MECE-410: Flight Dynamics **Project #4**
Spring 2014-2015 (2145) **Due:** *April 23th, 2015*

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

Assume the following aerodynamic "non-dimensional" coefficient model:

$$C_L = C_{L_0} + C_{L_\alpha}\alpha + \frac{\bar{c}}{2V_T}\left(C_{L_q}q + C_{L_{\dot{\alpha}}}\dot{\alpha}\right) + C_{L_{\delta e}}\delta e + C_{L_{\delta f}}\delta f$$

$$C_D = C_{D_0} + C_{D_\alpha}\alpha + \frac{\bar{c}}{2V_T}\left(C_{D_q}q + C_{D_{\dot{\alpha}}}\dot{\alpha}\right) + C_{D_{\delta e}}\delta e + C_{D_{\delta f}}\delta f$$

$$C_Y = C_{Y_0} + C_{Y_\beta}\beta + \frac{b}{2V_T}\left(C_{Y_p}p + C_{Y_r}r\right) + C_{Y_{\delta a}}\delta a + C_{Y_{\delta r}}\delta r$$

$$C_l = C_{l_0} + C_{l_\beta}\beta + \frac{b}{2V_T}\left(C_{l_p}p + C_{l_r}r\right) + C_{l_{\delta a}}\delta a + C_{l_{\delta r}}\delta r$$

$$C_m = C_{m_0} + C_{m_\alpha}\alpha + \frac{\bar{c}}{2V_T}\left(C_{m_q}q + C_{m_{\dot{\alpha}}}\dot{\alpha}\right) + C_{m_{\delta e}}\delta e + C_{m_{\delta f}}\delta f$$

$$C_n = C_{n_0} + C_{n_\beta}\beta + \frac{b}{2V_T}\left(C_{n_p}p + C_{n_r}r\right) + C_{n_{\delta a}}\delta a + C_{n_{\delta r}}\delta r$$

where:

$$C_{L_0} = 0.004608463,\ C_{L_\alpha} = 0.0794655, C_{L_q} = 0.0508476, C_{L_{\dot{\alpha}}} = 0.0, C_{L_{\delta e}} = 0.0121988, C_{L_{\delta f}} = 0.0144389$$

$$C_{D_0} = 0.01192128,\ C_{D_\alpha} = 0.00550063, C_{D_q} = 0.00315057, C_{D_{\dot{\alpha}}} = 0.0, C_{D_{\delta e}} = -0.000587647, C_{D_{\delta f}} = 0.00136385$$

$$C_{Y_0} = 0.0,\ C_{Y_\beta} = -0.0219309, C_{Y_p} = 0.00133787, C_{Y_r} = 0.0094053, C_{Y_{\delta a}} = 0.00049355, C_{Y_{\delta r}} = 0.00293048$$

$$C_{l_0} = 0.0,\ C_{l_\beta} = -0.00173748, C_{l_p} = -0.00739342, C_{l_r} = 0.0000699792, C_{l_{\delta a}} = -0.00213984, C_{l_{\delta r}} = 0.000479021$$

$$C_{m_0} = -0.02092347,\ C_{m_\alpha} = -0.0041873, C_{m_q} = -0.110661, C_{m_{\dot{\alpha}}} = 0.0, C_{m_{\delta e}} = -0.0115767, C_{m_{\delta f}} = 0.000580220$$

$$C_{n_0} = 0.0,\ C_{n_\beta} = 0.00320831, C_{n_p} = -0.000432575, C_{n_r} = -0.00886783, C_{n_{\delta a}} = -0.000206591, C_{n_{\delta r}} = -0.00144865$$

with units (/deg) expect for the "not" terms which are dimensionless

The external forces and moments acting on the aircraft are:

$$D = \bar{q}SC_D;\ Y = \bar{q}SC_Y;\ L = \bar{q}SC_L;\ M_{e_x} = \bar{q}SbC_l;\ M_{e_y} = \bar{q}S\bar{c}C_m;\ M_{e_z} = \bar{q}SbC_n$$

$$n_X = \left(X + T\right)/\left(g * mass\right);\ n_Y = Y/\left(g * mass\right);\ n_Z = -Z/\left(g * mass\right)$$

$$X = -D\cos(\alpha) + L\sin(\alpha);\ Z = -D\sin(\alpha) - L\cos(\alpha)$$

The aircraft properties are:

