_long[4,0] = -np.sin(alpha_rad)
```

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A_mat_long[4,1] = np.cos(alpha_rad)
A_mat_long[4,5] = -np.cos(alpha_rad)
    #Sixth Row
A_mat_long[5,2] = 1

#Fill in the B Matrix given what is known
B_mat_long[0,0] = R_rhox+CD_mu
B_mat_long[0,1] = CD_alpha_hat
B_mat_long[1,0] = CL_mu_hat
B_mat_long[1,1] = R_rhox+CL_alpha_hat
B_mat_long[2,0] = -Cm_mu_hat
B_mat_long[2,1] = -Cm_alpha_hat
B_mat_long[2,2] = R_yy

#Create a New matrix using the A and B matrix to do the Eigen value solve

C_mat_long = np.matmul(np.linalg.inv(B_mat_long),A_mat_long)

#Generating the Matrices, going for the nondimensional form, Lateral Equations
#10.77 B mat is the LHS matrix, A mat is the RHS matrix
A_mat_lat = np.zeros([6,6])
B_mat_lat = np.identity(6)

#Variables that could be changed, but assumed to be zero
CD_mu = 0
CL_mu_hat = 0
Cm_mu_hat = 0
CD_alpha_hat = 0
alpha_deg = 0
alpha_rad = alpha_deg*np.pi/180
#Fill in the A Matrix given what is known
    #Single Row
A_mat_lat[0,0] = CY_beta
A_mat_lat[0,1] = CY_pbar
A_mat_lat[0,2] = (CY_rbar-R_rhoy)
A_mat_lat[0,4] = R_rhoy*R_gy*np.cos(alpha_rad)
    #Second Row
A_mat_lat[1,0] = Cl_beta
A_mat_lat[1,1] = Cl_pbar
A_mat_lat[1,2] = Cl_rbar
    #Third Row
A_mat_lat[2,0] = Cn_beta
A_mat_lat[2,1] = Cn_pbar
A_mat_lat[2,2] = Cn_rbar
    #Fourth Row
A_mat_lat[3,0] = 1
A_mat_lat[3,5] = np.cos(alpha_rad)
```

```
    #Fifth Row
A_mat_lat[4,1] = 1
A_mat_lat[4,2] = np.tan(alpha_rad)
    #Sixth Row
A_mat_lat[5,2] = 1/np.cos(alpha_rad)

#Fill in the B Matrix given what is known
B_mat_lat[0,0] = R_rhoy
B_mat_lat[1,1] = R_xx
B_mat_lat[1,2] = -R_xz
B_mat_lat[2,1] = -R_xz
B_mat_lat[2,2] = R_zz

#Create a New matrix using the A and B matrix to do the Eigen value solve

C_mat_lat = np.matmul(np.linalg.inv(B_mat_lat),A_mat_lat)

#pd.DataFrame(C_mat_lat).head(6)
```

```
[ ]: #Getting the actual Eigenvalues and Eigenvectors

eigen_vals_long,eigen_vects_long = scilin.eig(C_mat_long)


# Print eigenvalues and eigenvectors
print("Eigenvalues:")
for i, val in enumerate(eigen_vals_long):
    print(f"Eigenvalue {i + 1}: {val.real:.4f} + {val.imag:.4f}j")

print("\nEigenvectors:")
for i in range(2,len(eigen_vects_long)):
    print(f"Eigenvector {i + 1}:")
    for j in range(len(eigen_vects_long)):
        print(f"   {eigen_vects_long[j, i].real:.4f} + {eigen_vects_long[j, i].
 ↪imag:.4f}j")

        #Getting the actual Eigenvalues and Eigenvectors

eigen_vals_lat,eigen_vects_lat = scilin.eig(C_mat_lat)


# Print eigenvalues and eigenvectors
print("Eigenvalues:")
for i, val in enumerate(eigen_vals_lat):
    print(f"Eigenvalue {i + 1}: {val.real:.4f} + {val.imag:.4f}j")

print("\nEigenvectors:")
```

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for i in range(2,len(eigen_vects_lat)):
    print(f"Eigenvector {i + 1}:")
    for j in range(len(eigen_vects_lat)):
        print(f"   {eigen_vects_lat[j, i].real:.4f} + {eigen_vects_lat[j, i].
 ↪imag:.4f}j")
```

```
Eigenvalues:
Eigenvalue 1: 0.0000 + 0.0000j
Eigenvalue 2: 0.0000 + 0.0000j
Eigenvalue 3: -0.3674 + 0.0000j
Eigenvalue 4: -0.1223 + 0.0000j
Eigenvalue 5: -0.0019 + 0.0323j
Eigenvalue 6: -0.0019 + -0.0323j

Eigenvectors:
Eigenvector 3:
   -0.0440 + 0.0000j
   0.3315 + 0.0000j
   0.0044 + 0.0000j
   0.1198 + 0.0000j
   -0.9347 + 0.0000j
   -0.0119 + 0.0000j
Eigenvector 4:
   0.0512 + 0.0000j
   -0.0501 + 0.0000j
   -0.0074 + 0.0000j
   -0.4186 + 0.0000j
   0.9033 + 0.0000j
   0.0604 + 0.0000j
Eigenvector 5:
   0.0017 + -0.0287j
   -0.0003 + 0.0074j
   -0.0001 + -0.0005j
   -0.8886 + 0.0000j
   0.0318 + -0.4563j
   -0.0150 + 0.0055j
Eigenvector 6:
   0.0017 + 0.0287j
   -0.0003 + -0.0074j
   -0.0001 + 0.0005j
   -0.8886 + -0.0000j
   0.0318 + 0.4563j
   -0.0150 + -0.0055j
Eigenvalues:
Eigenvalue 1: 0.0000 + 0.0000j
Eigenvalue 2: 0.0000 + 0.0000j
Eigenvalue 3: -34.5173 + 0.0000j
Eigenvalue 4: -0.8185 + 0.0000j
```

```
Eigenvalue 5: -0.4256 + 0.7548j
Eigenvalue 6: -0.4256 + -0.7548j

Eigenvectors:
Eigenvector 3:
   -0.0303 + 0.0000j
   -0.9984 + 0.0000j
   0.0388 + 0.0000j
   0.0009 + 0.0000j
   0.0289 + 0.0000j
   -0.0011 + 0.0000j
Eigenvector 4:
   -0.3738 + 0.0000j
   0.0869 + 0.0000j
   -0.5380 + 0.0000j
   -0.3464 + 0.0000j
   -0.1062 + 0.0000j
   0.6573 + 0.0000j
Eigenvector 5:
   0.6593 + 0.0000j
   -0.2947 + -0.0147j
   0.1036 + -0.1264j
   -0.3011 + -0.4575j
   0.1523 + 0.3046j
   -0.1858 + -0.0325j
Eigenvector 6:
   0.6593 + -0.0000j
   -0.2947 + 0.0147j
   0.1036 + 0.1264j
   -0.3011 + 0.4575j
   0.1523 + -0.3046j
   -0.1858 + 0.0325j
```

[ ]:

```
#Get the amplitude and phase of each component as a numpy array from the␣
↪eigenvectors

#long amp and phase matrices
amplitude_long = np.zeros_like(eigen_vects_long)
phase_long = np.zeros_like(eigen_vects_long)
#loop through columns
for j in range(eigen_vects_long.shape[0]):
    #loop through rows
    for i in range(eigen_vects_long.shape[1]):
        amplitude_long[i,j] = np.sqrt(eigen_vects_long[i,j].real**2 +␣
↪eigen_vects_long[i,j].imag**2)
        phase_long[i,j] = np.arctan2(eigen_vects_long[i,j].
↪imag,eigen_vects_long[i,j].real)*(180/np.pi)
```

