MECE-410: Flight Dynamics **Project #3**
Spring 2014-2015 (2145) **Due:** *April 2nd, 2015*

Instructions: Use Matlab to solve all problems. Save your work in an m-file.

Assume the following aerodynamic aircraft model:

$$C_X = C_{X_0} + C_{X_u} u + C_{X_w} w + \frac{\bar{c}}{2u} C_{X_q} q \frac{180}{\pi} + C_{X_{\delta e}} \delta e$$

$$C_Y = C_{Y_0} + C_{Y_v} v + \frac{b}{2u}\left(C_{Y_p} p + C_{Y_r} r\right)\frac{180}{\pi} + C_{Y_{\delta a}} \delta a + C_{Y_{\delta r}} \delta r$$

$$C_Z = C_{Z_0} + C_{Z_u} u + C_{Z_w} w + \frac{\bar{c}}{2u} C_{Z_q} q \frac{180}{\pi} + C_{Z_{\delta e}} \delta e$$

$$C_l = C_{l_0} + C_{l_v} v + \frac{b}{2u}\left(C_{l_p} p + C_{l_r} r\right)\frac{180}{\pi} + C_{l_{\delta a}} \delta a + C_{l_{\delta r}} \delta r$$

$$C_m = C_{m_0} + C_{m_u} u + C_{m_w} w + \frac{\bar{c}}{2u} C_{m_q} q \frac{180}{\pi} + C_{m_{\delta e}} \delta e$$

$$C_n = C_{n_0} + C_{n_v} v + \frac{b}{2u}\left(C_{n_p} p + C_{n_r} r\right)\frac{180}{\pi} + C_{n_{\delta a}} \delta a + C_{n_{\delta r}} \delta r$$

The external forces and moments acting on the aircraft are:

$$F_{A_x} = \bar{q} S C_X ; F_{A_y} = \bar{q} S C_Y ; F_{A_z} = \bar{q} S C_Z ; F_{T_x} = T ; F_{T_y} = 0 ; F_{T_z} = 0$$

$$M_{e_x} = \bar{q} S b C_l ; M_{e_y} = \bar{q} S \bar{c} C_m ; M_{e_z} = \bar{q} S b C_n$$

and:

C_{X_0} = -2.135364E-02 ; C_{X_u} = 1.289018E-04 ; C_{X_w} = –2.17775E-03 ; C_{X_q} = 2.1928052E-04

$C_{X_{\delta e}}$ = 1.386632E-03

C_{Y_0} = 0 ; C_{Y_v} = -6.4490425E-02 ; C_{Y_p} = 1.33481E-03 ; C_{Y_r} = 9.401418E-03;

$C_{Y_{\delta a}}$ = 4.618436E-04 ; $C_{Y_{\delta r}}$ = 2.991717E-03

C_{Z_0} = 5.092263E-02 ; C_{Z_u} = -4.3444023E-04 ; C_{Z_w} = -1.9946051E-03 ; C_{Z_q} = -5.3473522E-02;

$C_{Z_{\delta e}}$ = -1.2167892E-02

C_{l_0} = 0 ; C_{l_v} = -1.75539E-03 ; C_{l_p} = -7.392626E-03 ; C_{l_r} = 5.910111E-05

$C_{l_{\delta a}}$ = -2.089358E-03 ; $C_{l_{\delta r}}$ = 4.7651867E-04

C_{m_0} = -1.39985E-02 ; C_{m_u} = -1.15335756E-04 ; C_{m_w} = -1.16313463E-03 ; C_{m_q} = -6.08086182E-01;

$C_{m_{\delta e}}$ = -4.632495451E-02

C_{n_0} = 0 ; C_{n_v} = 5.1988574E-03 ; C_{n_p} = -4.294548E-04 ; C_{n_r} = -8.6047784E-03

$C_{n_{\delta a}}$ = -1.955539E-04 ; $C_{n_{\delta r}}$ = -5.50282873E-03

with units (/deg) expect for the "not" terms which are dimensionless and u, v, w which are (/ft/sec)

