AME532a Group Presentation

ASW28 Model Controller Design and Simulation

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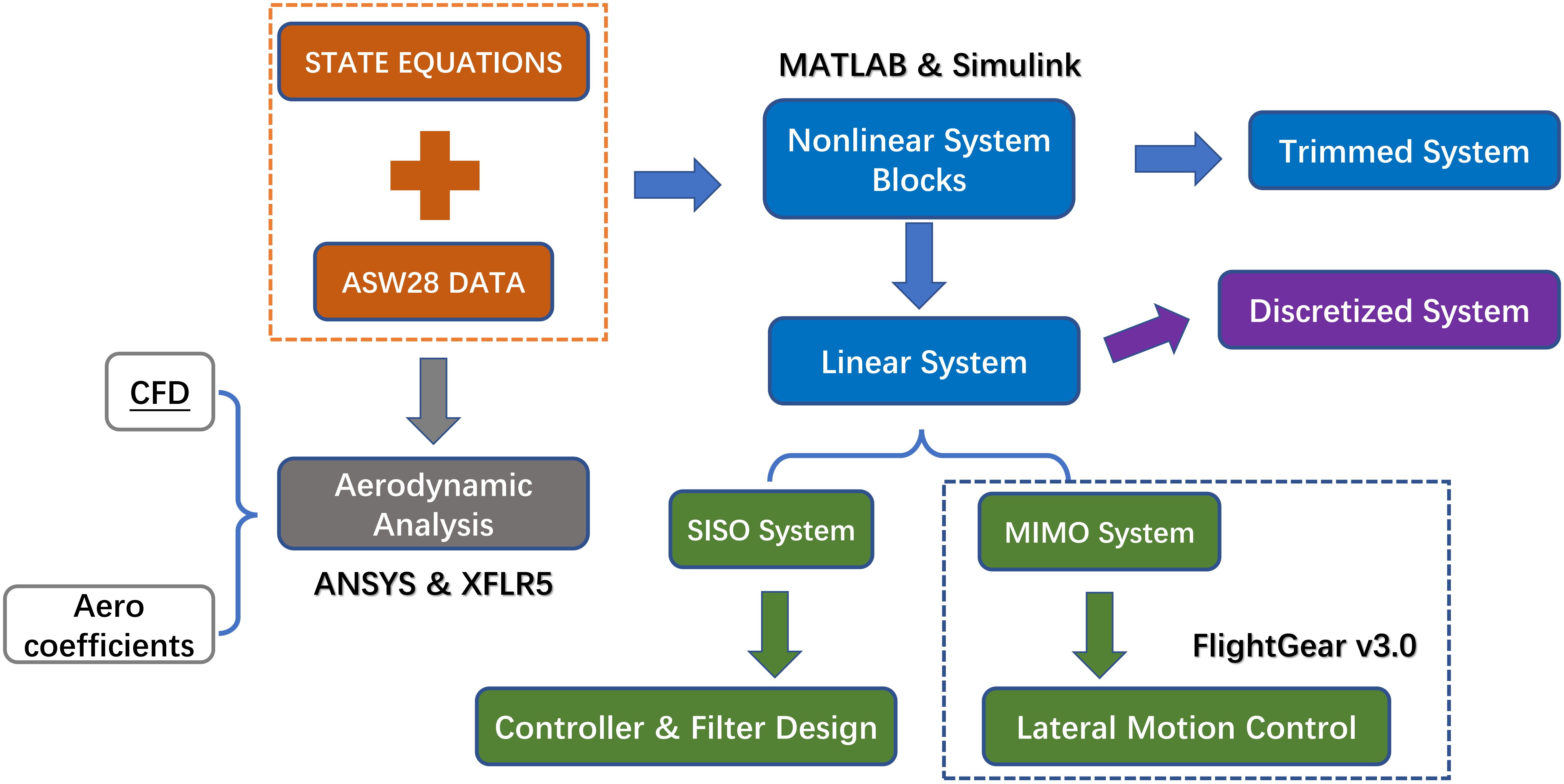
04/30/2020

Contents

Design Diagram

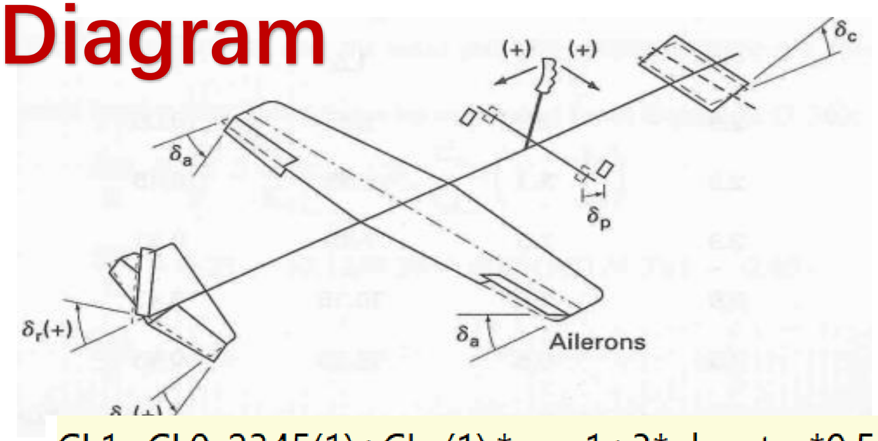


System Overall Block Diagram

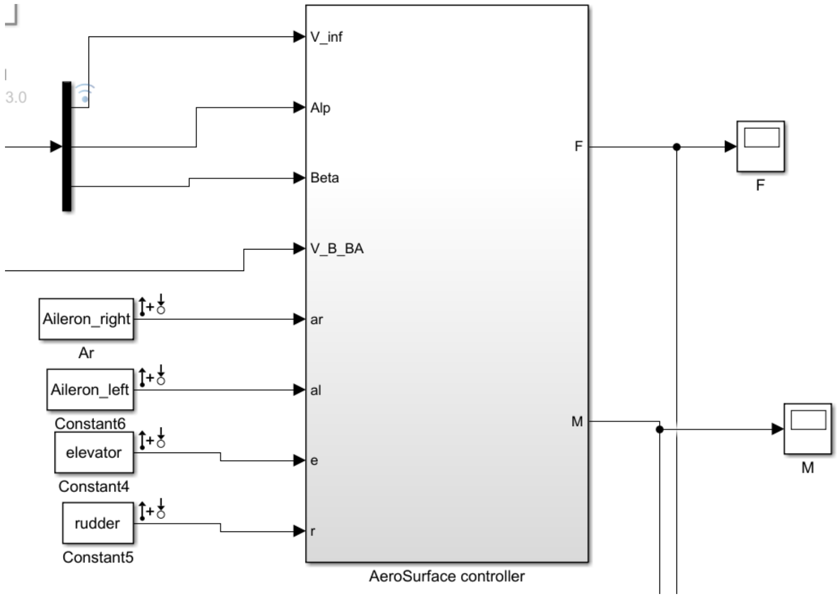
① Basic Control Blocks

② Attached Control Blocks(AeroSurf & Propeller)

System Block Diagram



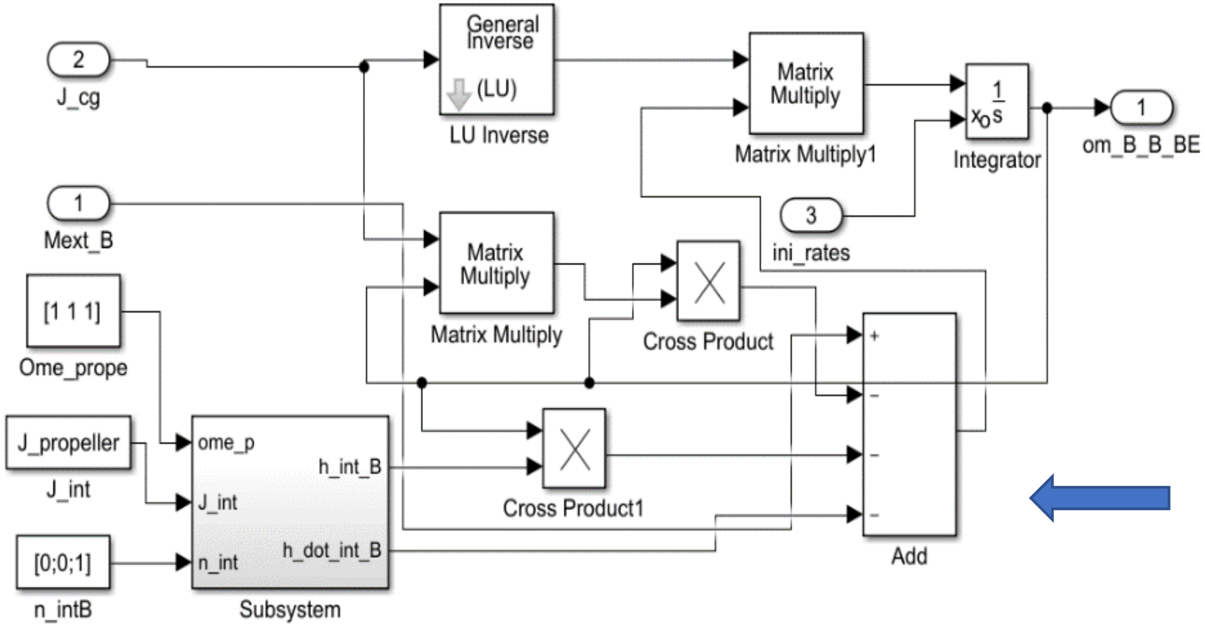

```
CL1=CL0_2345(1)+CLa(1).*a_ss1+3*elevator*0.5;
CL2=CL0_2345(2)+CLa(2).*a_ss2+3*rudder*0.5;
CL3=CL0_2345(3)+CLa(3).*a_ss3+3*aileron_r*0.5;
CL4=CL0_2345(4)+CLa(4).*a_ss4+3*aileron_l*0.5;
```

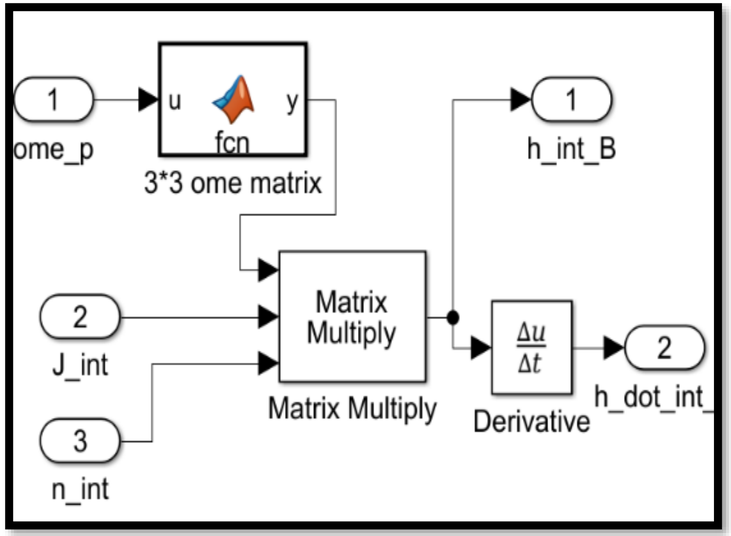


Basic Control Blocks

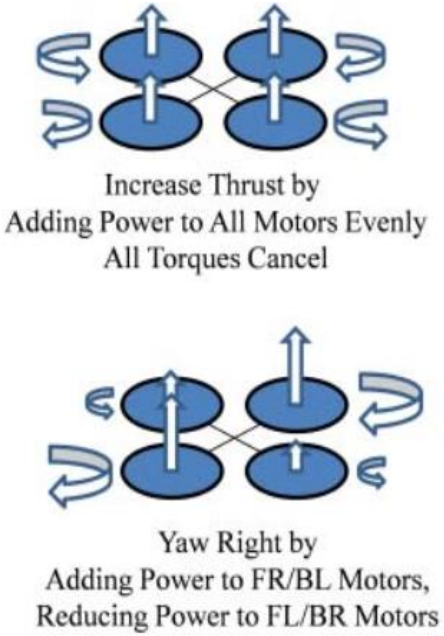
- Translational Kinematics
- Translational Dynamics
- Rotational Kinematics
- Rotational Dynamics