```
#Lateral amp and phase matrices
amplitude_lat = np.zeros_like(eigen_vects_lat)
phase_lat = np.zeros_like(eigen_vects_lat)
#loop through columns
for j in range(eigen_vects_lat.shape[0]):
     #loop through rows
     for i in range(eigen_vects_lat.shape[1]):
          amplitude_lat[i,j] = np.sqrt(eigen_vects_lat[i,j].real**2 +␣
 ↪eigen_vects_lat[i,j].imag**2)
          phase_lat[i,j] = np.arctan2(eigen_vects_lat[i,j].
 ↪imag,eigen_vects_lat[i,j].real)*(180/np.pi)
```

[ ]:
```
#Going through the damping rate

variable_symbols_lat = ['Δ ', 'Δp_bar', 'Δr_bar', 'Δ _y', 'ΔΦ', 'Δ ']
variable_symbols_long = ['Δ ', 'Δ ', 'Δq_bar', 'Δ _x', 'Δ _z', 'ΔΘ']


for z in range(len(eigen_vals_long)):
    i = eigen_vals_long[z]
   ␣
 ↪print(f'--------------------------------------------------------------------------------')
    print(f'Dimensionless Eigen Value: {i.real:8.6f}+{i.imag:12.8f}j')
    sigma = -i.real
    #Rigid Body mode
    if i.real == 0:
        print('\t Rigid Body Mode: Eigen Value: 0 ')
        print('\t No analysis required currently\n')
    #Convergent Modes Sigma > 0
    if sigma > 0:
        #Damping rate
        Damp_rate = sigma*2*V_0/Wing_MeanChord
        #99 Damping Time
        Damp_time_99 = np.log(0.01)/-Damp_rate
        #Damped natural frequency and Period
        if i.imag != 0:
            W_d = abs(i.imag)*2*V_0/Wing_MeanChord
            Period = (2*np.pi)/W_d
            #Damping Ratio
            Damp_Ratio =   -i.real/(np.sqrt(i.real**2 + i.imag**2))

        print(f'\t Damping Rate [1/s]: {Damp_rate:12.6f}')
        print(f'\t 99% Damping Time [s]: {Damp_time_99:12.6f}')
        if i.imag != 0:
            print(f'\t Damped Nat Freq: {W_d:12.6f}')
            print(f'\t Period: {Period:12.6f}')
```

```python
            print(f'\t Damping Ratio: {Damp_Ratio:12.6f}')
        print('')
    #Divergent Modes Sigma < 0
    if sigma < 0:
    #Damping rate
        Damp_rate = sigma*2*V_0/Wing_MeanChord
        #99 Damping Time
        Double_time = np.log(2.00)/-Damp_rate
        #Damped natural frequency and Period
        if i.imag != 0:
            W_d = abs(i.imag)*2*V_0/Wing_MeanChord
            Period = (2*np.pi)/W_d
            #Damping Ratio
            Damp_Ratio =   -i.real/(np.sqrt(i.real**2 + i.imag**2))

        print(f'\t Damping Rate [1/s]: {Damp_rate:12.6f}')
        print(f'\t Doubling Time [s]: {Double_time:12.6f}')
        if i.imag != 0:
            print(f'\t Damped Nat Freq: {W_d:12.6f}')
            print(f'\t Period: {Period:12.6f}')
            print(f'\t Damping Ratio: {Damp_Ratio:12.6f}')
        print('')

    #Print the Eigen Vector
    print(f'-------------------------------------------------------------------------------')
    print(f'{"Variable":<15} {"Real Part":<15} {"Imaginary Part":<20} {"Amplitude":<15} {"Phase":<15}')
    eigen_vects_long = np.asarray(eigen_vects_long)
    for j in range(6):
        real = eigen_vects_long[j,z].real
        imag = eigen_vects_long[j,z].imag
        amp = amplitude_long[j,z].real
        phase_deg = phase_long[j,z].real
        symbol = variable_symbols_long[j]
        print(f'{symbol:<15} {real:<15.6f} {imag:<20.6f} {amp:<15.6f} {phase_deg:<15.6f}')
    print(f'-------------------------------------------------------------------------------')
```

```
-------------------------------------------------------------------------------
Dimensionless Eigen Value: 0.000000+  0.00000000j
         Rigid Body Mode: Eigen Value: 0
         No analysis required currently

-------------------------------------------------------------------------------
Variable        Real Part       Imaginary Part       Amplitude       Phase
```

```
Δ              0.000000        0.000000             0.000000        0.000000
Δ              0.000000        0.000000             0.000000        0.000000
Δq_bar          0.000000        0.000000             0.000000        0.000000
Δ _x           1.000000        0.000000             1.000000        0.000000
Δ _z           0.000000        0.000000             0.000000        0.000000
ΔΘ              0.000000        0.000000             0.000000        0.000000
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
Dimensionless Eigen Value: 0.000000+  0.00000000j
         Rigid Body Mode: Eigen Value: 0
         No analysis required currently

-------------------------------------------------------------------------------
Variable        Real Part       Imaginary Part       Amplitude       Phase
Δ              0.000000        0.000000             0.000000        0.000000
Δ              0.000000        0.000000             0.000000        0.000000
Δq_bar          0.000000        0.000000             0.000000        0.000000
Δ _x           0.000000        0.000000             0.000000        0.000000
Δ _z           1.000000        0.000000             1.000000        0.000000
ΔΘ              0.000000        0.000000             0.000000        0.000000
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
Dimensionless Eigen Value: -0.367433+  0.00000000j
         Damping Rate [1/s]:    16.199771
         99% Damping Time [s]:     0.284274

-------------------------------------------------------------------------------
Variable        Real Part       Imaginary Part       Amplitude       Phase
Δ              -0.044019       0.000000             0.044019        180.000000
Δ              0.331499        0.000000             0.331499        0.000000
Δq_bar          0.004387        0.000000             0.004387        0.000000
Δ _x           0.119802        0.000000             0.119802        0.000000
Δ _z           -0.934696       0.000000             0.934696        180.000000
ΔΘ              -0.011939       0.000000             0.011939        180.000000
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
Dimensionless Eigen Value: -0.122344+  0.00000000j
         Damping Rate [1/s]:     5.394041
         99% Damping Time [s]:     0.853751

-------------------------------------------------------------------------------
Variable        Real Part       Imaginary Part       Amplitude       Phase
Δ              0.051212        0.000000             0.051212        0.000000
Δ              -0.050107       0.000000             0.050107        180.000000
Δq_bar          -0.007390       0.000000             0.007390        180.000000
Δ _x           -0.418588       0.000000             0.418588        180.000000
Δ _z           0.903298        0.000000             0.903298        0.000000
ΔΘ              0.060407        0.000000             0.060407        0.000000
```

```
--------------------------------------------------------------------------------
--------------------------------------------------------------------------------
Dimensionless Eigen Value: -0.001947+  0.03233351j
         Damping Rate [1/s]:     0.085822
         99% Damping Time [s]:    53.659487
         Damped Nat Freq:     1.425554
         Period:     4.407540
         Damping Ratio:     0.060094

--------------------------------------------------------------------------------
Variable        Real Part       Imaginary Part       Amplitude       Phase
Δ               0.001730        -0.028733            0.028785        -86.554800
Δ               -0.000306       0.007426             0.007432        92.355894
Δq_bar           -0.000149       -0.000496            0.000518        -106.728901
Δ _x            -0.888634       0.000000             0.888634        180.000000
Δ _z            0.031786        -0.456267            0.457372        -86.014944
ΔΘ               -0.014996       0.005510             0.015977        159.825900
--------------------------------------------------------------------------------
--------------------------------------------------------------------------------
Dimensionless Eigen Value: -0.001947+ -0.03233351j
         Damping Rate [1/s]:     0.085822
         99% Damping Time [s]:    53.659487
         Damped Nat Freq:     1.425554
         Period:     4.407540
         Damping Ratio:     0.060094

--------------------------------------------------------------------------------
Variable        Real Part       Imaginary Part       Amplitude       Phase
Δ               0.001730        0.028733             0.028785        86.554800
Δ               -0.000306       -0.007426            0.007432        -92.355894
Δq_bar           -0.000149       0.000496             0.000518        106.728901
Δ _x            -0.888634       -0.000000            0.888634        -180.000000
Δ _z            0.031786        0.456267             0.457372        86.014944
ΔΘ               -0.014996       -0.005510            0.015977        -159.825900
--------------------------------------------------------------------------------
```

[ ]:
```python
#Going through the damping rate for lateral mode

for z in range(len(eigen_vals_lat)):
    i = eigen_vals_lat[z]
    print(f'--------------------------------------------------------------------------------')
    print(f'Dimensionless Eigen Value: {i.real:8.6f}+{i.imag:12.8f}j')
    sigma = -i.real
    #Rigid Body mode
    if i.real == 0:
        print('\t Rigid Body Mode: Eigen Value: 0 ')
```