Assume $\bar{q} = 0.5\rho u^2$

The aircraft properties are:
$I_{xx} = 8691.46164$, $I_{yy} = 70668.585$, $I_{zz} = 70418.67355$, $I_{xz} = 151.43836$, $I_{xy} = I_{yz} = 0.0$ (slug-ft^2)
$S = 300$ (ft^2), $\bar{c} = 11.32$ (ft), $b = 30$ (ft), $m = mass = 756.5262463$ (slugs)

assume air density is constant: $\rho = 0.0012669984$ (slugs/ ft^3) and $g = 32.17561865$ (ft/sec^2)

The initial "trim" conditions are:
$u(0) = 670.360471$ (ft/sec), $w(0) = 40.362171$ (ft/sec), $\theta(0) = \tan^{-1}\left[w(0)/u(0)\right]$ (rad),
$T = thrust = 3767.207337$ (lbs), $\delta e = -2.9846046$ (deg), all others variable IC's are zero

In your m-file, program the nine nonlinear differential equations (axial velocity, u; side velocity, v; normal velocity, w; roll rate, p; pitch rate, q; yaw rate, r; bank angle, ϕ; pitch angle, θ; heading angle, ψ) for aircraft dynamics and:

1. Using the "ode45" command, simulate the response of the aircraft model for the time interval of $[0,10]$ sec with $\Delta t = 0.01$ sec using the "trim" conditions shown above. Plot Axial Velocity (ft/sec) vs time; Side Velocity (ft/sec) vs time; Normal Velocity (ft/sec) vs time; Roll Rate (deg/sec) vs time; Pitch Rate (deg/sec) vs time; Yaw Rate (deg/sec) vs time; Bank Angle (deg) vs time; Pitch Angle (deg) vs time; and Heading Angle (deg) vs time for the trim condition. Verify the aircraft is trimmed!

2. Using the "ode45" command, simulate the response of the aircraft model for the time interval of $[0,10]$ sec with $\Delta t = 0.01$ sec for a step "delta" input to the elevator with the step starting at time 1 sec and with a magnitude of "delta" -0.5 deg so that the total elevator deflection at 1 sec is -3.4846046 deg and equal to the trim condition before 1 sec. Plot Axial Velocity (ft/sec) vs time; Side Velocity (ft/sec) vs time; Normal Velocity (ft/sec) vs time; Roll Rate (deg/sec) vs time; Pitch Rate (deg/sec) vs time; Yaw Rate (deg/sec) vs time; Bank Angle (deg) vs time; Pitch Angle (deg) vs time; and Heading Angle (deg) vs time for the trim condition for the step response. The aileron and rudder position should be set fixed to their trim condition for this part.

3. Using the "ode45" command, simulate the response of the aircraft model for the time interval of $[0,10]$ sec with $\Delta t = 0.01$ sec for a step input to the aileron with the step starting at time 1 sec and with a magnitude of -0.5 deg. Plot Axial Velocity (ft/sec) vs time; Side Velocity (ft/sec) vs time; Normal Velocity (ft/sec) vs time; Roll Rate (deg/sec) vs time; Pitch Rate (deg/sec) vs time; Yaw Rate (deg/sec) vs time; Bank Angle (deg) vs time; Pitch Angle (deg) vs time; and Heading Angle (deg) vs time for the trim condition for the step response The elevator and rudder position should be set fixed to their trim condition for this part.

4. Using the "ode45" command, simulate the response of the aircraft model for the time interval of $[0,10]$ sec with $\Delta t = 0.01$ sec for a step input to the rudder with the step starting at time 1 sec and with a magnitude of -2.0 deg. Plot Axial Velocity (ft/sec) vs time; Side Velocity (ft/sec) vs time; Normal Velocity (ft/sec) vs time; Roll Rate (deg/sec) vs time; Pitch Rate (deg/sec) vs time; Yaw Rate (deg/sec) vs time; Bank Angle (deg) vs time; Pitch Angle (deg) vs time; and Heading Angle (deg) vs time for the trim condition for the step response The elevator and aileron position should be set fixed to their trim condition for this part.