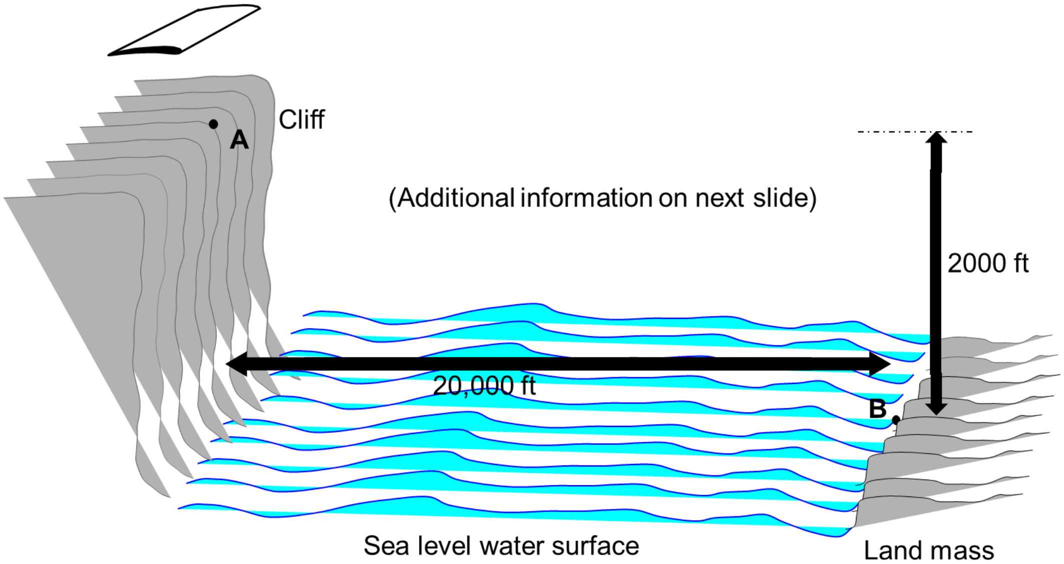
Problem 1. (30pts)

A flying wing glider configuration rests on the flat top of a mountain 2000 ft (MSL) high. The mountain is surrounded with water (sea level) and has steep cliffs on all sides. The nearest land mass is located 20,000 ft in the distance at sea level. Can the glider configuration fly from the mountain top to the land mass without touching water? Assuming initial condition V_h=0, V_x=51ft/s, h=2000ft, x=0, find the time history of altitude and range for wing glider from starting point to landing point when C_L =0.9.