$I_{xx} = 8890.63$, $I_{yy} = 71973.5$, $I_{zz} = 77141.1$, $I_{xz} = 181.119$, $I_{xy} = I_{yz} = 0.0$ (slug-ft^2)

$S = 300$ (ft^2), $\bar{c} = 11.32$ (ft), $b = 30$ (ft), $mass = 762.8447$ (slugs)

Assume air density is constant: $\rho = 0.0014962376$ (slugs/ ft^3) and $g = 32.17561865$ (ft/sec^2) and that dynamic pressure, $\bar{q} = 0.5\rho V_T^2$

The initial "trim" conditions are:

$V_T(0) = 626.81863$ (ft/sec), $\alpha(0) = \theta(0) = 3.6102915$ (deg), $T = thrust = 3146.482666$ (lbs), $\delta e = \text{-}3.03804303$ (deg), $\delta f = 1.5$ (deg), all others variable IC's are zero

In your Simulink mdl-file, program the nine nonlinear differential equations (True Velocity, Angle-of-Attack, Pitch Rate, Sideslip, Roll Rate, Yaw Rate, Pitch Angle, Bank Angle, Heading Angle). Simulate the following conditions:

1. Use Simulink with the "ode5" solver and a fixed step size to 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 for True Velocity, Angle-of-Attack, Pitch Angle, Thrust, and elevator, flap, aileron, and rudder deflections. Plot True Velocity (ft/sec) vs time, Angle-of-Attack (deg) vs time, Pitch Rate (deg/sec) vs time, and Pitch Angle (deg) vs time, Sideslip Angle (deg) vs time, Roll Rate (deg/sec) vs time, Yaw Rate (deg/sec) vs time, Bank Angle (deg) vs time, and Heading Angle (deg) vs time for the trim condition. Verify the aircraft is trimmed!

2. Use Simulink with the "ode5" solver and a fixed step size to 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” -0.5 deg so that the total elevator deflection at 1 sec is -3.53804303 deg and equal to the trim condition before 1 sec. Plot True Velocity (ft/sec) vs time, Angle-of-Attack (deg) vs time, Pitch Rate (deg/sec) vs time, and Pitch Angle (deg) vs time, Sideslip Angle (deg) vs time, Roll Rate (deg/sec) vs time, Yaw Rate (deg/sec) vs time, Bank Angle (deg) vs time, and Heading Angle (deg) vs time for the step response. The aileron and rudder position should be set fixed to their trim condition for this part.

3. Use Simulink with the "ode5" solver and a fixed step size to 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 True Velocity (ft/sec) vs time, Angle-of-Attack (deg) vs time, Pitch Rate (deg/sec) vs time, and Pitch Angle (deg) vs time, Sideslip Angle (deg) vs time, Roll Rate (deg/sec) vs time, Yaw Rate (deg/sec) vs time, Bank Angle (deg) vs time, and Heading Angle (deg) vs time for the step response. The elevator and rudder position should be set fixed to their trim condition for this part.

4. Use Simulink with the "ode5" solver and a fixed step size to 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 True Velocity (ft/sec) vs time, Angle-of-Attack (deg) vs time, Pitch Rate (deg/sec) vs time, and Pitch Angle (deg) vs time, Sideslip Angle (deg) vs time, Roll Rate (deg/sec) vs time, Yaw Rate (deg/sec) vs time, Bank Angle (deg) vs time, and Heading Angle (deg) vs time for the step response. The elevator and aileron position should be set fixed to their trim condition for this part.