```
        print('\t No analysis required currently\n')
    #Convergent Modes Sigma > 0
    if sigma > 0:
        #Damping rate
        Damp_rate = sigma*2*V_0/Wing_Span
        #99 Damping Time
        Damp_time_99 = np.log(0.01)/-Damp_rate
        #Damped natural frequency and Period
        if i.imag != 0:
            W_d = abs(i.imag)*2*V_0/Wing_Span
            Period = (2*np.pi)/W_d
            #Damping Ratio
            Damp_Ratio =   -i.real/(np.sqrt(i.real**2 + i.imag**2))

        print(f'\t Damping Rate [1/s]: {Damp_rate:12.6f}')
        print(f'\t 99% Damping Time [s]: {Damp_time_99:12.6f}')
        if i.imag != 0:
            print(f'\t Damped Nat Freq: {W_d:12.6f}')
            print(f'\t Period: {Period:12.6f}')
            print(f'\t Damping Ratio: {Damp_Ratio:12.6f}')
        print('')
    #Divergent Modes Sigma < 0
    if sigma < 0:
    #Damping rate
        Damp_rate = sigma*2*V_0/Wing_Span
        #99 Damping Time
        Double_time = np.log(2.00)/-Damp_rate
        #Damped natural frequency and Period
        if i.imag != 0:
            W_d = abs(i.imag)*2*V_0/Wing_Span
            Period = (2*np.pi)/W_d
            #Damping Ratio
            Damp_Ratio =   -i.real/(np.sqrt(i.real**2 + i.imag**2))

        print(f'\t Damping Rate [1/s]: {Damp_rate:12.6f}')
        print(f'\t Doubling Time [s]: {Double_time:12.6f}')
        if i.imag != 0:
            print(f'\t Damped Nat Freq: {W_d:12.6f}')
            print(f'\t Period: {Period:12.6f}')
            print(f'\t Damping Ratio: {Damp_Ratio:12.6f}')
        print('')

    #Print the Eigen Vector
 ␣
↪print(f'--------------------------------------------------------------------------------')
    print(f'{"Variable":<15} {"Real Part":<15} {"Imaginary Part":<20}␣
↪{"Amplitude":<15} {"Phase":<15}')
```

```
    eigen_vects_lat = np.asarray(eigen_vects_lat)
    for j in range(6):
        real = eigen_vects_lat[j,z].real
        imag = eigen_vects_lat[j,z].imag
        amp = amplitude_lat[j,z].real
        phase_deg = phase_lat[j,z].real
        symbol = variable_symbols_lat[j]
        print(f'{symbol:<15} {real:<15.6f} {imag:<20.6f} {amp:<15.6f}␣
↪{phase_deg:<15.6f}')
  ␣
↪print(f'--------------------------------------------------------------------------------')
```

```
--------------------------------------------------------------------------------
Dimensionless Eigen Value: 0.000000+  0.00000000j
         Rigid Body Mode: Eigen Value: 0
         No analysis required currently

--------------------------------------------------------------------------------
Variable        Real Part       Imaginary Part       Amplitude       Phase
Δ              0.000000        0.000000            0.000000        0.000000
Δp_bar          0.000000        0.000000            0.000000        0.000000
Δr_bar          0.000000        0.000000            0.000000        0.000000
Δ _y           1.000000        0.000000            1.000000        0.000000
ΔΦ              0.000000        0.000000            0.000000        0.000000
Δ              0.000000        0.000000            0.000000        0.000000
--------------------------------------------------------------------------------
--------------------------------------------------------------------------------
Dimensionless Eigen Value: 0.000000+  0.00000000j
         Rigid Body Mode: Eigen Value: 0
         No analysis required currently

--------------------------------------------------------------------------------
Variable        Real Part       Imaginary Part       Amplitude       Phase
Δ              0.000000        0.000000            0.000000        0.000000
Δp_bar          0.000000        0.000000            0.000000        0.000000
Δr_bar          0.000000        0.000000            0.000000        0.000000
Δ _y           -1.000000       0.000000            1.000000        180.000000
ΔΦ              0.000000        0.000000            0.000000        0.000000
Δ              0.000000        0.000000            0.000000        0.000000
--------------------------------------------------------------------------------
--------------------------------------------------------------------------------
Dimensionless Eigen Value: -34.517298+  0.00000000j
         Damping Rate [1/s]:    63.917059
         99% Damping Time [s]:     0.072049
```

```
--------------------------------------------------------------------------------
Variable        Real Part       Imaginary Part      Amplitude       Phase
Δ              -0.030333       0.000000            0.030333        180.000000
Δp_bar          -0.998368       0.000000            0.998368        180.000000
Δr_bar          0.038768        0.000000            0.038768        0.000000
Δ _y           0.000911        0.000000            0.000911        0.000000
ΔΦ              0.028924        0.000000            0.028924        0.000000
Δ              -0.001123       0.000000            0.001123        180.000000
--------------------------------------------------------------------------------
--------------------------------------------------------------------------------
Dimensionless Eigen Value: -0.818540+  0.00000000j
         Damping Rate [1/s]:     1.515724
         99% Damping Time [s]:     3.038265

--------------------------------------------------------------------------------
Variable        Real Part       Imaginary Part      Amplitude       Phase
Δ              -0.373762       0.000000            0.373762        180.000000
Δp_bar          0.086944        0.000000            0.086944        0.000000
Δr_bar          -0.538015       0.000000            0.538015        180.000000
Δ _y           -0.346377       0.000000            0.346377        180.000000
ΔΦ              -0.106218       0.000000            0.106218        180.000000
Δ              0.657285        0.000000            0.657285        0.000000
--------------------------------------------------------------------------------
--------------------------------------------------------------------------------
Dimensionless Eigen Value: -0.425593+  0.75475346j
         Damping Rate [1/s]:     0.788088
         99% Damping Time [s]:     5.843473
         Damped Nat Freq:     1.397607
         Period:     4.495674
         Damping Ratio:     0.491177

--------------------------------------------------------------------------------
Variable        Real Part       Imaginary Part      Amplitude       Phase
Δ              0.659280        0.000000            0.659280        0.000000
Δp_bar          -0.294734       -0.014701           0.295100        -177.144517
Δr_bar          0.103626        -0.126428           0.163470        -50.660266
Δ _y           -0.301057       -0.457519           0.547685        -123.345749
ΔΦ              0.152296        0.304626            0.340575        63.437539
Δ              -0.185839       -0.032507           0.188660        -170.078211
--------------------------------------------------------------------------------
--------------------------------------------------------------------------------
Dimensionless Eigen Value: -0.425593+ -0.75475346j
         Damping Rate [1/s]:     0.788088
         99% Damping Time [s]:     5.843473
         Damped Nat Freq:     1.397607
         Period:     4.495674
         Damping Ratio:     0.491177
```

```
--------------------------------------------------------------------------------
Variable          Real Part        Imaginary Part       Amplitude        Phase
Δ                 0.659280         -0.000000            0.659280         -0.000000
Δp_bar            -0.294734        0.014701             0.295100         177.144517
Δr_bar            0.103626         0.126428             0.163470         50.660266
Δ _y              -0.301057        0.457519             0.547685         123.345749
ΔΦ                0.152296         -0.304626            0.340575         -63.437539
Δ                 -0.185839        0.032507             0.188660         170.078211
--------------------------------------------------------------------------------
```

[ ]:

```python
#Longitude write file to txt to use

def write_info_file_long(output_file, eigen_vals, eigen_vects, amplitude,␣
↪phase, V_0, Wing_MeanChord):
    # Define the variable symbols list manually
    variable_symbols_long = ['Δ ', 'Δ ', 'Δq_bar', 'Δ _x', 'Δ _z', 'Δθ']

