List of Symbols

\[ a \] atmosphere speed of sound
\[ a \] exponent in approximate thrust formula
\[ ac \] aerodynamic center
\[ a \] acceleration vector
\[ a_0 \] airfoil angle of attack for zero lift
\[ A \] aspect ratio
\[ A \] system matrix
\[ A \] aerodynamic force vector
\[ b \] span
\[ b \] exponent in approximate SFC formula
\[ c \] chord
\[ c_d \] airfoil drag coefficient
\[ c_l \] airfoil lift coefficient
\[ c_{\alpha} \] airfoil lift curve slope
\[ c_{mac} \] airfoil pitching moment about the aerodynamic center
\[ c_r \] root chord
\[ c_t \] tip chord
\[ \bar{c} \] mean aerodynamic chord
\[ C \] specific fuel consumption
\[ C_c \] corrected specific fuel consumption
\[ C_D \] drag coefficient
\[ C_{Df} \] friction drag coefficient
\[ C_{D_i} \] induced drag coefficient
\[ C_{Dw} \] wave drag coefficient
\[ C_{D_0} \] zero-lift drag coefficient
\[ C_f \] skin friction coefficient
\[ CF \] compressibility factor
\[ C_L \] lift coefficient
$C_{L_{\alpha}}$ lift curve slope  
$C_{L_{\text{max}}}$ maximum lift coefficient  
$C_{m_{ac}}$ pitching moment about the aerodynamic center  
$C_T$ nondimensional thrust  
$C_{T_m}$ nondimensional thrust moment  
$C_W$ nondimensional weight  
$d$ diameter  
$det$ determinant  
$D$ drag  
$e$ Oswald’s efficiency factor  
$E$ origin of ground axes system  
$E$ aerodynamic efficiency or lift to drag ratio  
$EO$ position vector  
$f$ flap f factor  
$f$ equivalent parasite area  
$F$ distance factor  
$F_S$ stick force  
$F$ force vector  
$FF$ form factor  
$g$ acceleration of gravity  
$g$ acceleration of gravity vector  
$g_s$ acceleration of gravity at sea level  
$g_1$ function in Mach number for drag divergence  
$g_2$ function in Mach number for drag divergence  
$H$ elevator hinge moment  
$G$ time factor  
$G$ elevator gearing  
$h$ altitude above sea level  
$h_t$ altitude of the tropopause  
$h_{H}$ height of HT ac above wing $\bar{c}$  
$\dot{h}$ rate of climb
i \hspace{10pt} \text{unit vector}