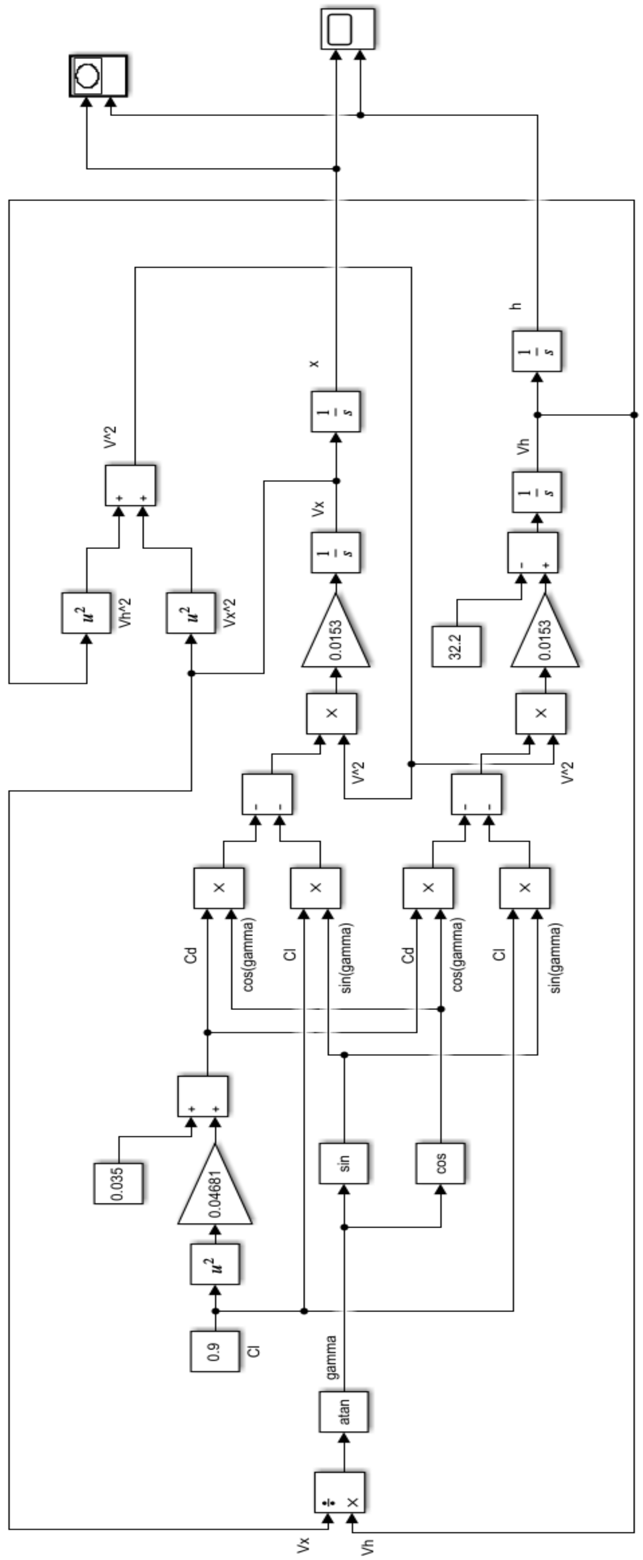


$$\frac{dV_x}{dt} = 0.0153V^2(-C_D\cos\gamma - C_L\sin\gamma)$$

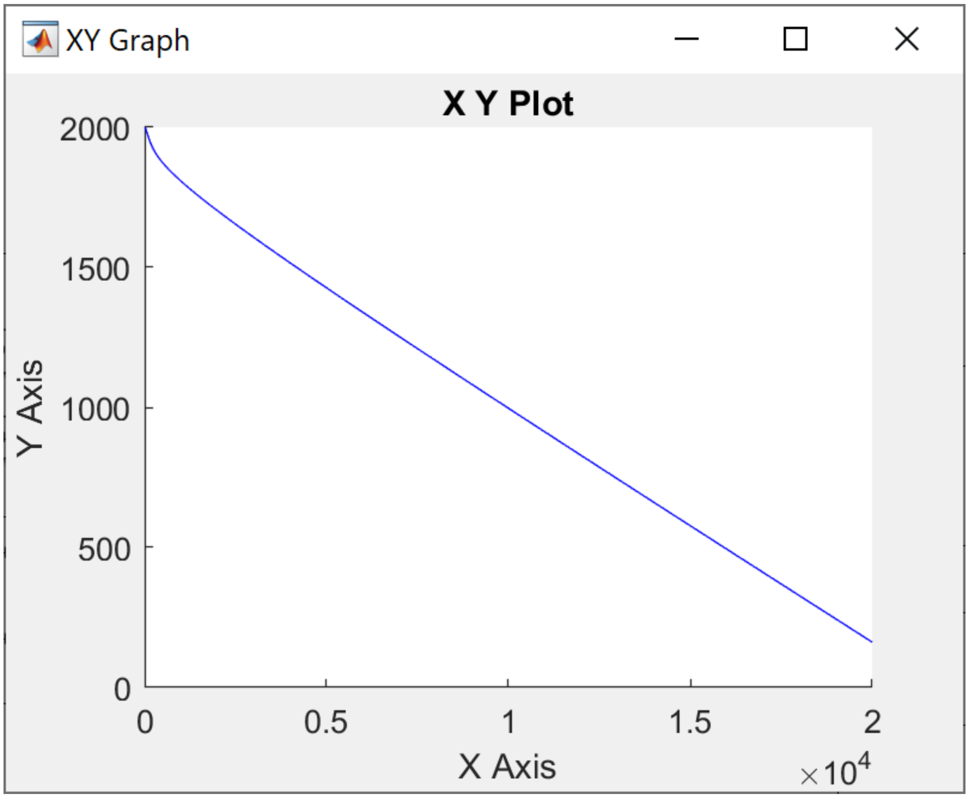
$$\frac{dV_h}{dt} = 0.0153V^2(C_L\cos\gamma - C_D\sin\gamma) - 32.17$$

$$\frac{dh}{dt} = V_h, \frac{dx}{dt} = V_x, V^2 = V_x^2 + V_y^2, \gamma = \tan^{-1}\frac{V_h}{V_x}$$

$$C_D = 0.035 + 0.04681\, C_L^2$$



Vx
Vh
atan
gamma
0.9
Cl
0.04681
0.035
sin
cos
Cd
cos(gamma)
Cl
sin(gamma)
V^2
0.0153
32.2
Vx
x
Vh
h
Vh^2
Vx^2
V^2



The glider configuration can fly from the mountain top to the land mass without touching water.