    # Open the output file for writing with UTF-8 encoding
    with open(output_file, 'w', encoding='utf-8') as file:
        file.
↪write('--------------------------------------------------------------------------------\n')
        file.write('Linearized Longitudinal Equation Results \n')
        for z in range(len(eigen_vals)):
            i = eigen_vals[z]
            file.
↪write('--------------------------------------------------------------------------------\n')
            file.write(f'Dimensionless Eigen Value: {i.real:8.6f}+{i.imag:12.
↪8f}j\n')
            sigma = -i.real
            # Rigid Body mode
            if i.real == 0:
                file.write('\t Rigid Body Mode: Eigen Value: 0 \n')
                file.write('\t No analysis required currently\n\n')
            # Convergent Modes Sigma > 0
            if sigma > 0:
                # Damping rate
                Damp_rate = sigma*2*V_0/Wing_MeanChord
                # 99 Damping Time
                Damp_time_99 = np.log(0.01)/-Damp_rate
                # Damped natural frequency and Period
                if i.imag != 0:
                    W_d = abs(i.imag)*2*V_0/Wing_MeanChord
                    Period = (2*np.pi)/W_d
                    #Damping Ratio
                    Damp_Ratio =   -i.real/(np.sqrt(i.real**2 + i.imag**2))
                file.write(f'\t Damping Rate [1/s]: {Damp_rate:12.6f}\n')
                file.write(f'\t 99% Damping Time [s]: {Damp_time_99:12.6f}\n')
```

```
                if i.imag != 0:
                    file.write(f'\t Damped Nat Freq: {W_d:12.6f}\n')
                    file.write(f'\t Period: {Period:12.6f}\n')
                    file.write(f'\t Damping Ratio: {Damp_Ratio:12.6f}\n\n')
            # Divergent Modes Sigma < 0
            if sigma < 0:
                # Damping rate
                Damp_rate = sigma*2*V_0/Wing_MeanChord
                # 99 Damping Time
                Double_time = np.log(2.00)/-Damp_rate
                # Damped natural frequency and Period
                if i.imag != 0:
                    W_d = abs(i.imag)*2*V_0/Wing_MeanChord
                    Period = (2*np.pi)/W_d
                    #Damping Ratio
                    Damp_Ratio =   -i.real/(np.sqrt(i.real**2 + i.imag**2))
                file.write(f'\t Damping Rate [1/s]: {Damp_rate:12.6f}\n')
                file.write(f'\t Doubling Time [s]: {Double_time:12.6f}\n')
                if i.imag != 0:
                    file.write(f'\t Damped Nat Freq: {W_d:12.6f}\n')
                    file.write(f'\t Period: {Period:12.6f}\n')
                    file.write(f'\t Damping Ratio: {Damp_Ratio:12.6f}\n\n')
            # Print the Eigen Vector
            file.
 ↪write('--------------------------------------------------------------------------------\n')
            file.write(f'{"Variable":<15} {"Real Part":<15} {"Imaginary Part":
 ↪<20} {"Amplitude":<15} {"Phase":<15}\n')
            eigen_vects = np.asarray(eigen_vects)
            for j in range(6):
                real = eigen_vects[j,z].real
                imag = eigen_vects[j,z].imag
                amp = amplitude[j,z].real
                phase_deg = phase[j,z].real
                symbol = variable_symbols_long[j]
                file.write(f'{symbol:<15} {real:<15.6f} {imag:<20.6f} {amp:<15.
 ↪6f} {phase_deg:<15.6f}\n')
            file.
 ↪write('--------------------------------------------------------------------------------\n')


#Lateral write file to txt to use

def write_info_file_lat(output_file, eigen_vals, eigen_vects, amplitude, phase,␣
 ↪V_0, Wing_Span):
    # Define the variable symbols list manually
    variable_symbols_long = ['Δ ', 'Δ ', 'Δq_bar', 'Δ _x', 'Δ _z', 'Δθ']
```

```
    # Open the output file for writing with UTF-8 encoding
    with open(output_file, 'w', encoding='utf-8') as file:
        file.
↪write('--------------------------------------------------------------------------------\n')
        file.write('Linearized Lateral Equation Results \n')
        for z in range(len(eigen_vals)):
            i = eigen_vals[z]
            file.
↪write('--------------------------------------------------------------------------------\n')
            file.write(f'Dimensionless Eigen Value: {i.real:8.6f}+{i.imag:12.
↪8f}j\n')
            sigma = -i.real
            # Rigid Body mode
            if i.real == 0:
                file.write('\t Rigid Body Mode: Eigen Value: 0 \n')
                file.write('\t No analysis required currently\n\n')
            # Convergent Modes Sigma > 0
            if sigma > 0:
                # Damping rate
                Damp_rate = sigma*2*V_0/Wing_Span
                # 99 Damping Time
                Damp_time_99 = np.log(0.01)/-Damp_rate
                # Damped natural frequency and Period
                if i.imag != 0:
                    W_d = abs(i.imag)*2*V_0/Wing_Span
                    Period = (2*np.pi)/W_d
                    #Damping Ratio
                    Damp_Ratio =   -i.real/(np.sqrt(i.real**2 + i.imag**2))
                file.write(f'\t Damping Rate [1/s]: {Damp_rate:12.6f}\n')
                file.write(f'\t 99% Damping Time [s]: {Damp_time_99:12.6f}\n')
                if i.imag != 0:
                    file.write(f'\t Damped Nat Freq: {W_d:12.6f}\n')
                    file.write(f'\t Period: {Period:12.6f}\n')
                    file.write(f'\t Damping Ratio: {Damp_Ratio:12.6f}\n\n')
            # Divergent Modes Sigma < 0
            if sigma < 0:
                # Damping rate
                Damp_rate = sigma*2*V_0/Wing_Span
                # 99 Damping Time
                Double_time = np.log(2.00)/-Damp_rate
                # Damped natural frequency and Period
                if i.imag != 0:
                    W_d = abs(i.imag)*2*V_0/Wing_Span
                    Period = (2*np.pi)/W_d
                    #Damping Ratio
                    Damp_Ratio =   -i.real/(np.sqrt(i.real**2 + i.imag**2))
                file.write(f'\t Damping Rate [1/s]: {Damp_rate:12.6f}\n')
```

```
                file.write(f'\t Doubling Time [s]: {Double_time:12.6f}\n')
                if i.imag != 0:
                    file.write(f'\t Damped Nat Freq: {W_d:12.6f}\n')
                    file.write(f'\t Period: {Period:12.6f}\n')
                    file.write(f'\t Damping Ratio: {Damp_Ratio:12.6f}\n\n')

            # Print the Eigen Vector
            file.
↪write('-------------------------------------------------------------------------------\n')
            file.write(f'{"Variable":<15} {"Real Part":<15} {"Imaginary Part":
↪<20} {"Amplitude":<15} {"Phase":<15}\n')
            eigen_vects = np.asarray(eigen_vects)
            for j in range(6):
                real = eigen_vects[j,z].real
                imag = eigen_vects[j,z].imag
                amp = amplitude[j,z].real
                phase_deg = phase[j,z].real
                symbol = variable_symbols_lat[j]
                file.write(f'{symbol:<15} {real:<15.6f} {imag:<20.6f} {amp:<15.
↪6f} {phase_deg:<15.6f}\n')
            file.
↪write('-------------------------------------------------------------------------------\n')
```

[ ]:
```
# Write the results to a file
write_info_file_lat(Output_File_Lat,eigen_vals_lat,eigen_vects_lat,amplitude_lat,phase_lat,V_C
write_info_file_long(Output_File_Long,eigen_vals_long,eigen_vects_long,amplitude_long,phase_lo
```

[ ]:
```
def mat_to_file(matrix_A, matrix_B, matrix_C, file_name, Mode_type=str):
    with open(file_name, 'w') as file:
        file.
↪write('---------------------------------------------------------\n')
        file.write(f'{Mode_type} A and B matrix Results:\n')
        file.
↪write('---------------------------------------------------------\n')
        file.write("Matrix A:\n")
        file.
↪write('---------------------------------------------------------\n')
        for row in matrix_A:
            formatted_row = ["{:12.7f}".format(element) for element in row]
            file.write(" ".join(formatted_row) + '\n')