Propeller Control Diagram





Aero-Surface Control

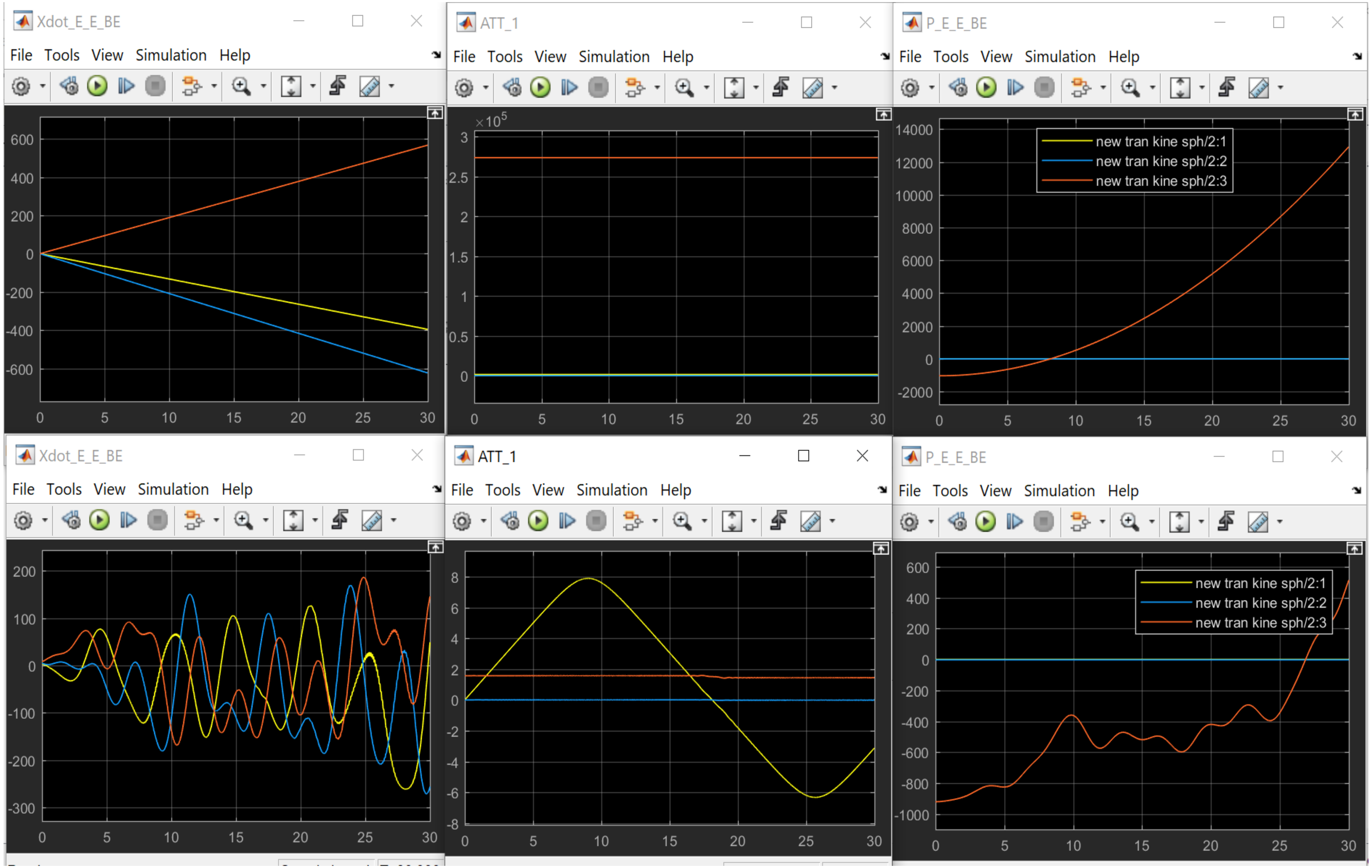


Non-linear System

① Trimmed Model

② PID Controller Design for System Damping

Model Trimming

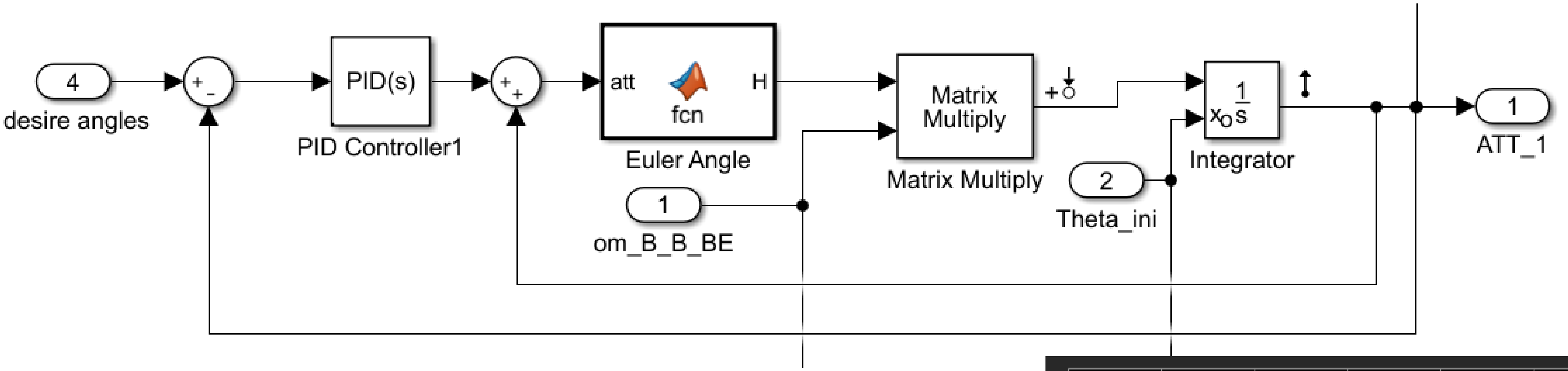


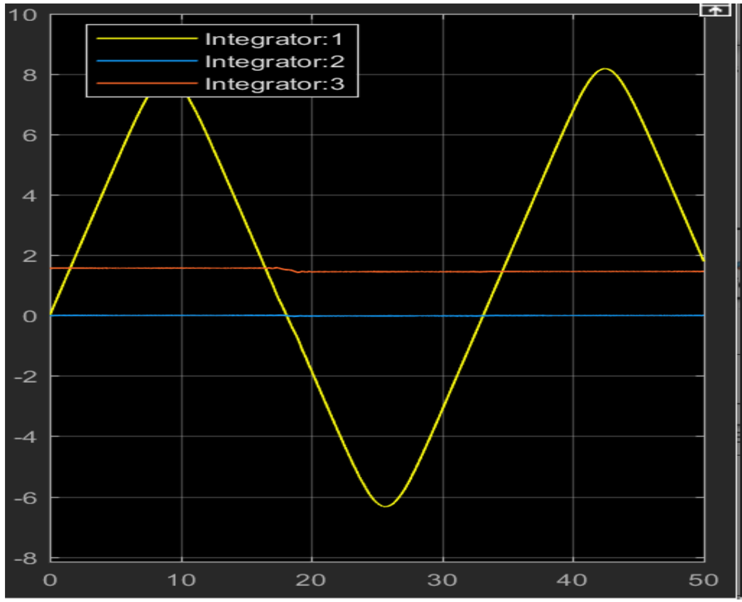
◆ Trimmed Model

◆ Untrimmed Model

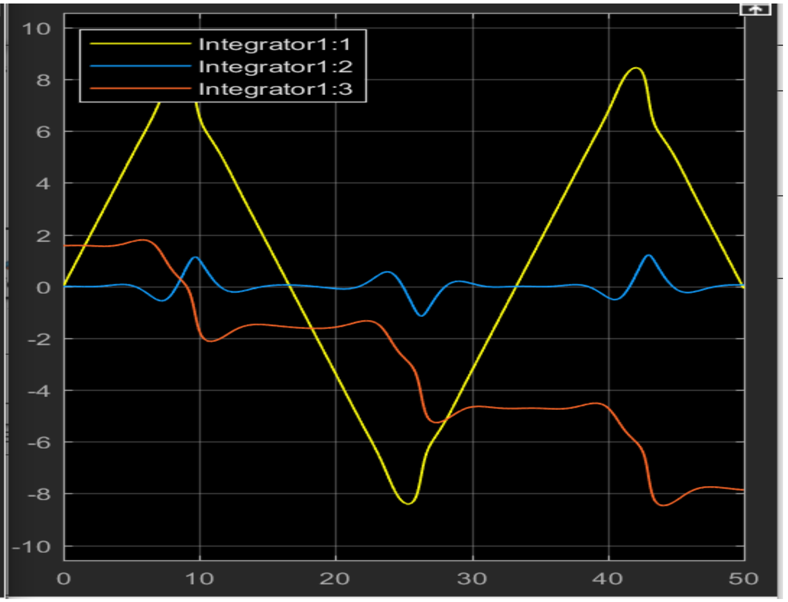
☐ Trimmed States [Alt, Phi, Psi, V, P, Q, R]