Problem 2. (40pts)
The equations below represent the longitudinal and lateral-directional equations of motion for the Boeing 727 aircraft. The pitch, roll, yaw variables (p, q, r) have been reinstated in the equations. The inertial orientation and position equations must be included in their full nonlinear form. The reference condition for the airplane is a steady level flight condition: W = 130,000 lb, Trim Velocity = 832 ft/sec, Trim altitude = 27,000 ft.

$$\dot{u} = -0.01008\,u + 2.425\,\dot{\alpha} + 7.055\,\alpha - 2.308q - 32.17\,\theta - 0.9679\,\Delta\,\delta_e + 0.004\,\Delta\delta_r$$
$$\dot{\alpha} = -0.0001\,u - 0.9967\,\alpha + 1.0046\,q + (\cos\theta\cos\phi - 1)0.03867 - 0.03827\,\Delta\delta_e$$
$$\dot{q} = 0.8277\,\dot{\alpha} - 0.000013\,u - 3.326\,\alpha - 1.337\,q - 2.57\,\Delta\delta_e$$

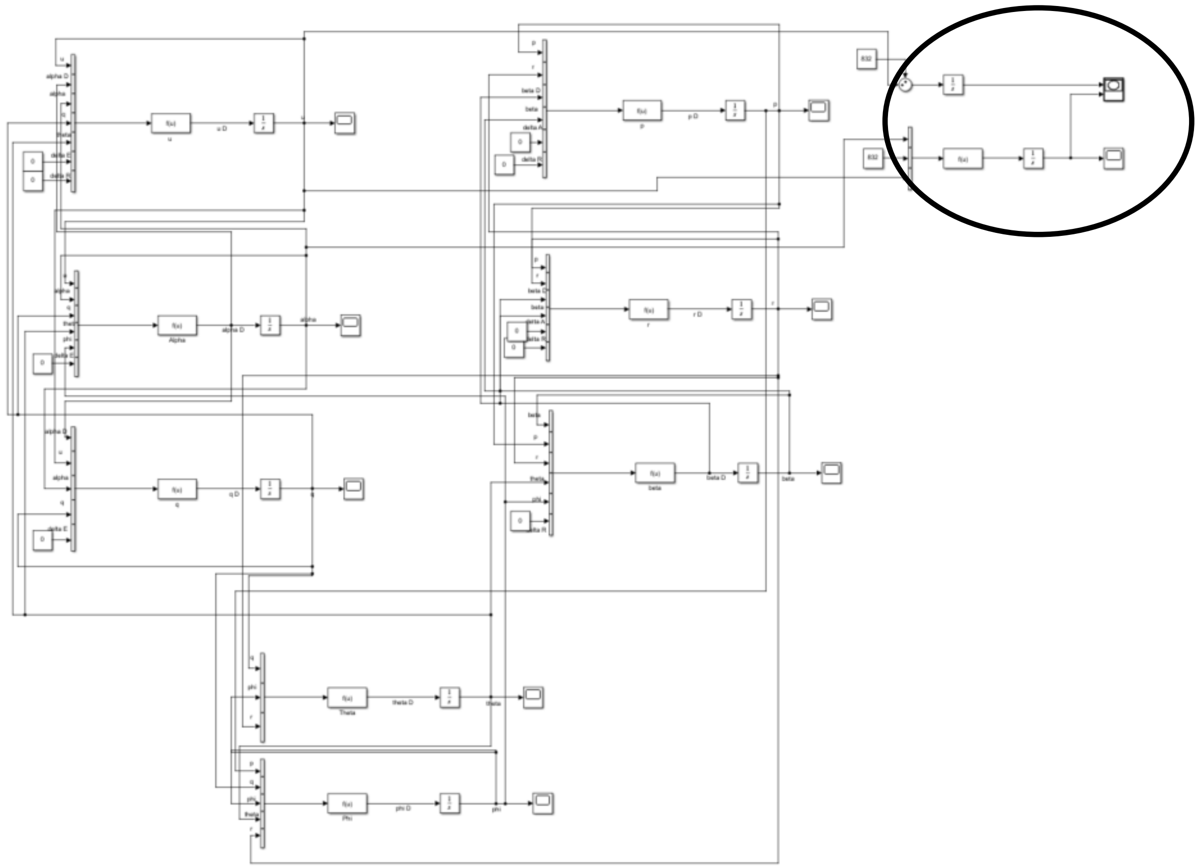
$$\dot{p} = -2.5612\,p + 0.7245\,r - 0.0677\,\dot{\beta} - 14.0174\,\beta + 0.4395\,\Delta\,\delta_a + 0.3830\,\Delta\delta_r$$
$$\dot{r} = 0.8476\,p - 0.4155\,r + 0.3564\,\dot{\beta} + 6.6931\,\beta - 0.1556\,\Delta\delta_a - 0.7090\,\Delta\delta_r$$
$$\dot{\beta} = -0.2127\,\beta - 0.0011p - 0.9957\,r + 0.03867\cos\theta\sin\phi + 0.03259\,\Delta\delta_r$$