        file.
↪write('---------------------------------------------------------\n')
        file.write("Matrix B:\n")
        file.
↪write('---------------------------------------------------------\n')
```

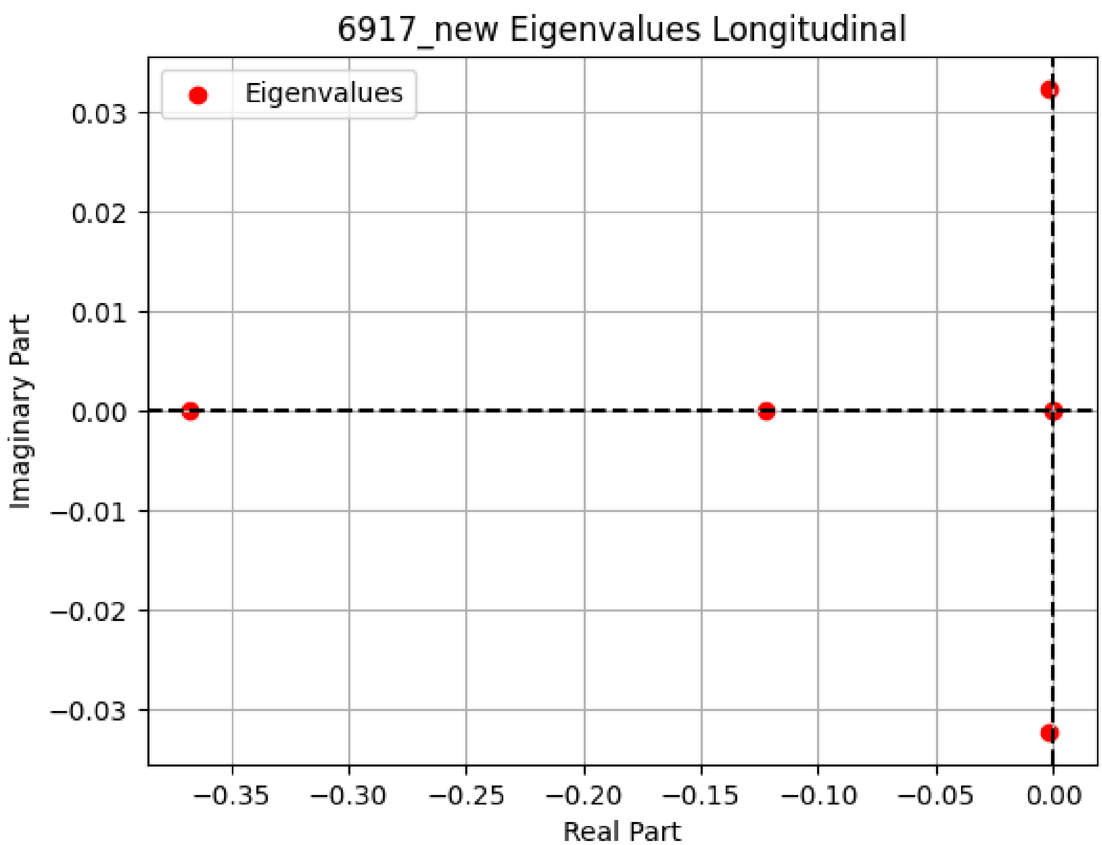
```
        for row in matrix_B:
            formatted_row = ["{:12.7f}".format(element) for element in row]
            file.write(" ".join(formatted_row) + '\n')

        file.
↪write('---------------------------------------------------------\n')
        file.write("Matrix C:\n")
        file.
↪write('---------------------------------------------------------\n')
        for row in matrix_C:
            formatted_row = ["{:12.7f}".format(element) for element in row]
            file.write(" ".join(formatted_row) + '\n')
```

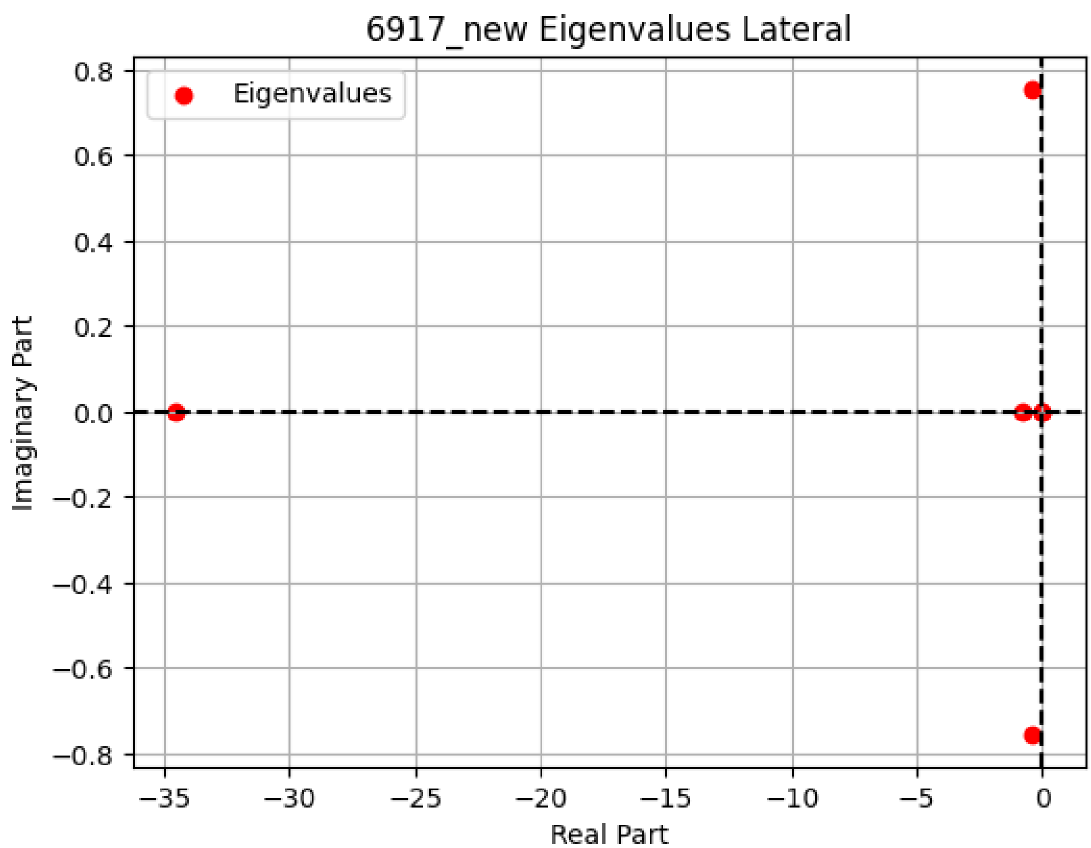
[ ]:
```
#Write the matrices to a file, long is one file lat is another file should have␣
↪the long matrices

mat_to_file(A_mat_long,B_mat_long,C_mat_long,Output_File_Long_mat,"Longitudinal")
mat_to_file(A_mat_lat,B_mat_lat,C_mat_lat,Output_File_Lat_mat,"Lateral")
```

[ ]:
```
#Creating the EigenValuePlots
print(eigen_vals_long)
print(eigen_vals_lat)
#Eigenvals #needs to be dimensional eigenvalues for plot, shows more
long_real = [val.real for val in eigen_vals_long]
long_imag = [val.imag for val in eigen_vals_long]
lat_real =[val.real for val in eigen_vals_lat]
lat_imag = [val.imag for val in eigen_vals_lat]

#Longitudinal

Long_plot = plt.figure()
plt.scatter(long_real,long_imag,color='red',label='Eigenvalues')
plt.axhline(0, color='black', linestyle='--')
plt.axvline(0, color='black', linestyle='--')
plt.xlabel('Real Part')
plt.ylabel('Imaginary Part')
plt.title(f'{base_name} Eigenvalues Longitudinal')
plt.legend()
plt.grid(True)
Long_plot.savefig(f'{base_name}/Long_Eig_plot.png',dpi=200)
plt.show()

