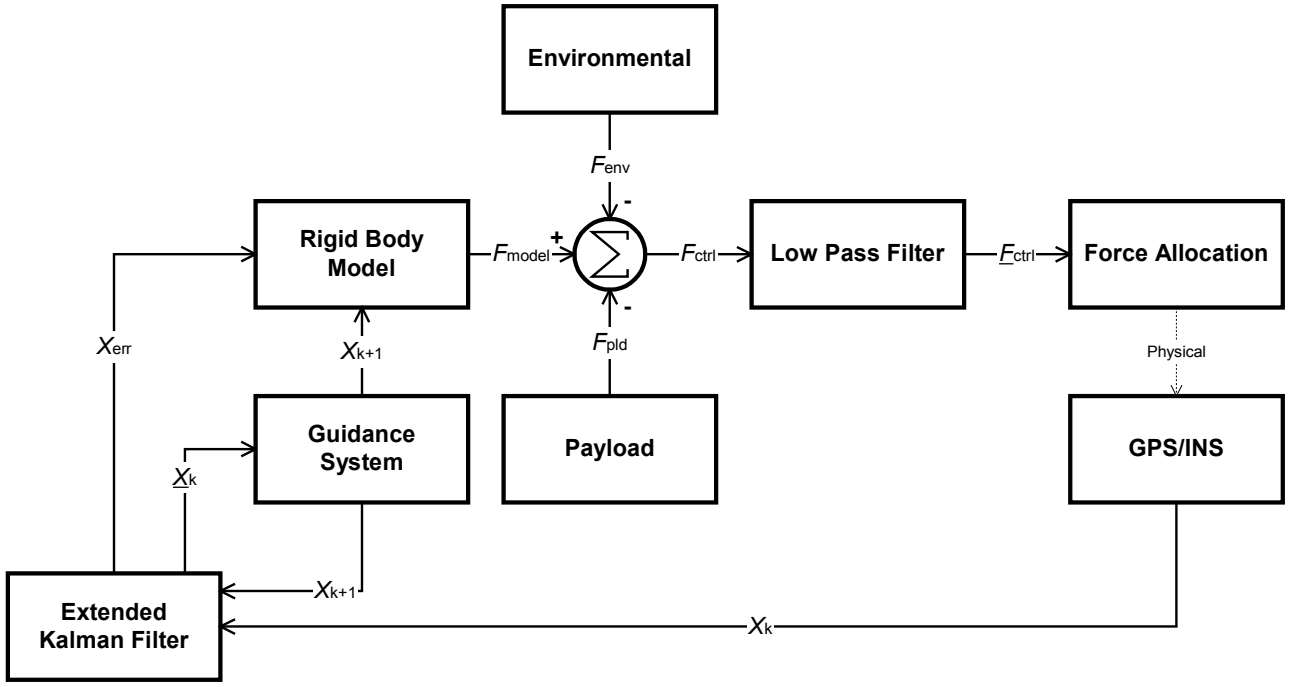
AM Auto Pilot Control Diagram



X_k	Current Measured State
$\underline{X}_k$	Current Compensated State
X_{k+1}	Next Target State
X_{err}	Estimated Error
F_{model}	Rigid Body Force of Ship
F_{env}	Environmental Forces on Ship
F_{pld}	Deployed Payload Force on Ship
F_{ctrl}	Resulting Control Force
$\underline{F}_{ctrl}$	Filtered Control Force

AM Auto Pilot Control Components

- Rigid Body Model
  - Initial Assumptions
    - 3 Degree of freedom: Surge, Sway and Yaw
    - Derived in body centric frame (b-frame)
  - $F_{model} + F_{err} = Mv' + D(v)v + C(v)v$

F_{model} = Rigid body force of ship [Surge, Sway, Yaw moment]
F_{err} = Forces and moments to compensated for error in model
This is learned from the Extended Kalman Filter
M = Vehicle rigid body mass + Mass of Inertia of surrounding fluid
D = Radiation induced damping, vortex shedding, wave drift, skin friction
C = Coriolis effect / Centripetal force
v = Ship velocity

AM Auto Pilot Control Components Cont'd

- Environmental
  - Assumption of Force and Moment superposition
    - $F_{env} = F_{wind} + F_{wave} + F_{current}$
  - Wind function
    - $F_{wind} = f(C(r'_r), \rho a, V_r, A)$

      $C(r'_r)$ = empirical force coefficient
      ρa = density of air
      V_r = velocity of wind relative to vehicle
      A = projected contact area

AM Auto Pilot Control Components Cont'd

- Environmental continued
  - Wind Generated Waves
    - Wavelets appearing on the water surface break and dissipate their energy when interacting with the vehicle, causing added force and moments
  - Ocean Currents
    - Forces caused due to horizontal and vertical circulations, Tidal components arising due to gravity, as well as other forces which are distinctive to a particular sea
    - Can be neglected at high speed

AM Auto Pilot Control Components Cont'd

- Payload
  - Accounts for drag generated by deployed payload
- Low Pass Filter
  - Smoothes instantaneous large forces and moments for safe vehicle operation
  - Output is the controlled driving force needed to drive the vehicle over the period of two states
- Force Allocation
  - Forces and moments needed to drive the vehicle are allocated to various actuators (throttles, water jet steering angles, reversing buckets, trim tabs)

AM Auto Pilot Control Components Cont'd

- INS/GPS
  - Provides measure of vehicle's current physical state
  - Includes measurement errors
- Extended Kalman Filter
  - Input
    - Next vehicle state
    - Current state measured by the INS/GPS
  - Output
    - Actual vehicle state, after removing INS/GPS measurement error
    - One can also learn, from the Kalman Gain, the errors in the initial approximations of the rigid body and environmental model. A compensating force, F_{err}, can then by applied in the rigid body model.