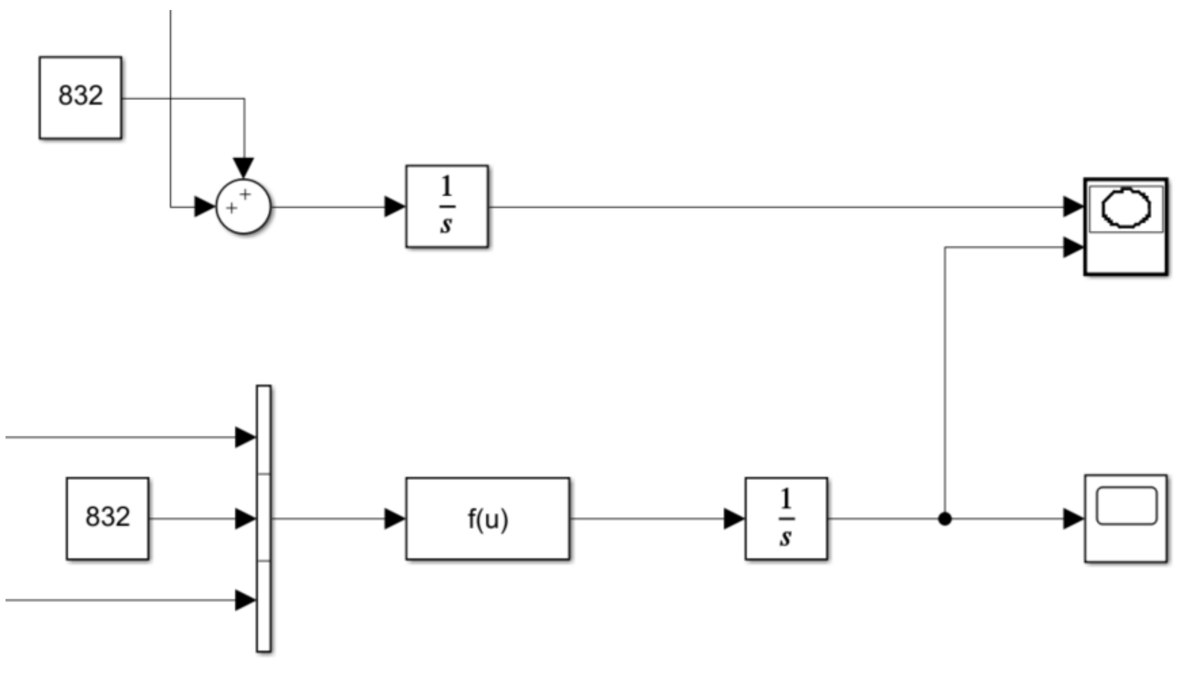
$$\tan\alpha = \frac{w}{u_o + u}, \tan\beta = \frac{v}{u_o + u}$$