#Lateral

Lat_plot = plt.figure()
plt.scatter(lat_real,lat_imag,color='red',label='Eigenvalues')
plt.axhline(0, color='black', linestyle='--')
```

```
plt.axvline(0, color='black', linestyle='--')
plt.xlabel('Real Part')
plt.ylabel('Imaginary Part')
plt.title(f'{base_name} Eigenvalues Lateral')
plt.legend()
plt.grid(True)
Lat_plot.savefig(f'{base_name}/Lat_Eig_plot.png',dpi=200)
plt.show()
```

```
[ 0.          +0.j           0.          +0.j          -0.36743301+0.j
 -0.12234424+0.j          -0.00194656+0.03233351j -0.00194656-0.03233351j]
[  0.          +0.j             0.          +0.j
 -34.51729821+0.j            -0.81854038+0.j
  -0.42559321+0.75475346j  -0.42559321-0.75475346j]
```






```
[ ]: #Approximations of the Short period and Phuguoid mode of the aircraft, compare␣
      ↪to true values

     print('Long. Mode Approximation')

     #Short Period Mode

     A_sp = R_yy*(R_rhox+CL_alpha_hat)
     B_sp = R_yy*(CL_alpha+CD_0)-Cm_qbar*(R_rhox +␣
      ↪CL_alpha_hat)-Cm_alpha_hat*(R_rhox - CL_qbar)
     C_sp = -Cm_qbar*(CL_alpha+CD_0)-Cm_alpha*(R_rhox-CL_qbar)

     eigen_sp = (-B_sp + np.sqrt(B_sp**2-4*A_sp*C_sp))/(2*A_sp)
     Damp_rate_sp = (V_0/Wing_MeanChord)*(B_sp/A_sp)
     Frequency_sp = (V_0/Wing_MeanChord)*abs(np.sqrt(B_sp**2 -4*A_sp*C_sp)/A_sp)

     print(f'\nShort Period Mode:\n')
     print(f'Damping Rate: {Damp_rate_sp}')
     if Damp_rate_sp < 0:
```

```
    print(f'Double Time: {np.log(2.00)/Damp_rate_sp}')
else:
    print(f'Damp Time 99%: {np.log(0.01)/(-Damp_rate_sp)}')
if Frequency_sp != 0:
    print(f'Damped Frequency[rad/s]: {Frequency_sp}')
    print(f'Period [s]: {2*np.pi/Frequency_sp}')

#Phugoid Mode

sigma_D = (g/V_0)*(CD_0/CL_0)
sigma_q = (g/V_0)*((Cm_qbar*(CL_0-CD_alpha))/
 ↪(R_rhox*Cm_alpha+(CD_0+CL_alpha)*Cm_qbar))
R_ps = (R_rhox*Cm_alpha)/(R_rhox*Cm_alpha + Cm_qbar*(CD_0 + CL_alpha))
sigma_phi = -(g/V_0)*R_gx*R_ps*((R_rhox*Cm_qbar-R_yy*(CD_0+CL_alpha))/
 ↪(R_rhox*Cm_alpha + (CD_0+CL_alpha)*Cm_qbar))

Damp_rate_phug = sigma_D + sigma_q + sigma_phi
Frequency_phug = np.sqrt(2*R_ps*(g/V_0)**2 - (sigma_D+sigma_q)**2)

print(f'\nPhugoid Mode:\n')
print(f'Damping Rate: {Damp_rate_phug}')
if Damp_rate_phug < 0:
    print(f'Double Time: {np.log(2.00)/Damp_rate_phug}')
else:
    print(f'Damp Time 99%: {np.log(0.01)/(-Damp_rate_phug)}')
if Frequency_phug != 0:
    print(f'Damped Frequency[rad/s]: {Frequency_phug}')
    print(f'Period [s]: {2*np.pi/Frequency_phug}')
```

```
Long. Mode Approximation

Short Period Mode:

Damping Rate: 10.795802372184895
Damp Time 99%: 0.42657044166102864
Damped Frequency[rad/s]: 6.156358534650823
Period [s]: 1.0206009399574316

Phugoid Mode:

Damping Rate: 0.03567998429740071
Damp Time 99%: 129.06872793449008
Damped Frequency[rad/s]: 1.4748504198606485
Period [s]: 4.260218678836091
```

[ ]:
```
# Lateral Mode Approximations
```

```python
print(f'Lateral Mode Approximation \n')

#Roll Mode

sigma_r = ((-V_0*Air_Density*Wing_Area*Wing_Span**2)/(4*I_xx))*Cl_pbar
print(f'\nDamping Rate Roll Mode: {sigma_r}')
if sigma_r > 0:
    print(f'Damping Time 99%: {np.log(0.01)/-sigma_r}')
else:
    print(f'Doubling Time: {np.log(2)/sigma_r}')

#spiral mode

sigma_spiral = (g/V_0)*((Cl_beta*Cn_rbar - Cl_rbar*Cn_beta)/(Cl_beta*Cn_pbar -
 ↪Cl_pbar*Cn_beta))
print(f'\nDamping Rate Spiral Mode: {sigma_spiral}')
if sigma_spiral > 0:
    print(f'Damping Time 99%: {np.log(0.01)/-sigma_spiral}')
else:
    print(f'Doubling Time: {np.log(2)/-sigma_spiral}')

#Dutch Roll Approx
R_Ds = (Cl_beta*(R_gy*R_rhoy*R_zz-(R_rhoy-CY_rbar)*Cn_pbar)
 ↪-CY_beta*Cl_rbar*Cn_pbar)/(R_rhoy*R_zz*Cl_pbar)
sigma_dr = (-V_0/Wing_Span)*(CY_beta/R_rhoy + Cn_rbar/R_zz - (Cl_rbar*Cn_pbar)/
 ↪(Cl_pbar*R_zz) + (R_gy*(Cl_rbar*Cn_beta - Cl_beta*Cn_rbar))/
 ↪(Cl_pbar*(Cn_beta+CY_beta*Cn_rbar/R_rhoy)) - R_xx*(R_Ds/Cl_pbar) )
Frequency_dr = (2*V_0/Wing_Span)*np.sqrt((1-CY_rbar/R_rhoy)*(Cn_beta/R_zz) +
 ↪(CY_beta*Cn_rbar)/(R_rhoy*R_zz) + R_Ds -0.25*(CY_beta/R_rhoy + Cn_rbar/
 ↪R_zz)**2 )


print(f'\nDamping Rate Dutch Roll Mode: {sigma_dr}')
if sigma_dr > 0:
    print(f'Damping Time 99%: {np.log(0.01)/-sigma_dr}')
else:
    print(f'Doubling Time: {np.log(2)/-sigma_dr}')
if Frequency_dr != 0:
    print(f'Damped Frequency[rad/s]: {Frequency_dr}')
    print(f'Period [s]: {2*np.pi/Frequency_dr}')
#print results
```

```
Lateral Mode Approximation
```

```
Damping Rate Roll Mode: 62.696073068514906
Damping Time 99%: 0.07345229071931689

Damping Rate Spiral Mode: 4.846484274436409
Damping Time 99%: 0.950208424337376

Damping Rate Dutch Roll Mode: 1.7671176647259874
Damping Time 99%: 2.6060348316998896
Damped Frequency[rad/s]: 1.1592683527698955
Period [s]: 5.419957589773645
```

[ ]:
```python
#Problem A14: Print the dimensional eigenvalues for the short period, phugoid,␣
↪roll, spiral and dutch roll modes
#On a single graph
long_co = 2*V_0/Wing_MeanChord
lat_co = 2*V_0/Wing_Span
print(eigen_vals_long)
print(eigen_vals_lat)
eigen_vals_long_dim = np.asarray(eigen_vals_long)*long_co
eigen_vals_lat_dim = np.asarray(eigen_vals_lat)*lat_co

#Eigenvals #needs to be dimensional eigenvalues for plot, shows more
long_real = [val.real for val in eigen_vals_long_dim]
long_imag = [val.imag for val in eigen_vals_long_dim]
lat_real =[val.real for val in eigen_vals_lat_dim]
lat_imag = [val.imag for val in eigen_vals_lat_dim]



#Longitudinal

Eig_both = plt.figure()
plt.scatter(long_real,long_imag,color='red',label='Eigenvalues Long',marker='v')
plt.scatter(lat_real,lat_imag,color='blue',label='Eigenvalues Lat',marker='o')
plt.axhline(0, color='black', linestyle='--')
plt.axvline(0, color='black', linestyle='--')
plt.xlabel('Real Part')
plt.ylabel('Imaginary Part')
plt.title(f'{base_name} Eigenvalues plotted')
plt.legend()
plt.grid(True)
Eig_both.savefig(f'{base_name}/Eig_both_plot.png',dpi=200)
plt.show()
```

```
[ 0.         +0.j          0.         +0.j          -0.36743301+0.j
 -0.12234424+0.j          -0.00194656+0.03233351j -0.00194656-0.03233351j]
[  0.         +0.j            0.         +0.j
 -34.51729821+0.j            -0.81854038+0.j
```

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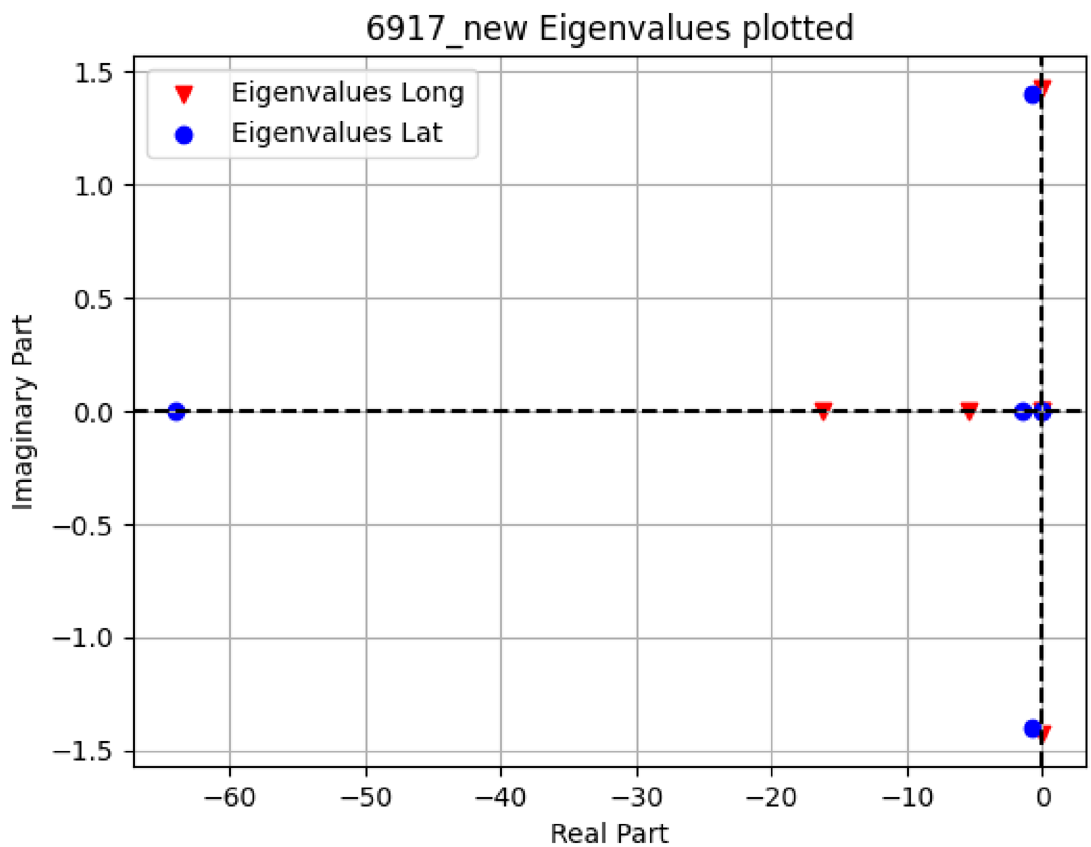
-0.42559321+0.75475346j  -0.42559321-0.75475346j]
```



[ ]:
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#A 15, getting the CAP factor for the aircraft

#Need the short period values
W_n_sp = np.sqrt((eigen_vals_long[2].real*eigen_vals_long[3].real))*(2*V_0/
  ↪Wing_MeanChord)

print(f'Undamped Natural Frequency: {W_n_sp}')

#solve for the cap parameter

CAP = W_n_sp**2/(CL_alpha/CW)

print(f'CAP Value: {CAP}')
```

```
Undamped Natural Frequency: 9.34784611423023
CAP Value: 13.222627365519735
```

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[ ]: #A 16, compute the handling qualities for the baseline glider Category B flight␣
     ↪phases

     #Get all the needed values for each mode

     #shortperiod
     def shortperiod_B_handleval(eigenvalue1,eigenvalue2,vel,chord,CL_alpha,CW):
         #get the cap value
         wn_sp = np.sqrt((eigenvalue1*eigenvalue2))*(2*vel/chord)
         print(wn_sp)
         print(CL_alpha/CW)
         CAP = wn_sp**2/(CL_alpha/CW)
         print(f'Short Period CAP value: {round(CAP.real,4)}\n')

         #now we need the squiggle of the Short period
         num = -(eigenvalue1+eigenvalue2)
         denom = np.sqrt((eigenvalue1*eigenvalue2))

         squiggle = num/denom
         #give value dependent on CAP and Squiggle
         if 0.30 < squiggle < 2.00:
             print(f'Short Period Handling Level: 1\n')

         elif 0.20 < squiggle < 2.00:
             print(f'Short Period Handling Level: 2\n')
         elif 0.16 < squiggle:
             print(f'Short Period Handling Level: 3\n')
         else:
             print(f'Short Period Handling Level: 4, Iteration of Design Required\n')


     #phugoid
     def phugoid_B_handleval(eigenvalue1,eigenvalue2):
         sigma = -eigenvalue1.real

         #evaluate the squiggle
         num = -(eigenvalue1+eigenvalue2)
         denom = np.sqrt((eigenvalue1.real*eigenvalue2.real))
         squiggle = num/denom

         if sigma > 0:
             if sigma > 0.04:
                 print(f'Phugoid Handling Level: 1\n')
             else:
                 print(f'Phugoid Handling Level: 2\n')
         else:
             #check the doubling time
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        double_time = -np.log(2.00)/sigma
        print(f'Divergent Mode: Doubling Time {round(double_time,2)}[sec]\n')
        if double_time > 55:
            print(f'Phugoid Handling Level: 3\n')
        else:
            print(f'Phugoid Handling Level: 4, Iteration of Design Required\n')

#Roll
def roll_B_handleval(eigenvalue):
    sigma = -eigenvalue.real

    HandlingQual = 1/sigma
    #give rating dependent on this value
    if HandlingQual > 0:
        if HandlingQual < 1.4:
            print(f'Roll Handling Level: 1\n')
        if 1.4 < HandlingQual < 3.0:
            print(f'Roll Handling Level: 2\n')
        if 3.0 < HandlingQual < 10.0:
            print(f'Roll Handling Level: 3\n')
        if HandlingQual > 10.0:
            print(f'Roll Handling Level: 4, Iteration of Design Required\n')
    else:
        print(f'Roll Handling Level: 4 Iteration of Design Required\n')

#dutch roll

def dutch_roll_B_handlevel(eigenvalue1,eigenvalue2,vel,span):
    #get the cap value
    wn_dutch = np.sqrt((eigenvalue1*eigenvalue2))*(2*vel/span)

    #now we need the squiggle of the Short period
    num = -(eigenvalue1+eigenvalue2)
    denom = np.sqrt((eigenvalue1.real*eigenvalue2.real))

    squiggle = num/denom

    cond_1 = squiggle
    cond_2 = squiggle*wn_dutch
    cond_3 = wn_dutch

    #Conditions for handling
    #first is it is divergent it is unacceptable
    if squiggle < 0:
        print(f'Ducth Roll Handling Level: 4, Iteration of Design Required\n')
    else:
        if cond_1 > 0.08 and cond_2 > 0.15 and cond_3 > 0.4:
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```
            print(f'Dutch Roll Handling Level: 1\n')
        elif cond_1 > 0.02 and cond_2 > 0.05 and cond_3 > 0.4:
            print(f'Dutch Roll Handling Level: 2\n')
        elif cond_1 > 0.00 and cond_3 > 0.4:
            print(f'Dutch Roll Handling Level: 3\n')
        else:
            print(f'Dutch Roll Handling Level: 4, Iteration of Design␣
↪Required\n')

#spiral

def spiral_B_handlevel(eigenvalue):
    sigma_spiral = -eigenvalue.real

    if sigma_spiral < 0:
        double_time = np.log(2.00)/-sigma_spiral
        if double_time > 20:
            print(f'Spiral Handling Level: 1\n')
        elif 20 > double_time > 12:
            print(f'Spiral Handling Level: 2\n')
        elif 12 > double_time > 4:
            print(f'Spiral Handling Level: 3\n')
        else:
            print(f'Spiral Handling Level: 4, Interation of Design Required\n')
    else:
        print(f'Spiral Handling Level: 1\n')
```

[ ]:
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#Give the Eigenvalues to each mode

#phugoid mode

Phugoid_eigenvalue_1 = eigen_vals_long[4]
Phugoid_eigenvalue_2 = eigen_vals_long[5]
phugoid_B_handleval(Phugoid_eigenvalue_1,Phugoid_eigenvalue_2)
#short period mode

Short_pred_eigenvalue_1 = eigen_vals_long[3]
Short_pred_eigenvalue_2 = eigen_vals_long[2]

shortperiod_B_handleval(Short_pred_eigenvalue_1,Short_pred_eigenvalue_2,vel=V_0,chord=Wing_Mea

#Roll

Roll_eigenval = eigen_vals_lat[2]
roll_B_handleval(Roll_eigenval)

#spiral
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Spiral_eigenval = eigen_vals_lat[5]
spiral_B_handlevel(Spiral_eigenval)

#dutchroll
dutch_eigenval_1 = eigen_vals_lat[3]
dutch_eigenval_2 = eigen_vals_lat[4]

dutch_roll_B_handlevel(dutch_eigenval_1,dutch_eigenval_2,vel=V_0,span=Wing_Span)
```

```
Phugoid Handling Level: 2

(9.34784611423023+0j)
6.608537362490705
Short Period CAP value: 13.2226

Short Period Handling Level: 3

Roll Handling Level: 1

Spiral Handling Level: 1

Dutch Roll Handling Level: 1
```

[ ]:
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#Plot of all the eigenvalues with the modes labeled

#get the dimensional eigenvalues

#Phugoid

Phugoid_eigenvalue_1 = eigen_vals_long_dim[4]
Phugoid_eigenvalue_2 = eigen_vals_long_dim[5]

#short period mode

Short_pred_eigenvalue_1 = eigen_vals_long_dim[3]
Short_pred_eigenvalue_2 = eigen_vals_long_dim[2]

#Roll

Roll_eigenval = eigen_vals_lat_dim[2]

#spiral
Spiral_eigenval = eigen_vals_lat_dim[5]

#dutchroll
dutch_eigenval_1 = eigen_vals_lat_dim[4]
```

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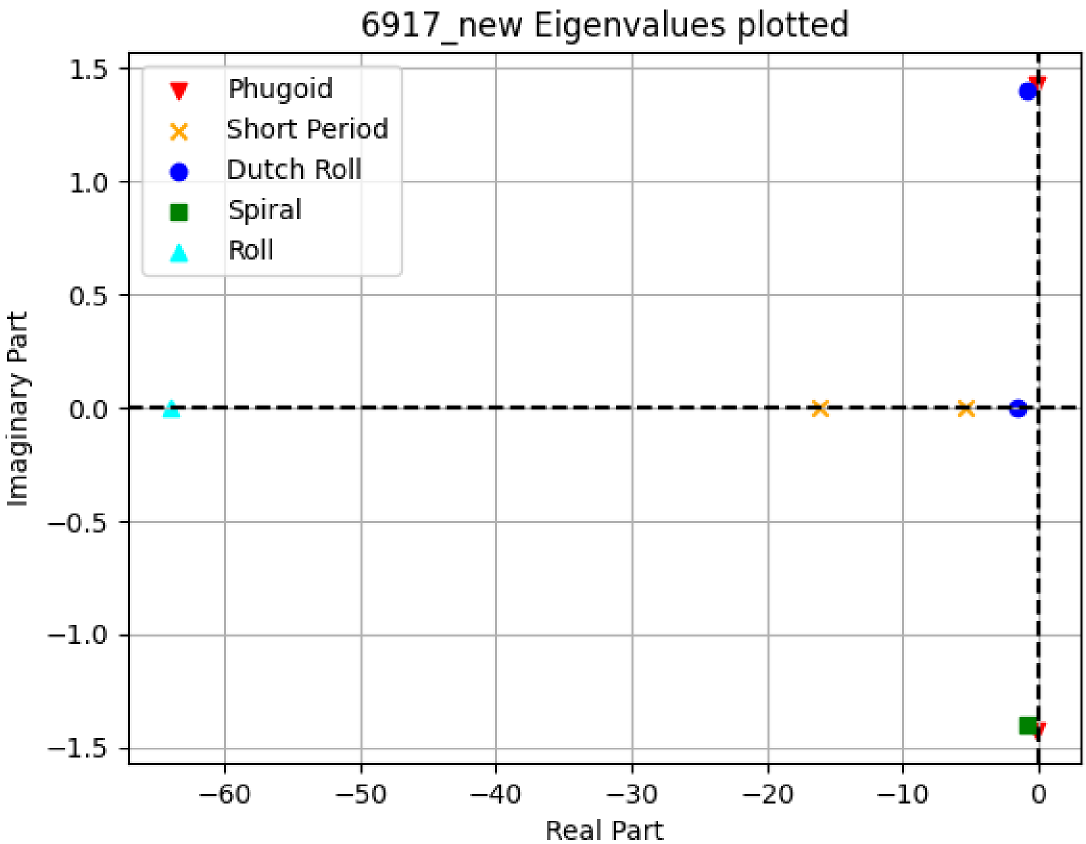
dutch_eigenval_2 = eigen_vals_lat_dim[3]

#Put evergything into one figure to see

Eigen_dim_plot = plt.figure()
plt.scatter(Phugoid_eigenvalue_1.real,Phugoid_eigenvalue_1.
 ↪imag,color='red',label='Phugoid',marker='v')
plt.scatter(Phugoid_eigenvalue_2.real,Phugoid_eigenvalue_2.
 ↪imag,color='red',marker='v')
plt.scatter(Short_pred_eigenvalue_2.real,Short_pred_eigenvalue_2.
 ↪imag,color='orange',label='Short Period',marker='x')
plt.scatter(Short_pred_eigenvalue_1.real,Short_pred_eigenvalue_1.
 ↪imag,color='orange',marker='x')
plt.scatter(dutch_eigenval_1.real,dutch_eigenval_1.
 ↪imag,color='blue',label='Dutch Roll',marker='o')
plt.scatter(dutch_eigenval_2.real,dutch_eigenval_2.imag,color='blue',marker='o')
plt.scatter(Spiral_eigenval.real,Spiral_eigenval.
 ↪imag,color='green',label='Spiral',marker='s')
plt.scatter(Roll_eigenval.real,Roll_eigenval.
 ↪imag,color='cyan',label='Roll',marker='^')
plt.axhline(0, color='black', linestyle='--')
plt.axvline(0, color='black', linestyle='--')
plt.xlabel('Real Part')
plt.ylabel('Imaginary Part')
plt.title(f'{base_name} Eigenvalues plotted')
plt.legend()
plt.grid(True)
Eigen_dim_plot.savefig(f'{base_name}/Eig_Model_labeled.png',dpi=200)
plt.show()
```



6917_new Eigenvalues plotted
Phugoid
Short Period
Dutch Roll
Spiral
Roll
Imaginary Part
Real Part
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
−60
−50
−40
−30
−20
−10
0