Symbols

\( c \) \hspace{1cm} \text{Reference length for longitudinal plane dynamics} \hspace{1cm} (m)

\( b \) \hspace{1cm} \text{Reference length for lateral plane dynamics} \hspace{1cm} (m)

\( C_{\ell r} \) \hspace{1cm} \text{Effect of yaw rate on rolling moment coefficient}

\( C_{nr} \) \hspace{1cm} \text{Effect of yaw rate on yawing moment coefficient}

\( C_{mr} \) \hspace{1cm} \text{Effect of yaw rate on pitching moment coefficient}

\( C_{\alpha} \) \hspace{1cm} \text{Static longitudinal stability} \hspace{1cm} (1/\text{rad})

\( C_{Na} \) \hspace{1cm} \text{Aerodynamic normal force coefficient} \hspace{1cm} (1/\text{rad})

\( C_{xu} \) \hspace{1cm} \text{Variation of axial force with respect to } u \hspace{1cm} (s/m)

\( C_{xa} \) \hspace{1cm} \text{Axial force variation with angle of attack} \hspace{1cm} (1/\text{rad})

\( C_{xq} \) \hspace{1cm} \text{Effect of pitch rate on axial force} \hspace{1cm} (s/\text{rad})

\( C_{w} \) \hspace{1cm} \text{Gravity Component} \hspace{1cm} (m/s^2)

\( C_{y\beta} \) \hspace{1cm} \text{Variation of side force with respect to } \beta \hspace{1cm} (1/\text{rad})

\( C_{yp} \) \hspace{1cm} \text{Effect of roll rate on side force} \hspace{1cm} (s/\text{rad})

\( C_{yr} \) \hspace{1cm} \text{Effect of yaw rate on side force} \hspace{1cm} (s/\text{rad})

\( C_{zu} \) \hspace{1cm} \text{Variation of normal force with respect to } u \hspace{1cm} (s/m)

\( C_{z\alpha} \) \hspace{1cm} \text{Normal force co-efficient slope} \hspace{1cm} (1/\text{rad})

\( C_{zq} \) \hspace{1cm} \text{Effect of pitch rate on normal force}

\( I_{xx}, I_{yy}, I_{zz} \) \hspace{1cm} \text{Moment of Inertia (Roll, Pitch, Yaw)} \hspace{1cm} (kg-m^2)

\( I_{xz}, I_{zx} \) \hspace{1cm} \text{Product of inertia} \hspace{1cm} (kg-m^2)

\( K_{A} \) \hspace{1cm} \text{Forward gain}

\( L_{a} \) \hspace{1cm} \text{Aerodynamic normal force coefficient} \hspace{1cm} (N/\text{rad})

\( l_{c} \) \hspace{1cm} \text{Control moment arm} \hspace{1cm} (m)

\( l_{p} \) \hspace{1cm} \text{Distance of slosh pendulum from centre of gravity} \hspace{1cm} (m)

\( l_{r} \) \hspace{1cm} \text{Distance between engine centre of gravity and hinge point} \hspace{1cm} (m)

\( m \) \hspace{1cm} \text{Vehicle mass} \hspace{1cm} (kg)
\( m_r \)  
Engine mass  
\( (kg) \)

\( P_{\text{indep}} \)  
Set of plants with independent uncertainty

\( P_{\text{affine}} \)  
Set of plants with affine uncertainty

\( P_{\text{multilin}} \)  
Set of plants with multi-linear uncertainty

\( q \)  
Dynamic Pressure  
\( (Pa) \)

\( S \)  
Reference area  
\( (m^2) \)

\( T_c \)  
Control force  
\( (N) \)

\( U_0 \)  
Forward velocity  
\( (m/s) \)

\( \alpha \)  
Angle of attack  
\( (rad) \)

\( \beta \)  
Side slip angle  
\( (rad) \)

\( \delta_{el} \)  
Elevon1 deflection angle  
\( (rad) \)

\( \delta_{rl} \)  
Rudder1 deflection angle  
\( (rad) \)

\( \zeta_a \)  
Actuator damping ratio  
\( (rad/s) \)

\( \omega_a \)  
Actuator bandwidth  
\( (rad/s) \)

\( \phi \)  
Roll attitude angle  
\( (rad) \)

\( \psi \)  
Yaw attitude angle  
\( (rad) \)

\( \theta \)  
Pitch attitude angle  
\( (rad) \)

\( \theta_0 \)  
Inertial Pitch angle  
\( (rad) \)

\( \theta_s \)  
Sensed attitude angle  
\( (rad) \)

\( \dot{\theta} \)  
Pitch body rate  
\( (rad/s) \)

\( \tau_i \)  
Oxidiser tank slosh angle – pitch  
\( (rad) \)

\( \dot{\tau}_i \)  
Oxidiser tank slosh rate – pitch  
\( (rad/s) \)

\( \tau_{2p} \)  
Fuel tank slosh angle – pitch  
\( (rad) \)

\( \dot{\tau}_{2p} \)  
Fuel tank slosh rate – pitch  
\( (rad/s) \)

\( \delta_p \)  
Engine gimbal deflection angle in pitch  
\( (rad) \)

\( \dot{\delta}_p \)  
Engine gimbal deflection rate in pitch  
\( (rad/s) \)

\( \rho \)  
Atmospheric Density  
\( (kg/m^3) \)
\sigma(l_{ps,t}) \quad \text{Mode slope at Attitude sensor location}

\sigma_{lact} \quad \text{Mode slope at actuator location}

**Abbreviations**

- **ITAE** \quad \text{Integral of the Time-Multiplied Absolute Error}
- **LQG** \quad \text{Linear Quadratic Gaussian}
- **MIMO** \quad \text{Multi Input Multi Output}
- **PD** \quad \text{Proportional Derivative}
- **PID** \quad \text{Proportional Integral Derivative}
- **QFT** \quad \text{Quantitative Feedback Theory}
- **SOPTD** \quad \text{Second Order Model Plus Time Delay}
- **UAV** \quad \text{Unmanned Aerial Vehicle}
- **TP-LQG** \quad \text{Two Phase LQG}