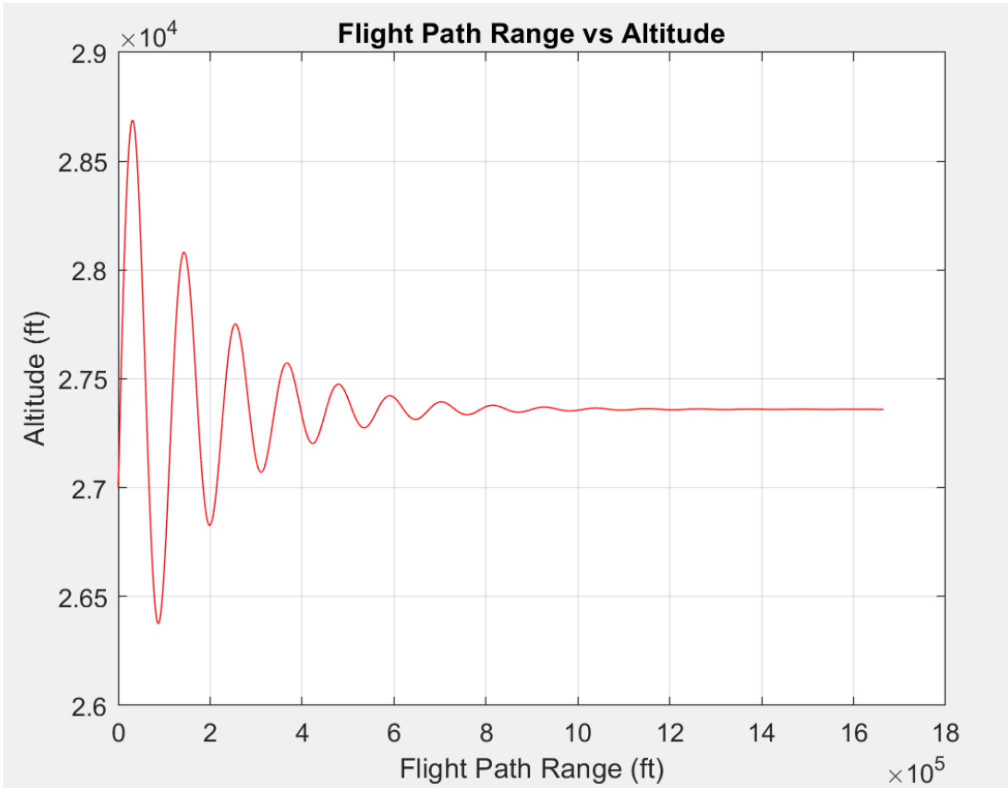
$$\dot{\theta} = q\cos\phi - r\sin\phi$$
$$\dot{\phi} = p + q\sin\phi\tan\theta + r\cos\phi\tan\theta$$
$$\dot{\psi} = (q\sin\phi + r\cos\phi)\sec\theta$$

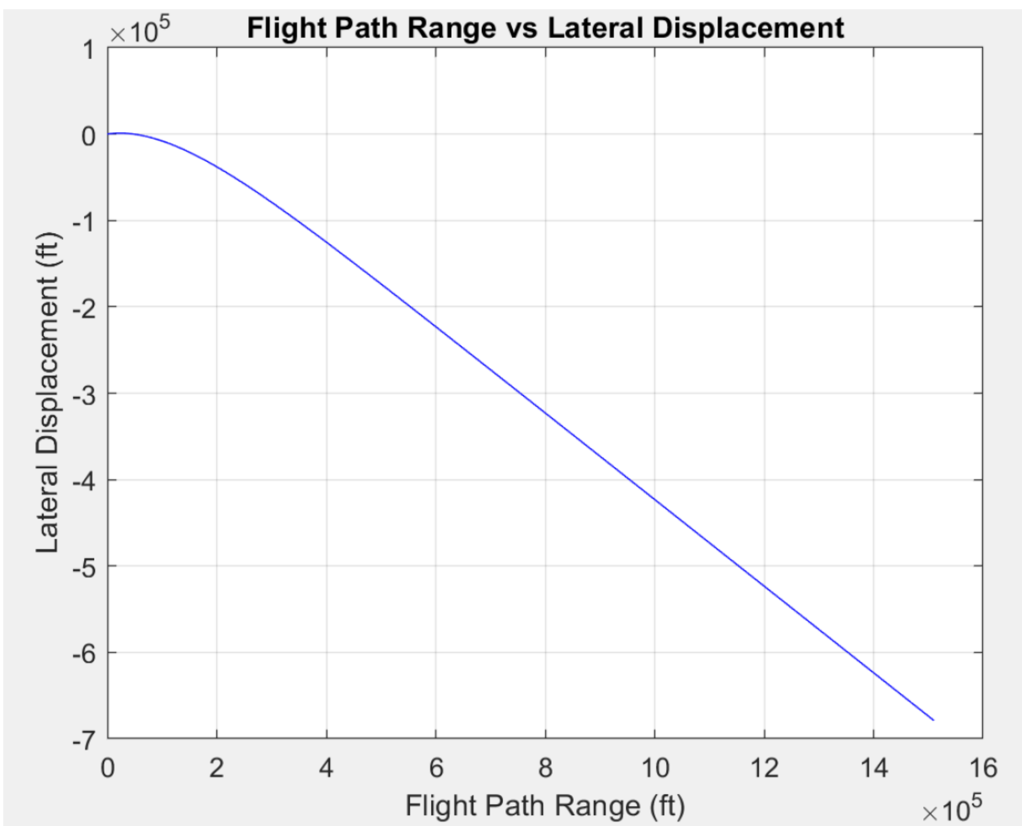
Prepare a SIMULINK simulation circuit for the Boeing B727 aircraft using the equations of motion given above. A trajectory module is required to be made available that will allow system plots of flight path range vs altitude and flight path range vs lateral displacement, or you may incorporate your own. Upon completion of your overall simulation circuit with appropriate debugging perform the following simulation tasks.