\text{i}_{H} \hspace{10pt} \text{horizontal tail incidence}

\text{i}_{W} \hspace{10pt} \text{wing incidence}

IF \hspace{10pt} \text{interference factor}

ISA \hspace{10pt} \text{ideal subsonic airplane}

ISBJ \hspace{10pt} \text{ideal subsonic business jet}

I_{yy} \hspace{10pt} \text{mass moment of inertia about the } y_{b} \text{ axis}

j \hspace{10pt} \text{unit vector}

J \hspace{10pt} \text{performance index}

k \hspace{10pt} \text{ratio of specific heats}

\text{k} \hspace{10pt} \text{unit vector}

K \hspace{10pt} \text{induced drag factor}

K \hspace{10pt} \text{correction factor}

l \hspace{10pt} \text{length}

L \hspace{10pt} \text{lift}

L \hspace{10pt} \text{rolling moment}

m \hspace{10pt} \text{mass}

M \hspace{10pt} \text{Mach number}

M \hspace{10pt} \text{pitching moment}

IF \hspace{10pt} \text{interference factor}

M_{D} \hspace{10pt} \text{Mach number for drag divergence}

M^{A} \hspace{10pt} \text{aerodynamic pitching moment}

M^{T} \hspace{10pt} \text{thrust pitching moment}

IF \hspace{10pt} \text{interference factor}

n \hspace{10pt} \text{number of intervals}

n \hspace{10pt} \text{load factor}

N \hspace{10pt} \text{yawing moment}

O \hspace{10pt} \text{center of gravity}

p \hspace{10pt} \text{atmospheric pressure}

P \hspace{10pt} \text{power setting}

P_{S} \hspace{10pt} \text{specific excess power}

q \hspace{10pt} \text{pitch rate perturbation}
\( \bar{q} \)  dynamic pressure
\( \bar{q}_H \)  dynamic pressure in front of horizontal tail
\( Q \)  pitch rate
\( \dot{Q} \)  nondimensional pitch rate
\( r \)  turn radius
\( r_s \)  radius of the earth at sea level
\( R \)  gas constant for air
\( R_e \)  Reynolds number
\( s \)  distance along a turn
\( S \)  planform area
\( SBJ \)  subsonic business jet in App. A
\( SFC \)  specific fuel consumption
\( S_c \)  planform area of wing associated with control
\( S_{\text{wet}} \)  wetted area
\( 6DOF \)  six degree of freedom motion
\( t \)  time
\( t \)  maximum thickness
\( t/c \)  thickness ratio
\( T \)  Thrust
\( T_c \)  corrected thrust
\( T \)  thrust vector
\( 3DOF \)  three degree of freedom motion
\( u \)  nondimensional speed
\( u \)  velocity component along ground x axis
\( U \)  velocity component along body x axis
\( v \)  velocity along the ground y axis
\( V \)  velocity
\( V_C \)  corner speed
\( V_D \)  decision speed
\( V_{LO} \)  lift-off speed
$V_R$ rotation speed
$V_{TD}$ touchdown speed
$\mathbf{V}$ velocity vector
$V_e$ equivalent airspeed
$\bar{V}_H$ horizontal tail volume coefficient
$V_0$ velocity of the airplane relative to the ground
$w$ velocity component along ground h axis
$w$ wind speed
$w_h$ component of wind speed in the h direction
$w_x$ component of wind speed in the x direction
$\mathbf{w}$ velocity vector of the atmosphere relative to the ground
$W$ weight
$W$ velocity component on body z axis
$x$ distance
$x$ coordinate axis
$X$ distance aft of the wing mean aerodynamic chord leading edge
$\bar{X}$ X divided by $\bar{c}$
y distance
$y$ coordinate axis
$z$ coordinate axis
$\alpha$ angle of attack
$\alpha$ angle of attack perturbation
$\bar{\alpha}$ angle of attack in Chaps, 10 and 11
$\dot{\alpha}$ angle of attack rate perturbation
$\alpha_H$ horizontal tail angle of attack
$\alpha_{0L}$ zero lift angle of attack
$\dot{\alpha}$ angle of attack rate
$\beta$ sideslip angle
$\gamma$ flight path inclination, climb angle
\( \delta \) control deflection angle
\( \delta_E \) elevator angle
\( \delta_E \) elevator angle in Chaps. 10 and 11
\( \delta_E \) elevator angle perturbation
\( \delta_T \) trim tab angle
\( \varepsilon \) thrust angle of attack
\( \varepsilon \) downwash at the horizontal tail
\( \varepsilon_\alpha \) slope of the downwash curve
\( \varepsilon_0 \) angle between thrust vector and the body x-axis
\( \varepsilon_0 \) HT downwash angle at \( \alpha = 0 \)
\( \zeta \) damping ratio
\( \eta \) corrected engine speed
\( \eta_H \) horizontal tail efficiency factor
\( \theta \) perturbed pitch angle
\( \Theta \) pitch angle perturbation
\( \kappa \) ratio of \( c_{l_{\alpha}} \) to \( (c_{l_{\alpha}})_{theory} \)
\( \lambda \) scale height
\( \lambda \) taper ratio
\( \lambda \) root of the characteristic equation
\( \Lambda \) sweep angle
\( \mu \) atmospheric viscosity
\( \mu \) bank angle
\( \mu \) coefficient of rolling friction
\( \xi \) coordinate of the aerodynamic center in the x direction
\( \rho \) atmospheric density
\( \sigma \) ratio of density to density at sea level
\( \Sigma \) summation
\( \tau \) atmosphere absolute temperature
\( \tau \) control surface effectiveness
\( \tau \) nondimensional thrust
$\tau_E$  elevator effectiveness
$\theta$  pitch angle perturbation
$\tau$  airfoil elevator effectiveness
$\phi$  angle between regular body x axis and stability x axis
$\psi$  heading angle
$\dot{\psi}$  turn rate
$\omega_n$  natural frequency

**Subscripts**

$ac$  aerodynamic center
$b$  body
$cg$  center of gravity
$D$  drag
$F$  flap
$h$  local horizon
$h$  hinge moment
$hc$  half chord
$H$  horizontal tail
$le$  leading edge
$L$  lift
$LO$  lift-off
$m$  moment
$max$  maximum
$mt$  maximum thickness
$o$  relative to the ground
$ps$  peak suction
$q$  pitch rate perturbation
$qc$  quarter chord
$Q$  nondimensional pitch rate
\( r \) reference
\( s \) sea level
\( s \) stability
\( S \) slat
\( S \) specific
\( t \) troposphere
\( TD \) touchdown
\( x \) component in the x direction
\( h \) component in the h direction
\( stall \) stall speed
\( te \) trailing edge
\( T \) tip tank
\( u \) velocity perturbation
\( w \) wind
\( W \) wing
\( W \) weight
\( WB \) wing-body
\( 0 \) a value with \( \alpha = 0 \) and \( \delta_E = 0 \)
\( 1 \) steady state
\( \alpha \) angle of attack
\( \delta_E \) elevator angle
\( \dot{\alpha} \) angle of attack rate

**Superscripts**
- \( A \) aerodynamic
- \( T \) thrust
- \( ' \) stick free
- \( * \) maximum lift to drag ratio