PID Controller Design for System Damping

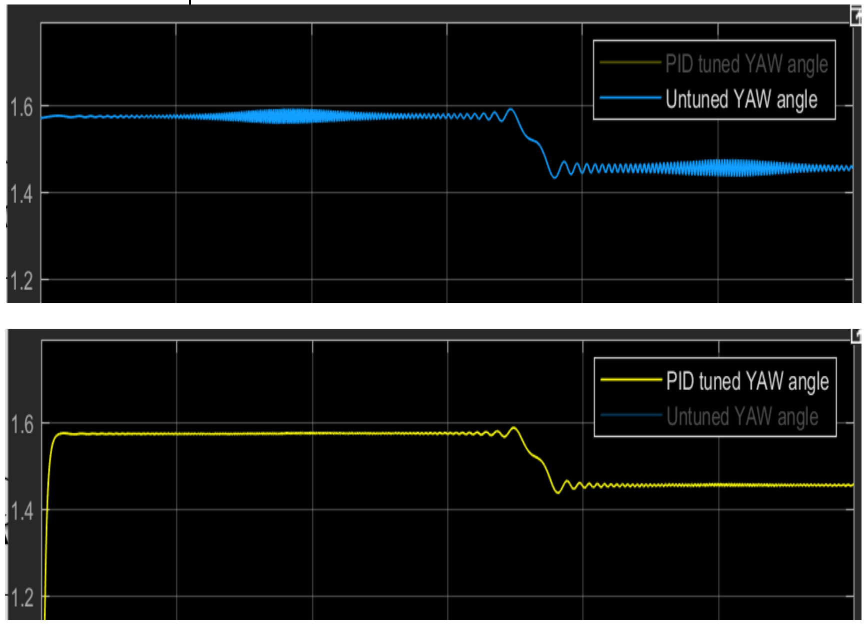




◆ **With PID**



◆ **Without PID**



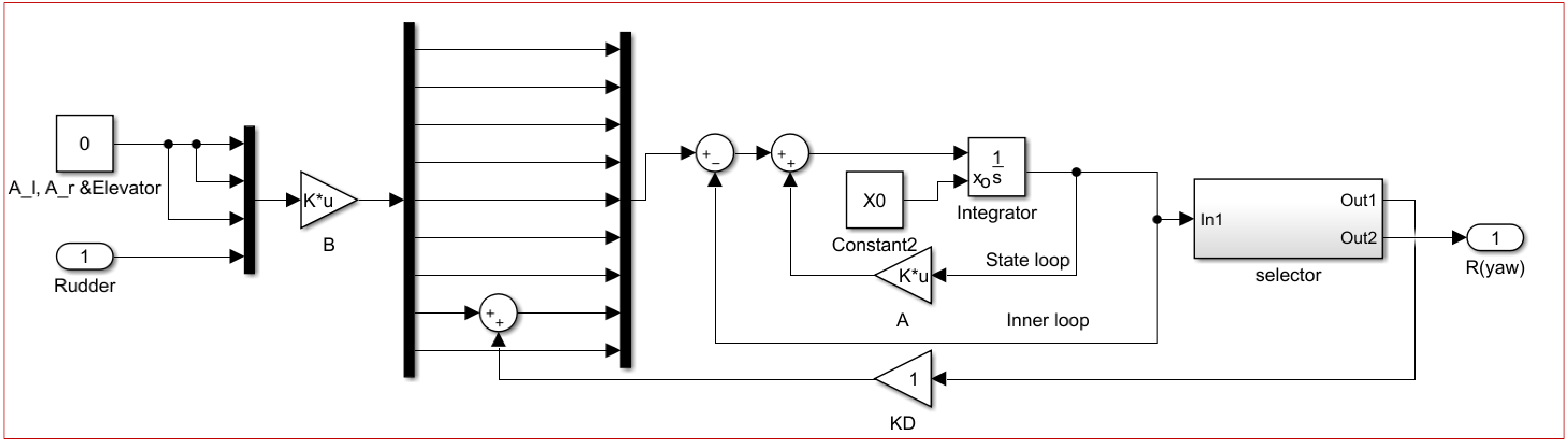
◆ **Yaw Angle Tuned**

System Linearization

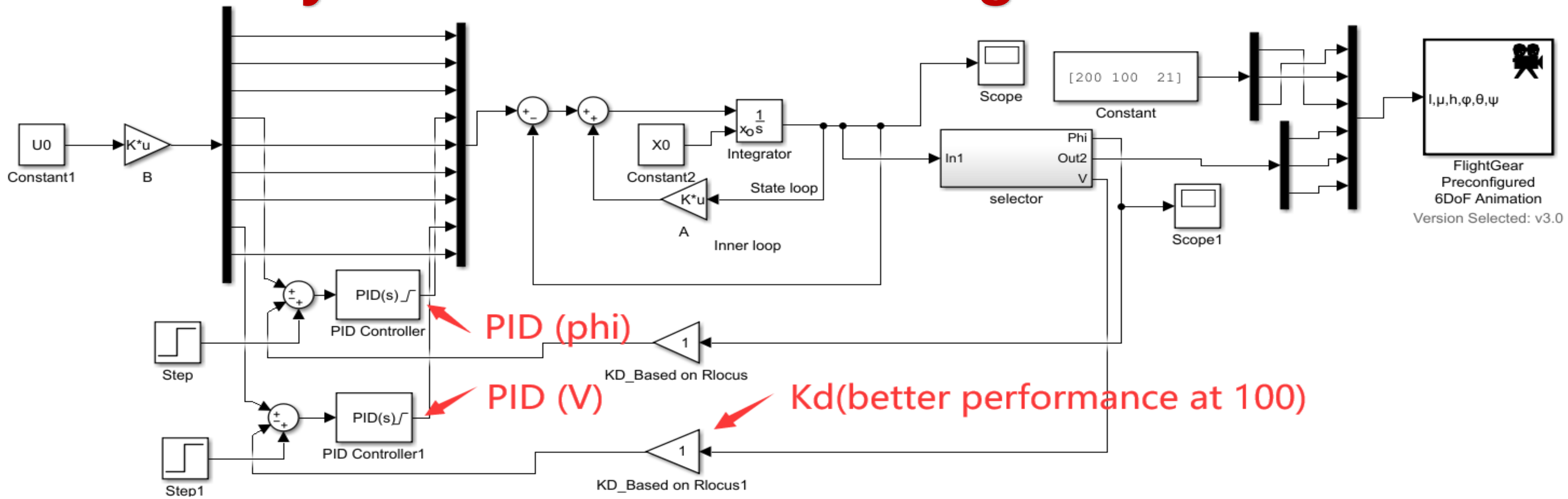
① Linearized System Behaviors & PID design
② Steady State Analysis.
③ Lateral Motion Control (Wash out Filter).
④ System Discretization

Model Linearization

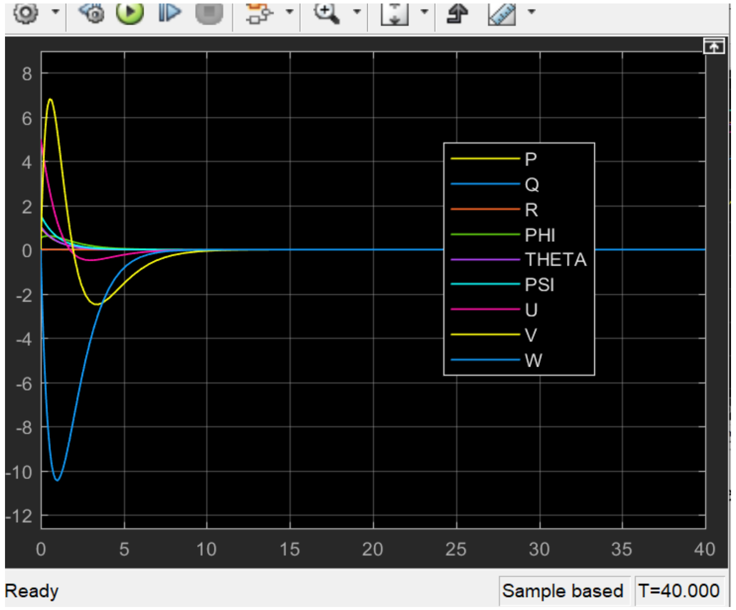
A	P	Q	R	PHI	THETA	PSI	U	V	W	Wash out
P_dot	-1	0.00017	-0.000284	0	0	0	-2.56E-06	-7.97E-06	3.61E-06	6.88E-09
Q_dot	9.76E-07	-1	0.004509	0	0	0	-0.00094	0.0007193	-0.001111	1.18E-07
R_dot	0.00011	0.00178	-1	0	0	0	-4.48E-05	-0.000135	6.26E-05	-3.80E-08
PHI_dot	1	0.3858	-0.8841	-1	0.000664	0	0	0	0	0
THETA_dot	0	-0.9165	-0.3999	-0.000344	-1	0	0	0	0	0
PSI_dot	0	0.5557	-1.273	-0.000229	0.000461	-1	0	0	0	0
U_dot	0	-0.00335	0.002001	-3.476	-2.786	3.102	-0.9998	-0.000298	-0.0001301	-8.55E-09
V_dot	0.003349	0	0.002582	-30.67	-2.13	30.73	0.0002746	7.64E-05	0.00463	7.35E-09
W_dot	-0.002	-0.00258	-1.24E-09	-1.42E-10	-22.26	-3.329	0.0001314	-0.004547	-1	6.18E-09
Wash out	0	0	1	0	0	0	0	0	0	-5.00E+00



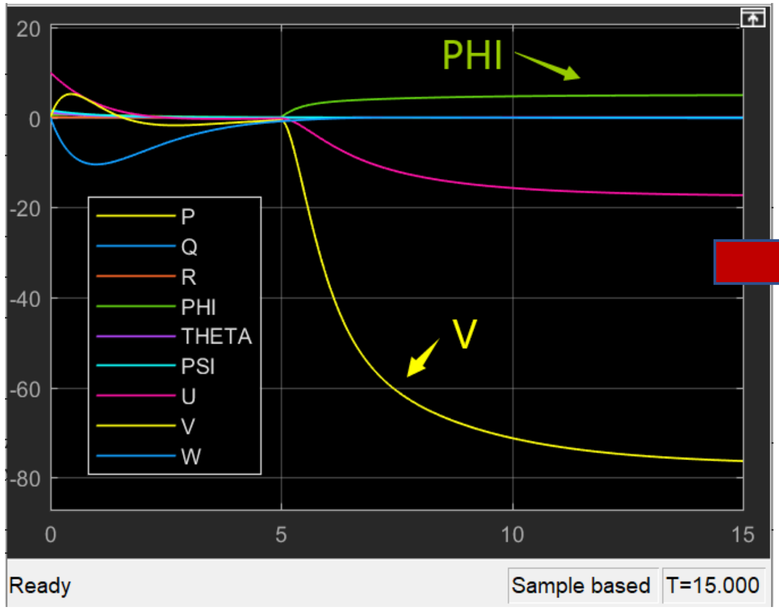
Linearized System Controller Design



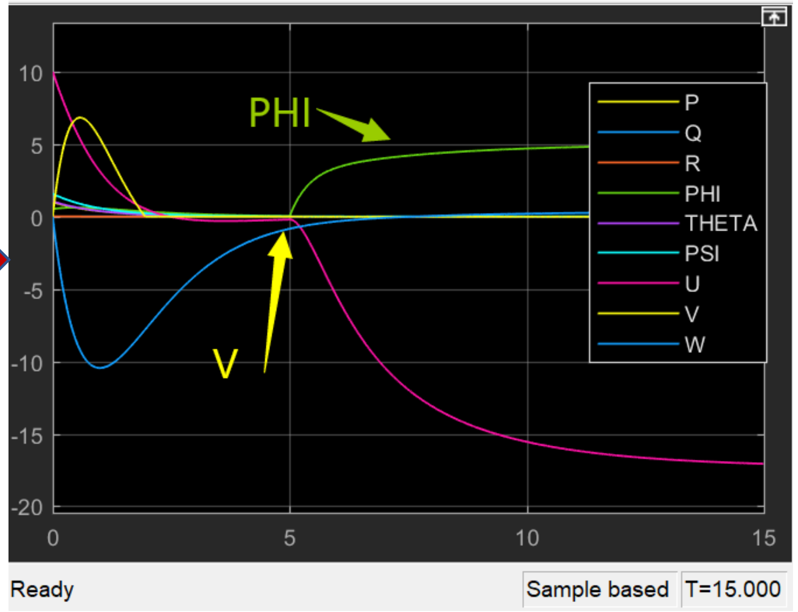
◆ No PID Applied



◆ PID only applied to ‘phi’



◆ PID applied to ‘phi’ &’V’



Steady State Analysis.

Oscillatory Mode

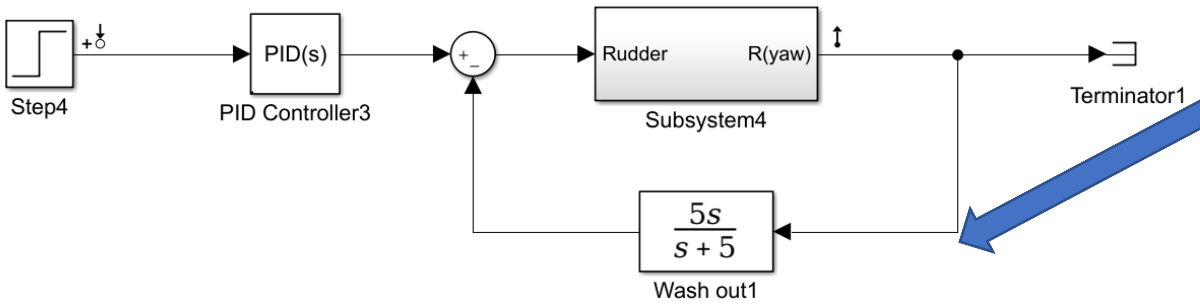
$$\lambda = \begin{cases} -\zeta\omega_n \pm \omega_n\sqrt{\zeta^2 - 1} & \text{for } \zeta > 1 \\ -\zeta\omega_n & \text{for } \zeta = 1 \\ -\zeta\omega_n \pm i\omega_n\sqrt{1 - \zeta^2} & \text{for } \zeta < 1 \end{cases}$$

Short-period			Dutch Roll Mode		
-0.86282	+	0.25016i	-1.0241	+	0.058674i
-0.86282	-	0.25016i	-1.0241	-	0.058674i
Damping Ratio		0.96045	Damping Ratio		0.99836
Natural Freq (rad/s)		0.89835	Natural Freq (rad/s)		1.0258
Time Period (s)		6.9906	Time Period (s)		6.1221

Stable Exponential Mode

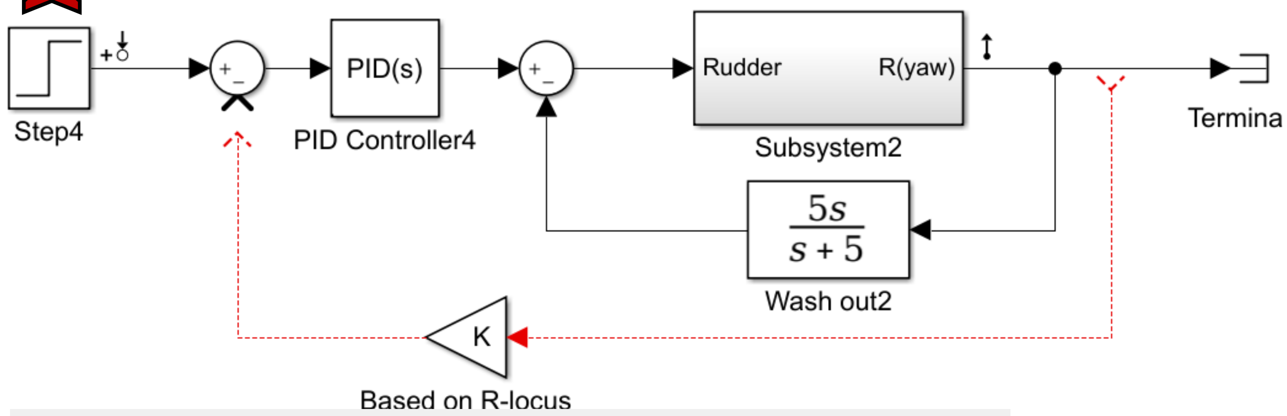
$$\lambda_{roll} = -\frac{1}{\tau} = L_p$$

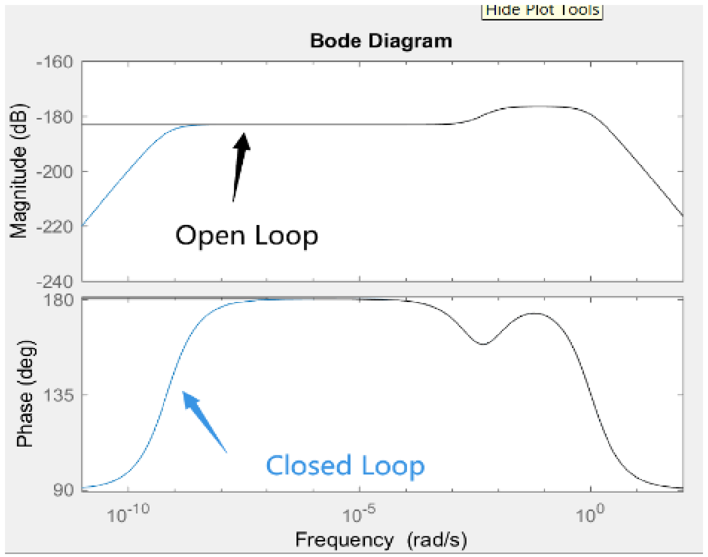
Roll Mode			Time Constant(s)
-1.0002	+	0i	0.99980004
-0.99896	+	0i	1.00104108
-0.9549	+	0i	1.04723008
-1.2786	+	0i	0.78210543
Roll Mode (unstable)			Time Constant(s)
0.0068486	+	0i	146.015244 (Long)
Roll Mode (From Washout)			Time Constant(s)
-5	+	0i	0.2



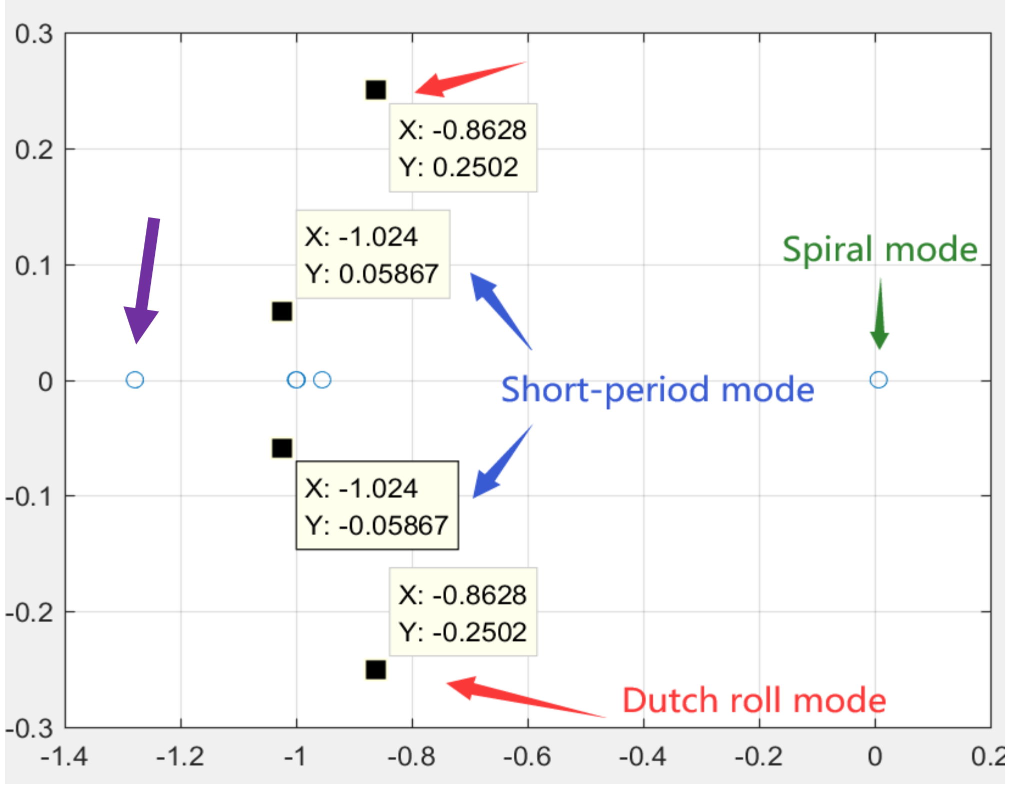
HOW can I change these Dynamic Behaviors?

‘K’ Design Using R-locus

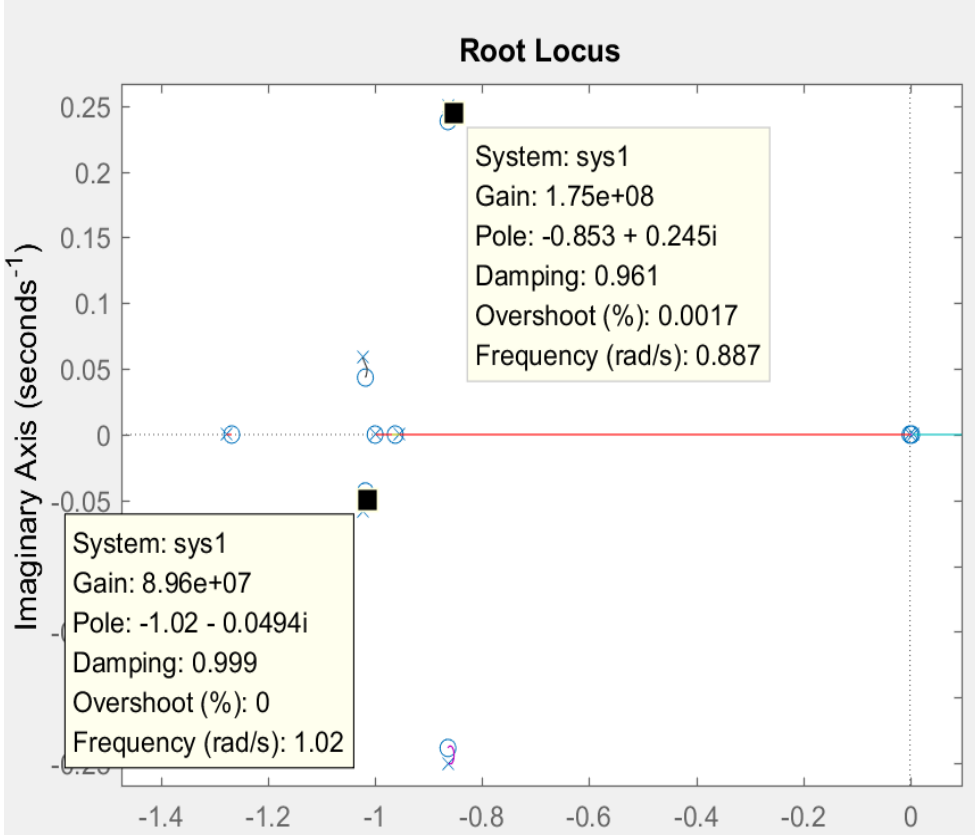




◆ Bode in Freq Domain

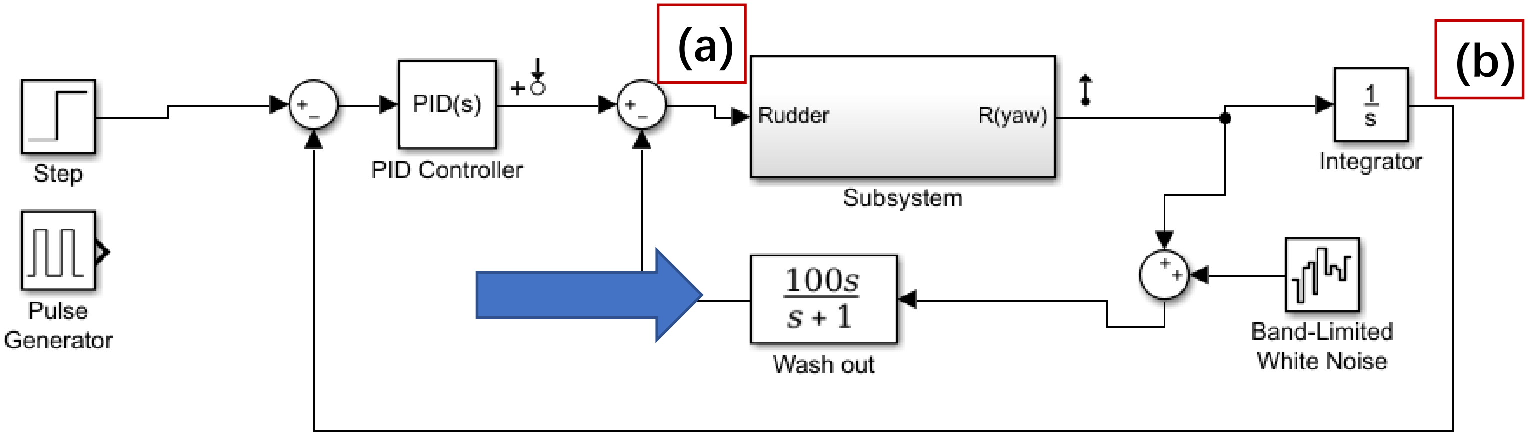


◆ Eigenvalue(A) Distribution



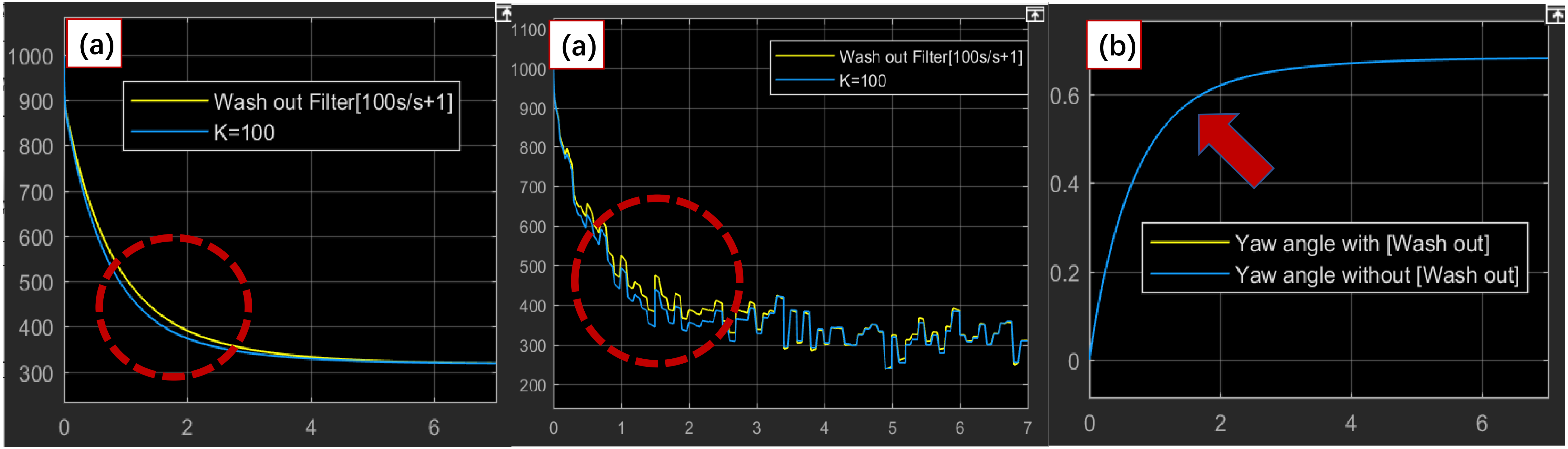
◆ Rlocus in Time Domain

Wash Out Filter



① **Washout Filter** removes slowly-changing component and preserves the fast-changing component in **INPUT**

② **OUTPUT** remains unchanged



Discretized System (Digital Control)

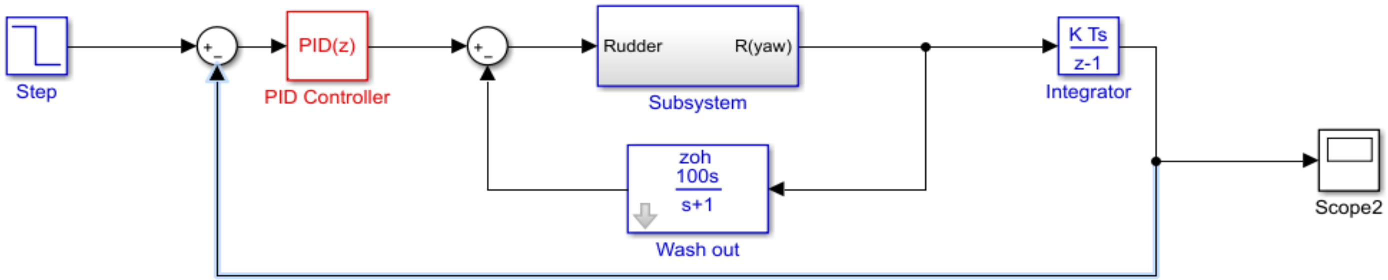


Figure-1 Discrete System

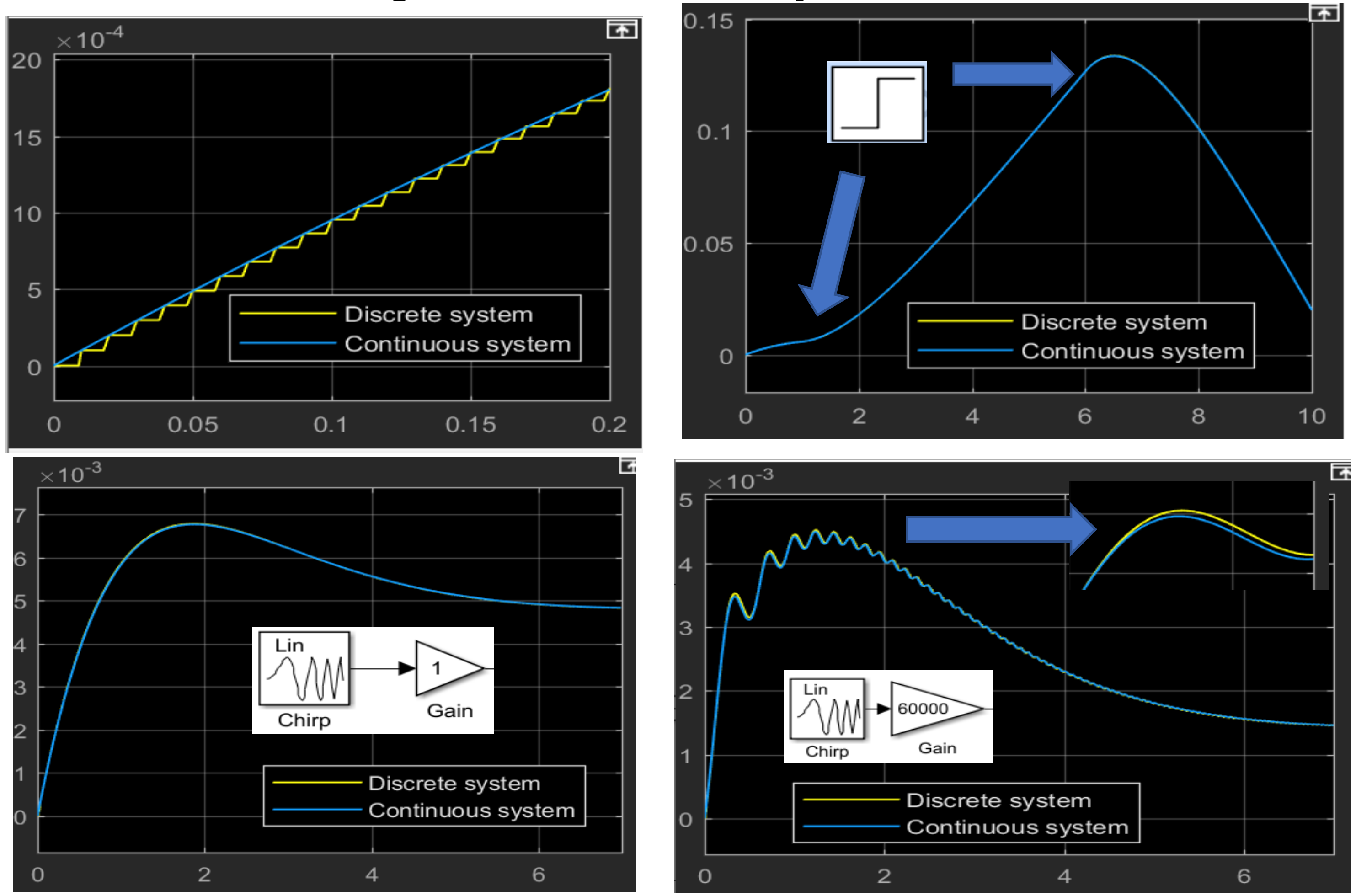


Figure-2 Discrete VS Continuous

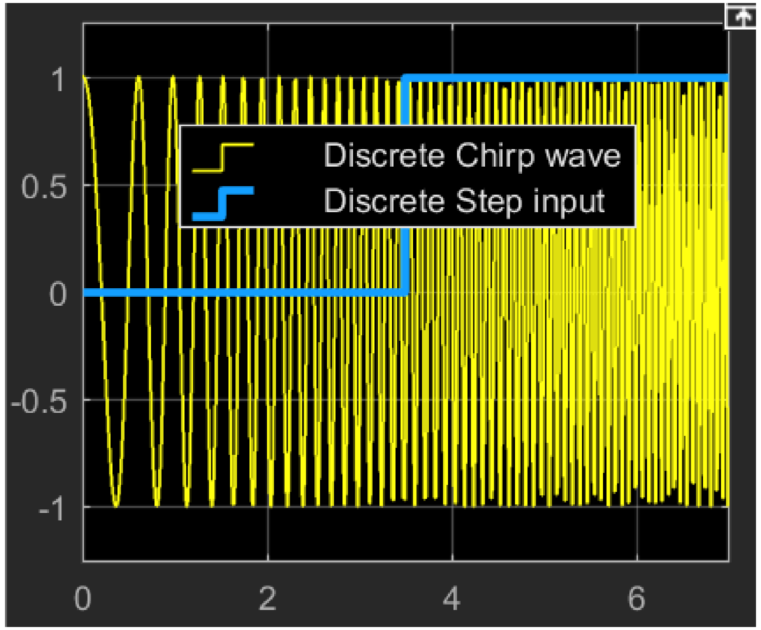


Figure-3 Signals

Signal: STEP & CHIRP

Sample time: 0.01s

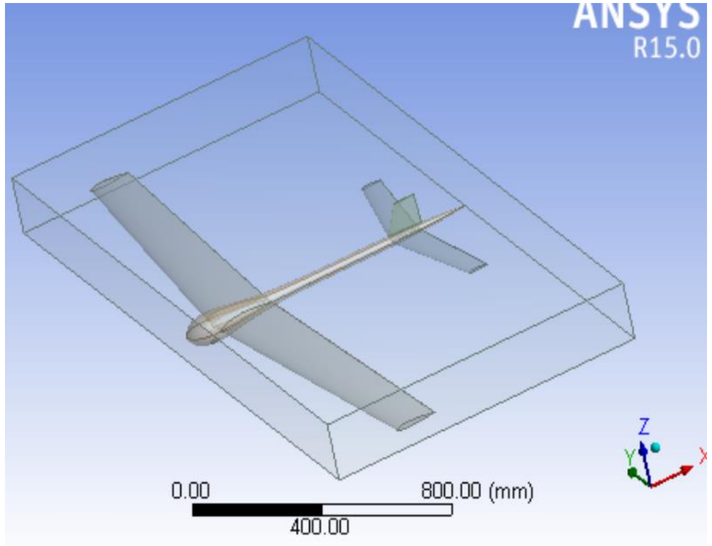
Discrete Method: ZOH

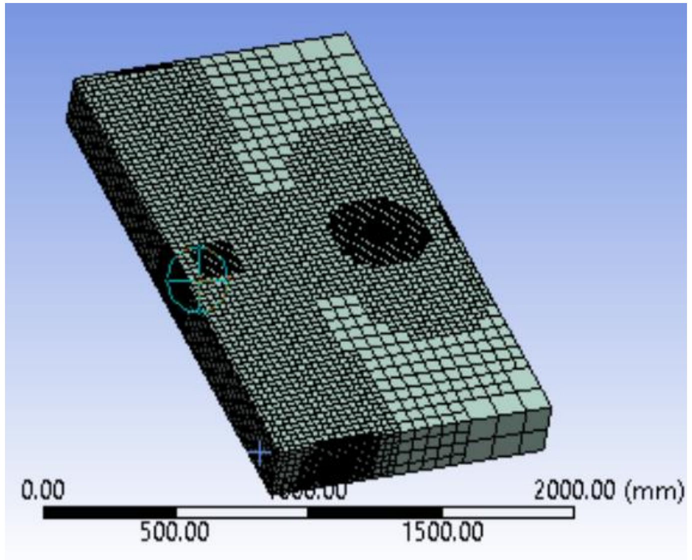
Aerodynamic Analysis for *Sonic Flight*

① FEA in ANSYS
② CFD & Wind Tunnel Analysis in ANSYS
③ Aero-coefficient Comparison (Alpha=Beta=0[deg])

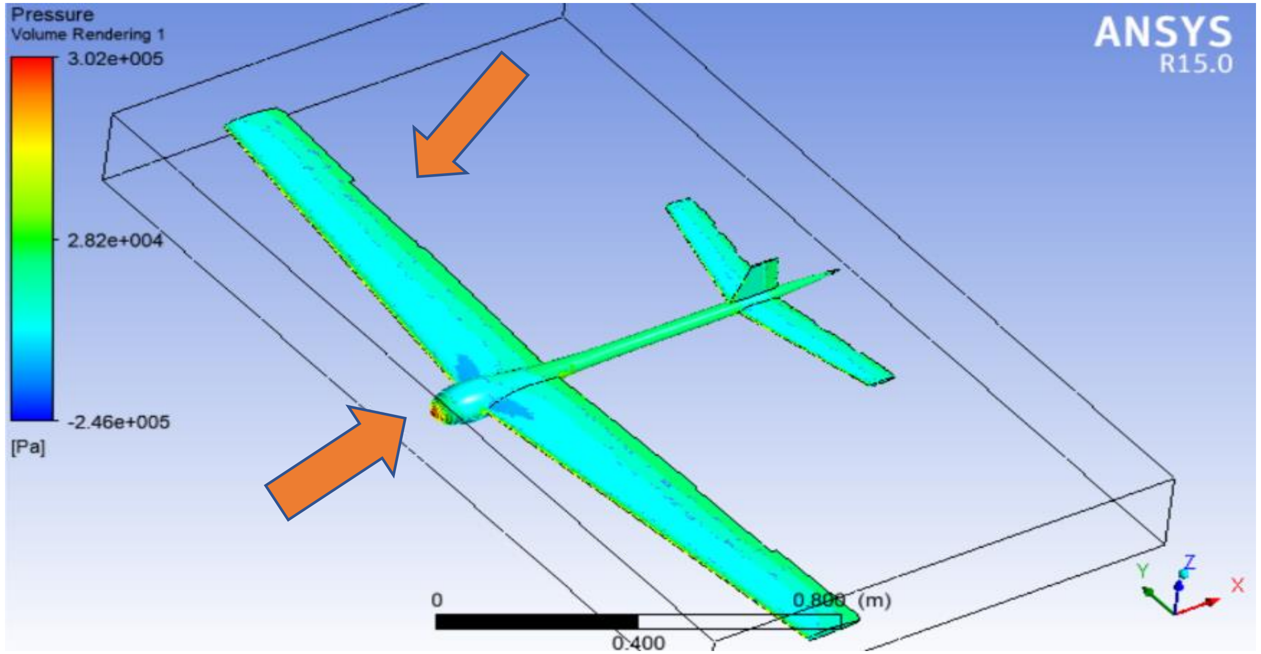
The Aerodynamic Analysis in ANSYS

Model Name	ASW28
Velocity(m/s)	400
Temperature(ºF)	77
Altitude(m)	1000
Air Density(kg/m^3)	1.074

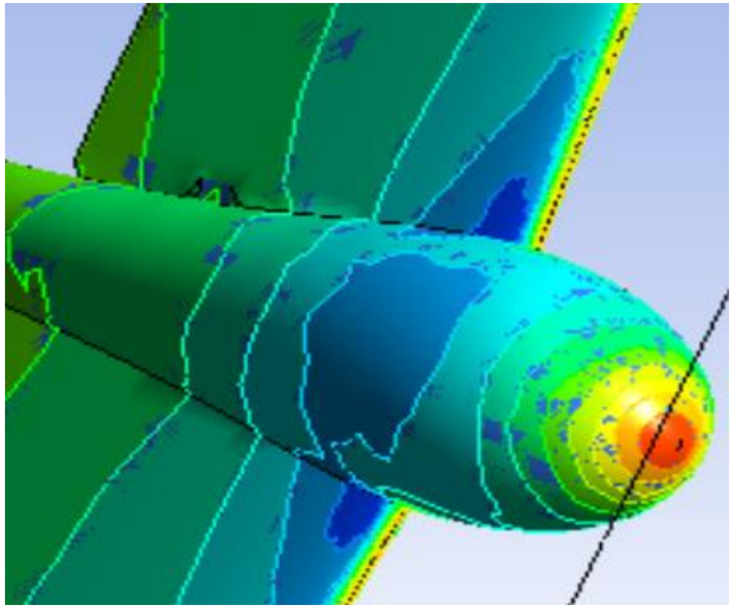




◆ Pressure Distribution



◆ Finite Element Analysis(FEA)



Cephalic Cone

Wind Tunnel & CFD Analysis in ANSYS

◆ Velocity Distribution

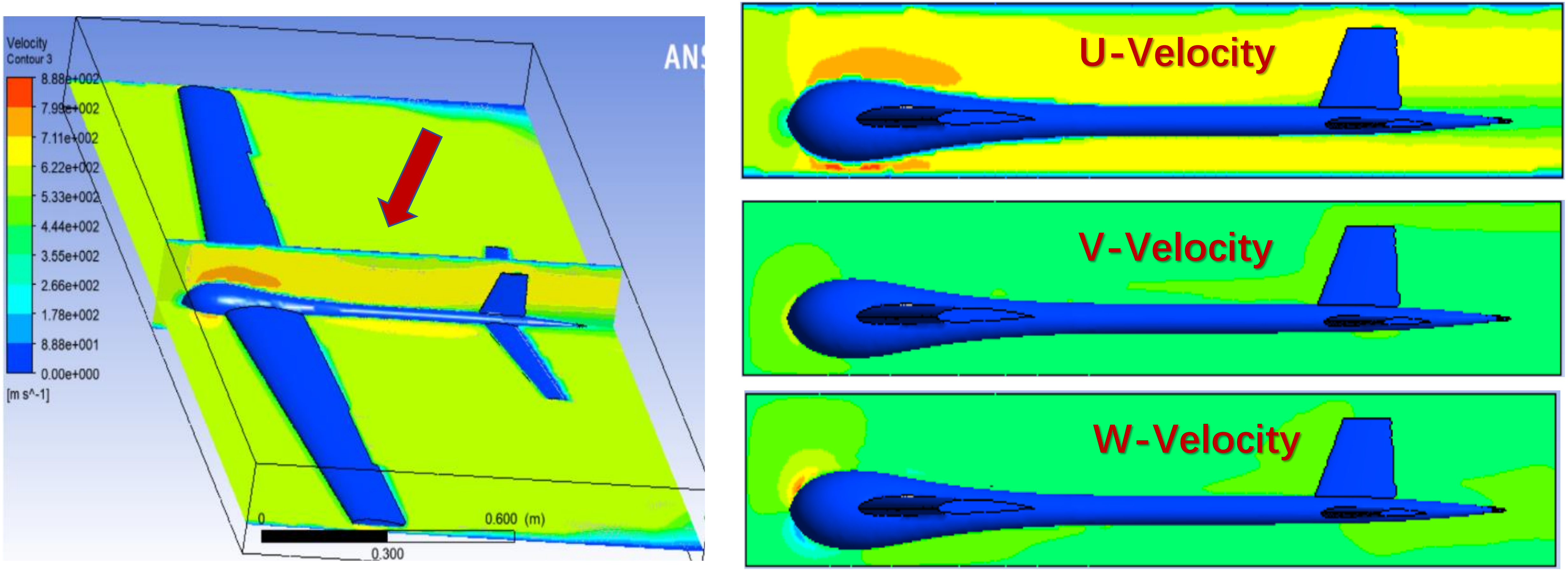
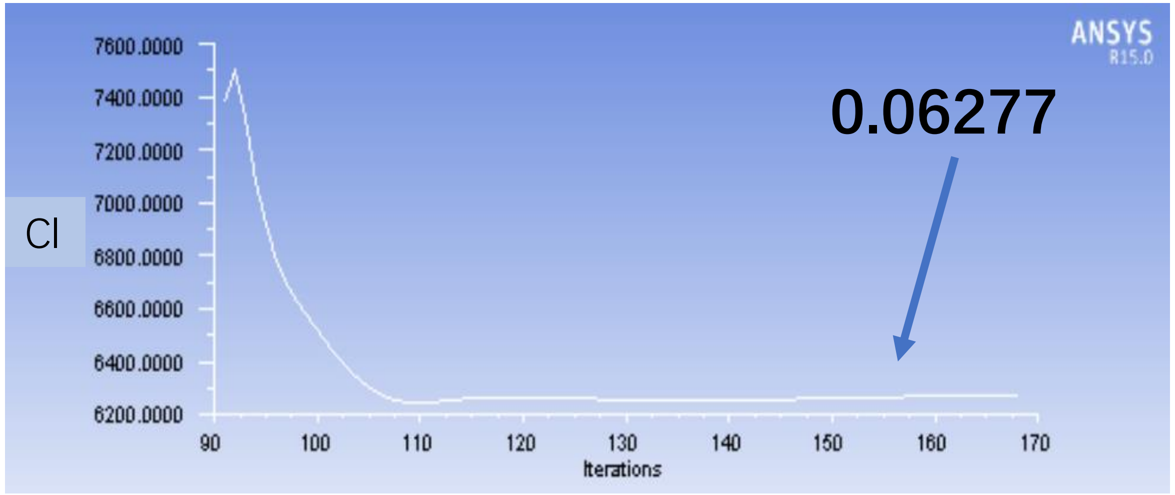
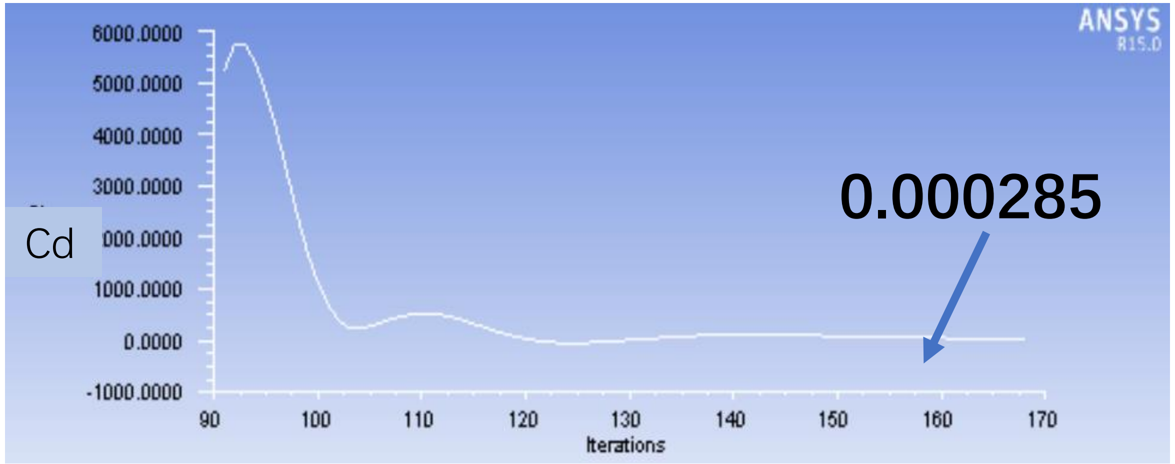


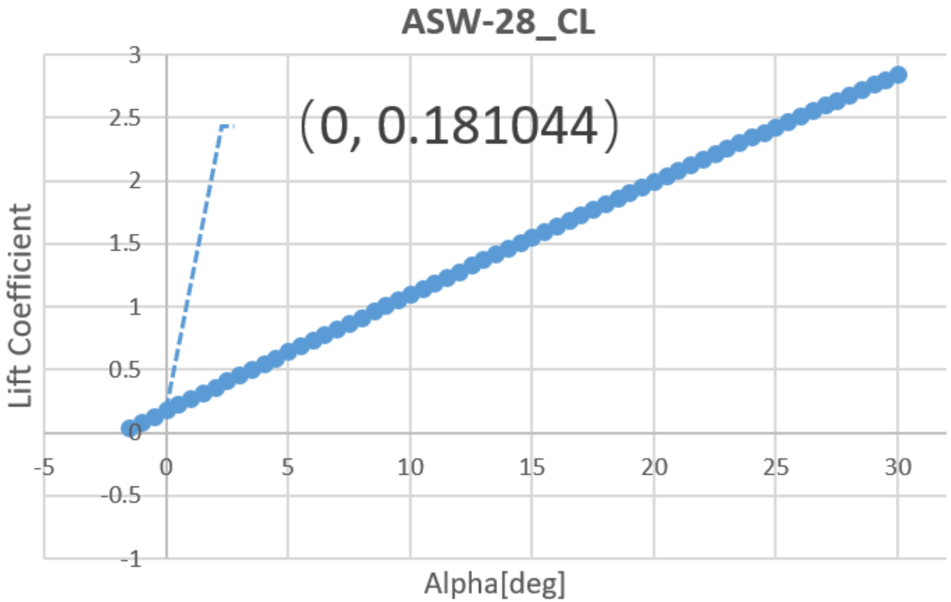
Figure. Velocity Contour (left); [u; v; w] in Longitudinal Symmetry Plane

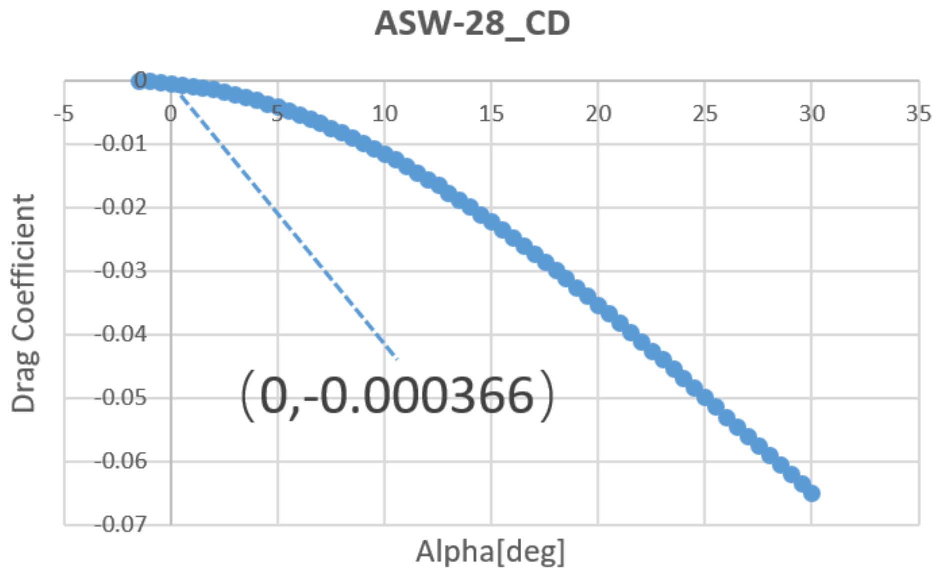
Aero-coefficient Comparison (Alpha=Beta=0[deg])





ANSYS (x-time, y-coefficient)





XFLR5

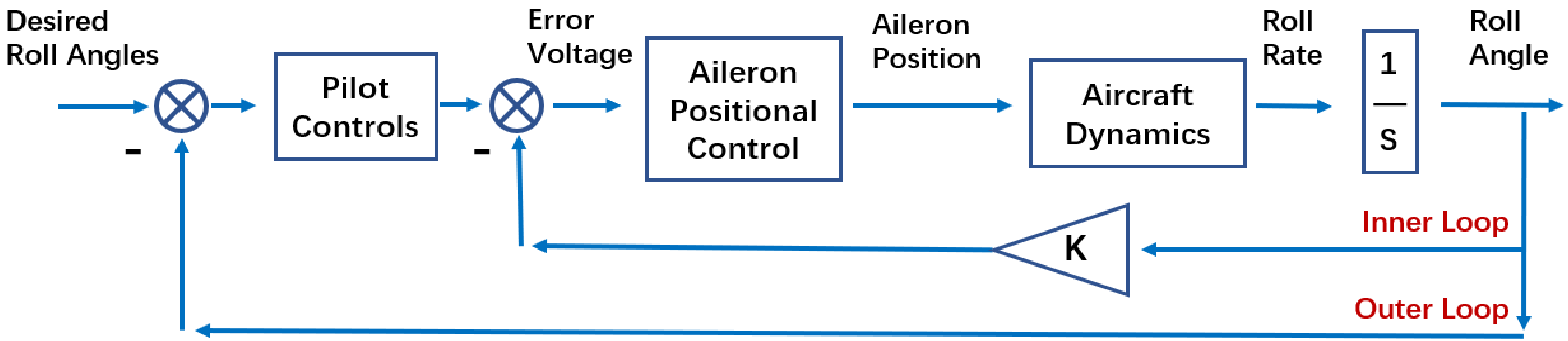
Simulation

① Pilot Control System

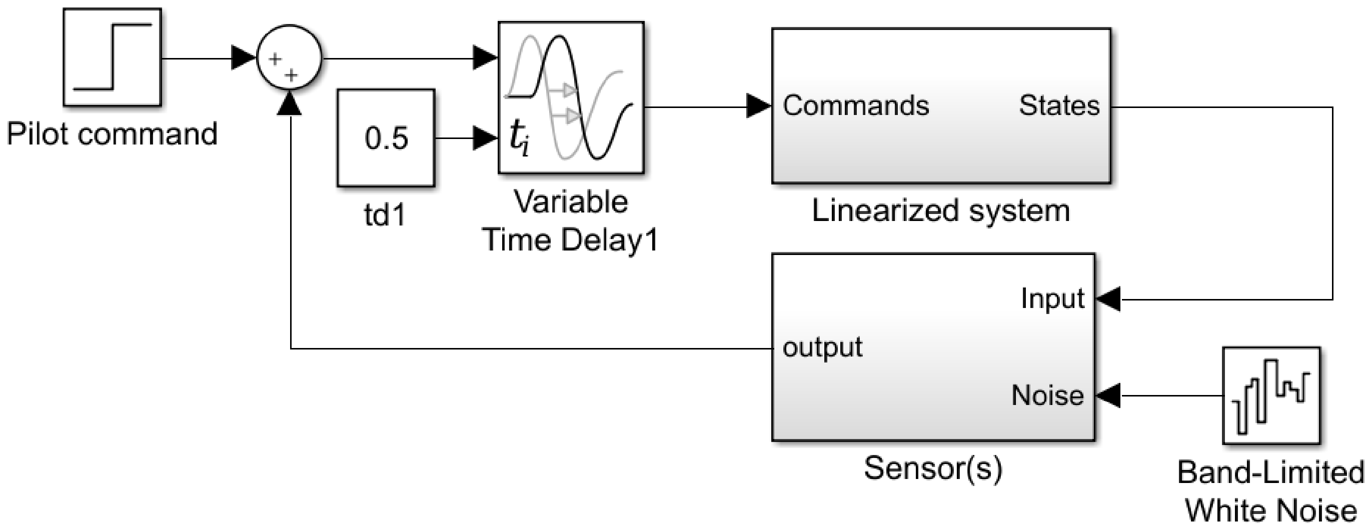
② Skidded to Turn Simulation

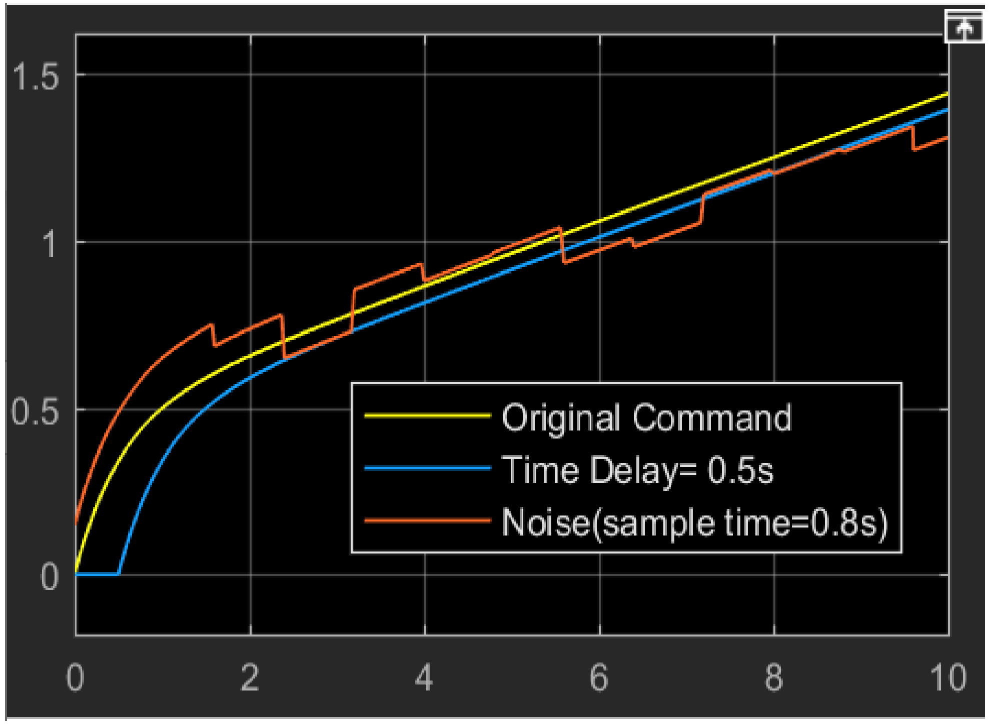
Pilot Control Simulation

➢ Autopilot Roll Angle Control Theorem

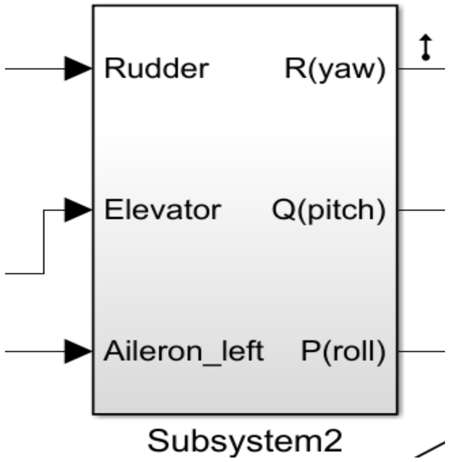


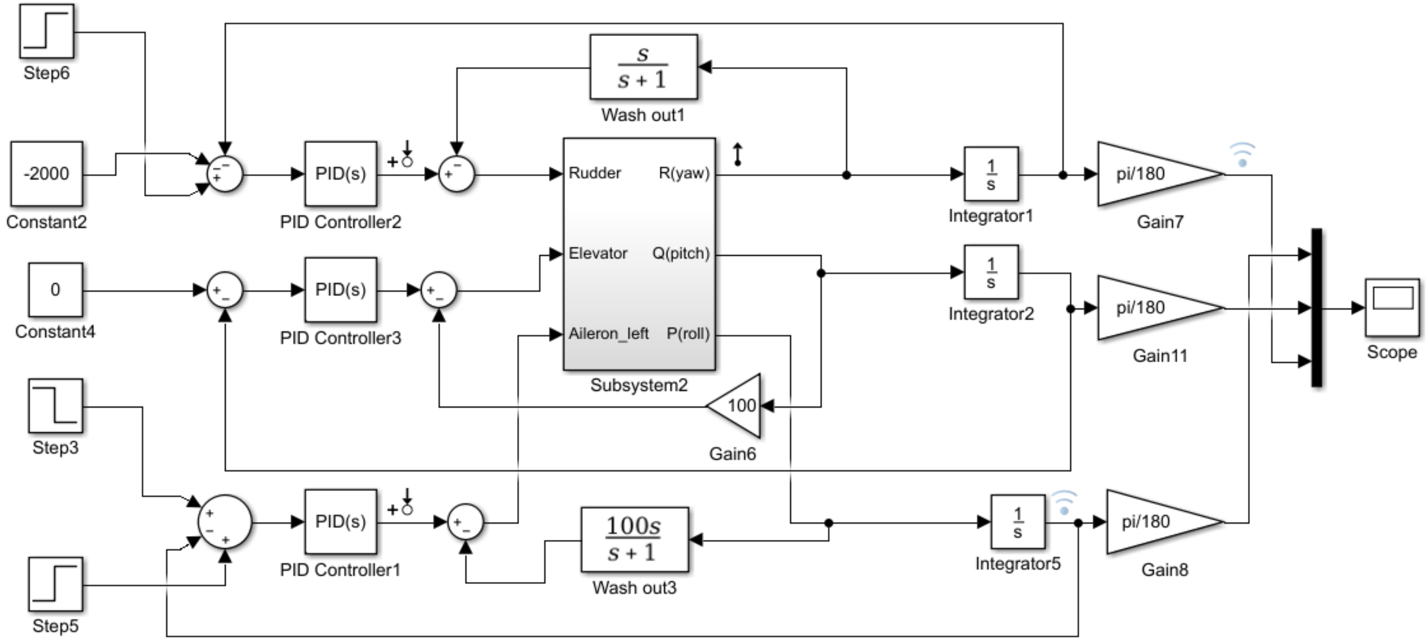
➢ Pilot Control (with Time-delay & Disturbance)



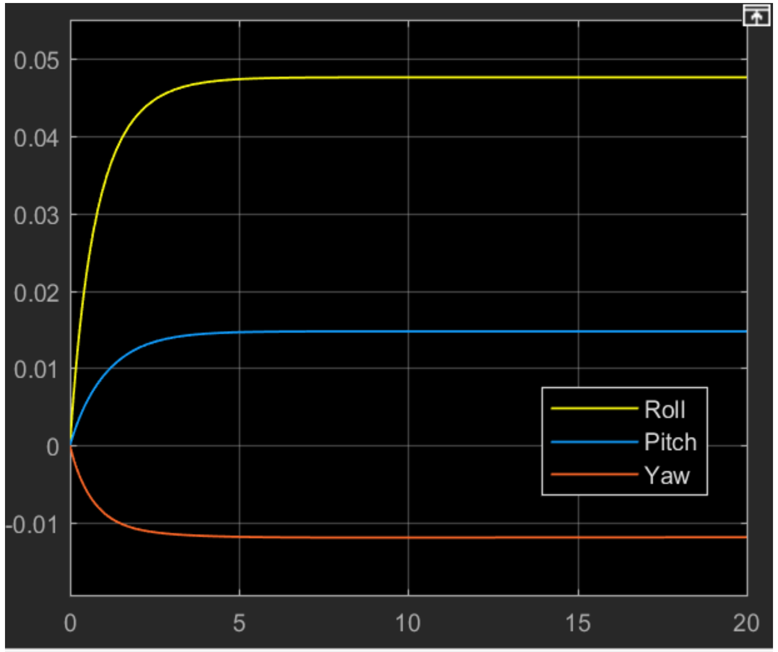


MIMO System Control

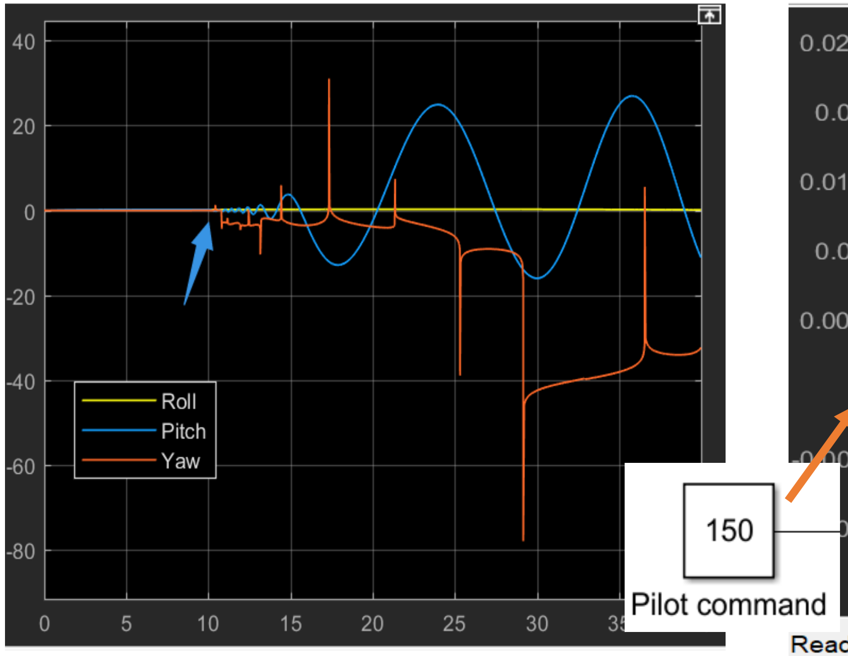




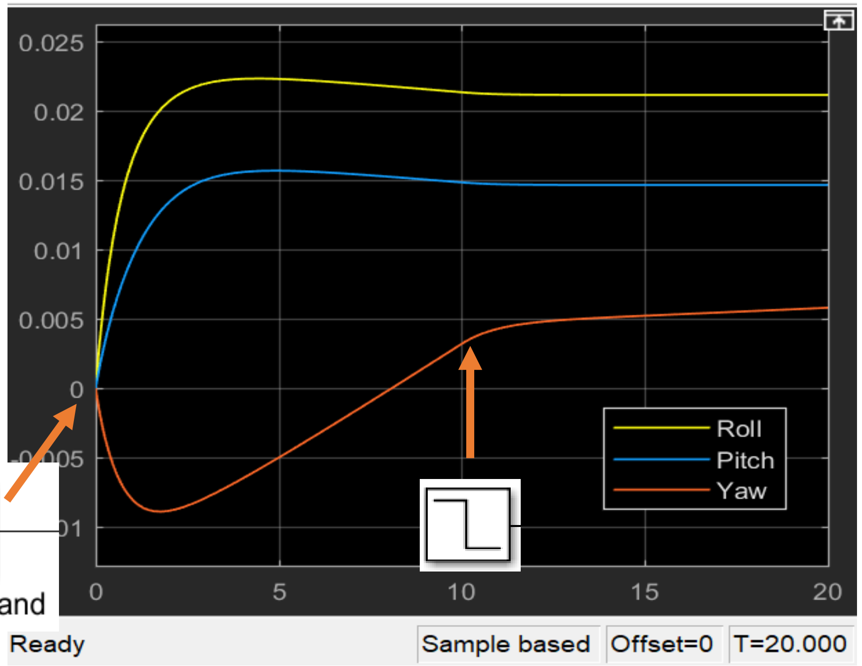
➢ No Signal Input



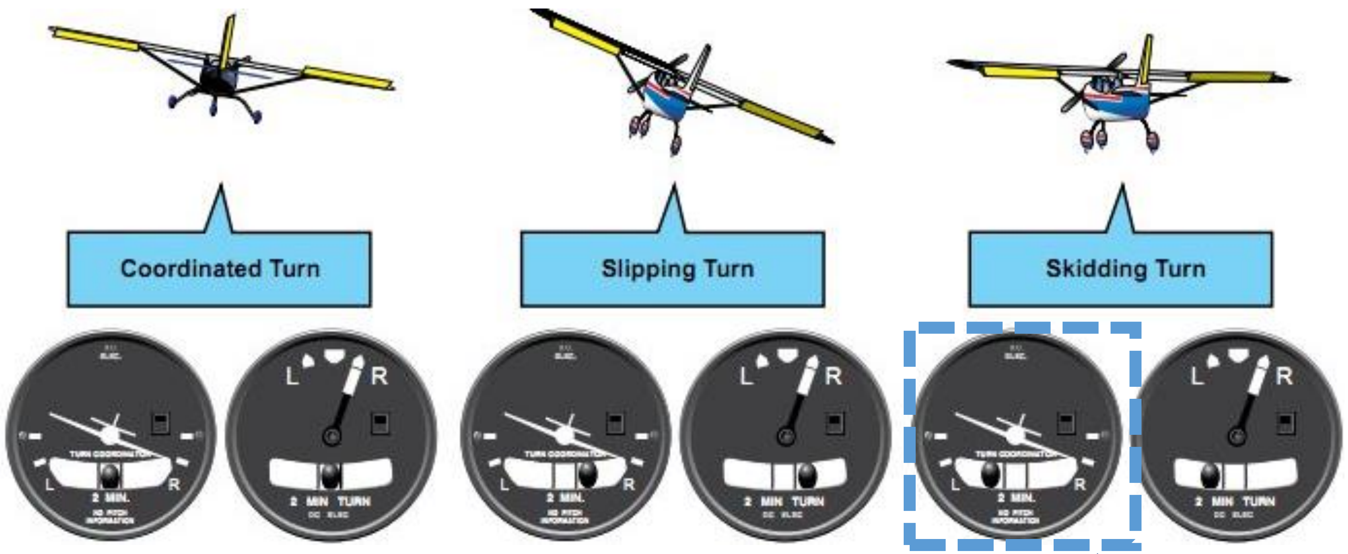
➢ Large Signal Input

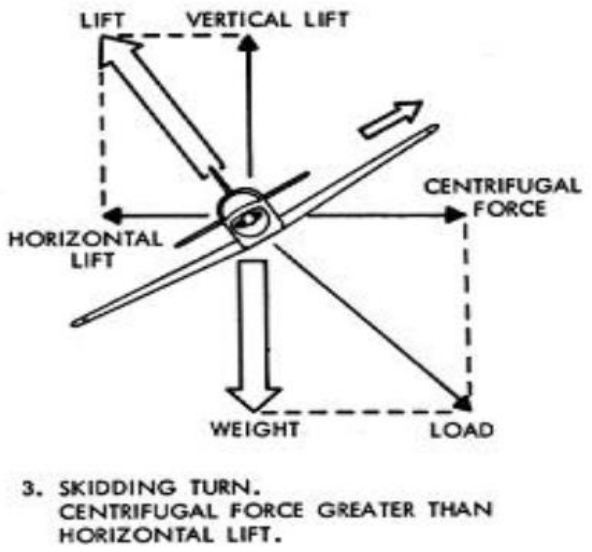


➢ Motion Control

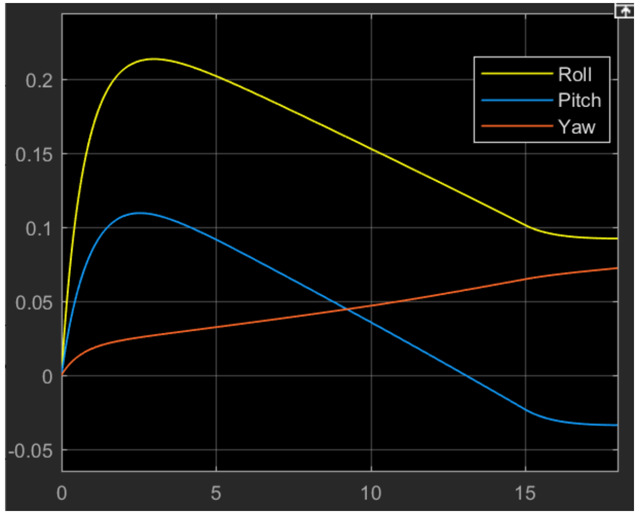


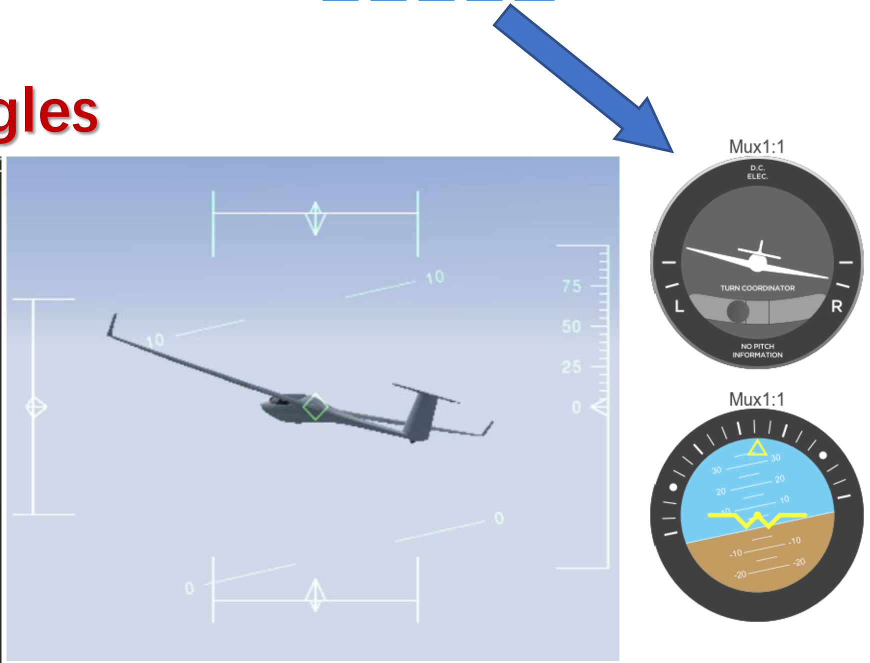
Skid to Turn

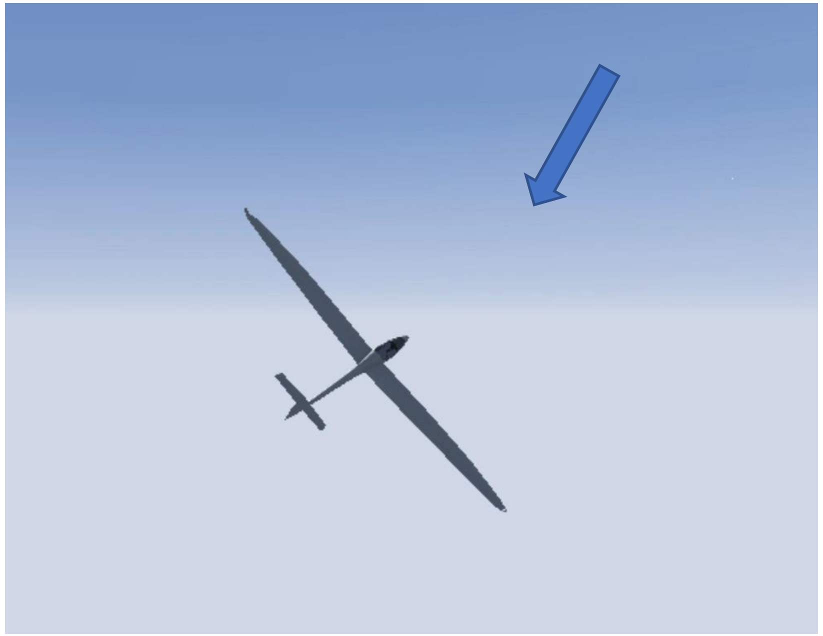




➢ Skid to Turn angles







➢ Skid to Turn Simulation