a) All initial conditions set to zero except alpha. Set initial condition for alpha at 0.1 rad. Keep all control inputs set to zero. Show plots for the trajectory of flight path range vs altitude.
b) All initial conditions set to zero except beta. Set initial condition for beta at 0.1 rad. Keep all control inputs set to zero. Show plots for the trajectory of flight path range vs lateral displacement.



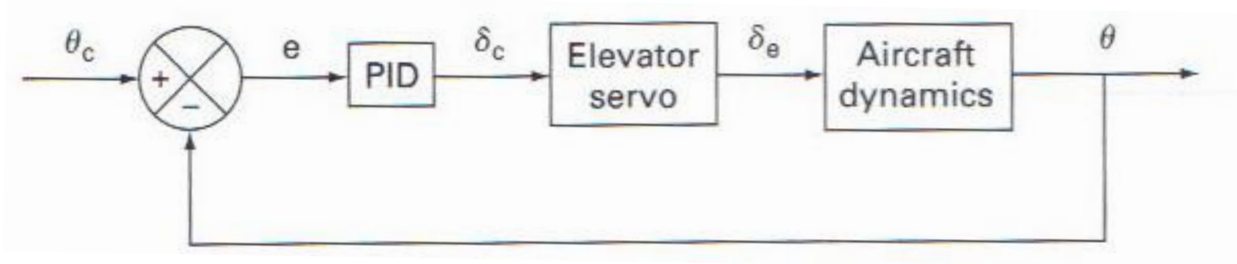

832
1/s
832
f(u)
1/s


Flight Path Range vs Altitude
$\times 10^4$
Altitude (ft)
2.9
2.85
2.8
2.75
2.7
2.65
2.6
0 2 4 6 8 10 12 14 16 18
Flight Path Range (ft)
$\times 10^5$

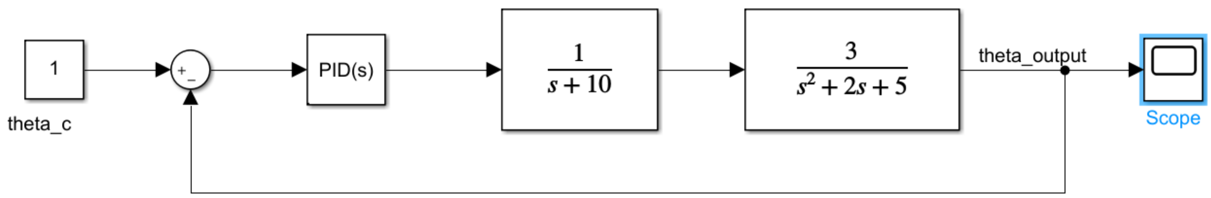

Flight Path Range vs Lateral Displacement
$\times 10^5$
Lateral Displacement (ft)
1
0
-1
-2
-3
-4
-5
-6
-7
0 2 4 6 8 10 12 14 16
Flight Path Range (ft)
$\times 10^5$

Problem 3. (30pts)

For an Autopilot system shown below with $\frac{\Delta\theta}{\Delta\delta_c(s)} = \frac{3}{(s+10)(s^2+2s+5)}$, design a PID controller using the Control System Tuner Toolbox such that when tracking the input signal θ_c, the system has a second order approximation with time constant =1 sec, overshoot less than 5%, and steady state error less than 10%.



The Simulink model of the autopilot is:



From the control system tuner toolbox, I have the PID set as: