?
T

$\eta = [p^e \Theta]^T : p^e = [xyz]^T, \Theta = [\varphi\theta\psi]^T$

$\nu = [v_o^b \omega_{nb}^b]^T : v_o^b = [uvw]^T, \omega_{nb}^b = [pqr]^T$

$\tau = [f_o^b m_o^b]^T : f_o^b = [XYZ]^T, m_o^b = [KMN]^T$

η
$BODY$
$J_1(\Theta)$
Θ
p^e

$\dot{p}_e = v_o^n = J_1(\Theta) v_o^b$
(1)
$J_1(\Theta)$
$J_1^{-1}(\Theta) = J_1^T(\Theta)$
$s =$
$sin()$
$c =$
$cos()$

$J_1(\Theta) = c\psi c\vartheta - s\psi c\vartheta + c\psi s\vartheta s\varphi s\psi s\vartheta + c\psi c\varphi s\vartheta s\psi c\vartheta c\psi c\vartheta + s\varphi s\vartheta s\psi - c\psi s\vartheta + s\vartheta s\psi c\varphi - s\vartheta c\vartheta s\varphi c\vartheta c\varphi$
(2)
b-
$frame$
η-
$frame$

$\dot{\Theta} = J_2(\Theta) \omega_{nb}^b$
(3)
$J_2(\Theta)$

$J_2(\Theta) = 1 s\varphi t\vartheta c\varphi t\vartheta 0 c\varphi - s\varphi 0 s\varphi / c\vartheta c\varphi / c\vartheta$
(4)
$J_2(\Theta)$
$(\theta) =$
$\pm 90^o$
$\dot{p}_e \dot{\Theta} = J_1(\Theta) 0_{3x3} 0_{3x3} J_2(\Theta) v_o^b \omega_{nb}^b$
(5)
$M_{RB} \dot{\nu} + C_{RB}(\nu)\nu = \tau_{RB}$
(6)
M_{RB} :
C_{RB} :
τ_{RB} :
ν :
b-
$frame$
τ_{RB}
τ_H
τ_E
$\tau_{RB} = \tau_H + \tau_E + \tau$
(7)
$\tau_H = -M_A \dot{\nu} - C_A(\nu)\nu - D(\nu)\nu - g(\eta)$
(8)
M_A :
C_A :
$D(\nu)$:
$g(\eta)$:

$M\dot{\nu} = -C(\nu)\nu - D(\nu)\nu - g(\eta) + \tau_E + \tau$
(9)
$M = M_{RB} + M_A$
$C(\nu) = C_{RB}(\nu) + C_A(\nu)$
$surge$
$sway$
yaw
$\eta =$
$[xyz]^T$
$\nu =$
$[uvr]^T$
$roll$
$pitch$
$heave$
$M_{RB}\dot{\nu} + C_{RB}(\nu)\nu = \tau_{RB}$
(10)
$m 0 0 0 m m x_g 0 m x_g I_Z \dot{\nu} + 0 0 - m(x_g r + v) 0 0 m u m(x_g r + v) - m u 0 \nu = XYN$
(11)
τ_{RB}
$\dot{u}, \delta, T)$
$Y =$
$Y(v, r, \dot{v}, \dot{r}, \delta)$
$N =$
$N(v, r, \dot{v}, \dot{r}, \delta)$

$\nu =$
$[uvpr]^T$

$M_{RB}\dot{\nu} + C_{RB}(\nu)\nu = \tau_{RB}$
(12)
$_{RB} =$
$m00-$
my_g
$0m-$
mz_gmx_g
$0-$
mz_gI_X-
I_{XZ}
$-$
my_gmx_g-
$I_{ZX}I_Z\tau_{RB} =$
X
Y
K
N
$_{RB}(\nu) =$
$00mz_gr-$
$m(x_gr+$
$v)$
$00-$
$my_gpm(y_gr-$
$u)$
$-$
$mz_grmy_gp0I_{YZ}r+$
$I_{XY}p$
$m(x_gr+$
$v)m(y_gr-$
$u)-$
$I_{YZ}r-$
$I_{XY}p0$