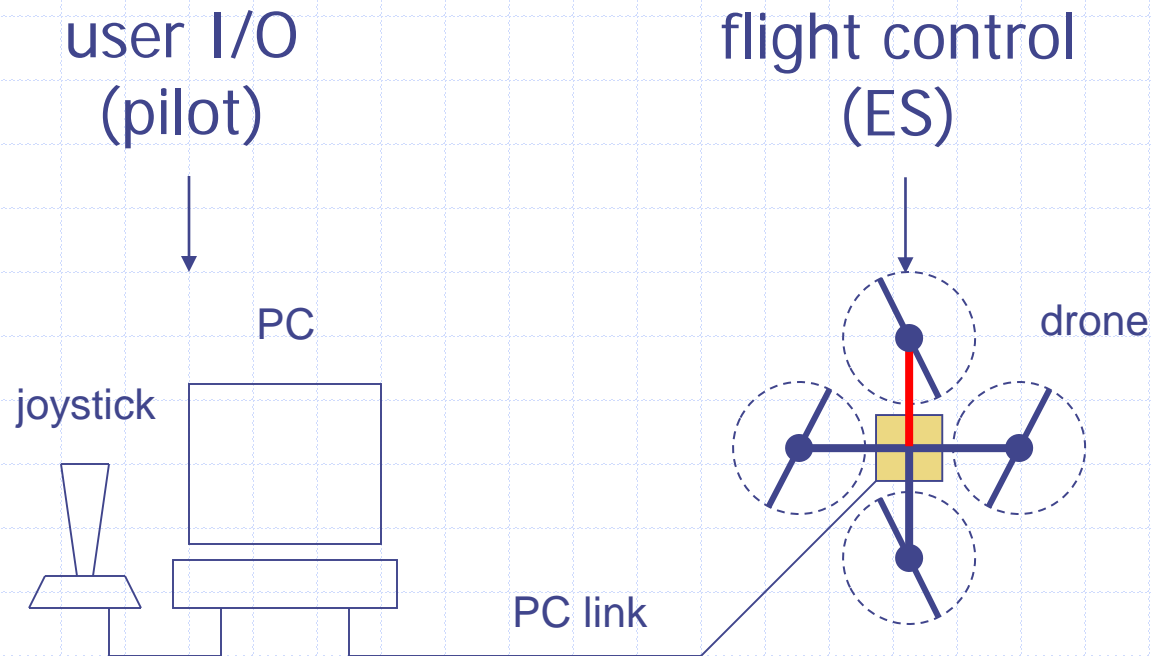


CESE4030

Embedded Systems Laboratory

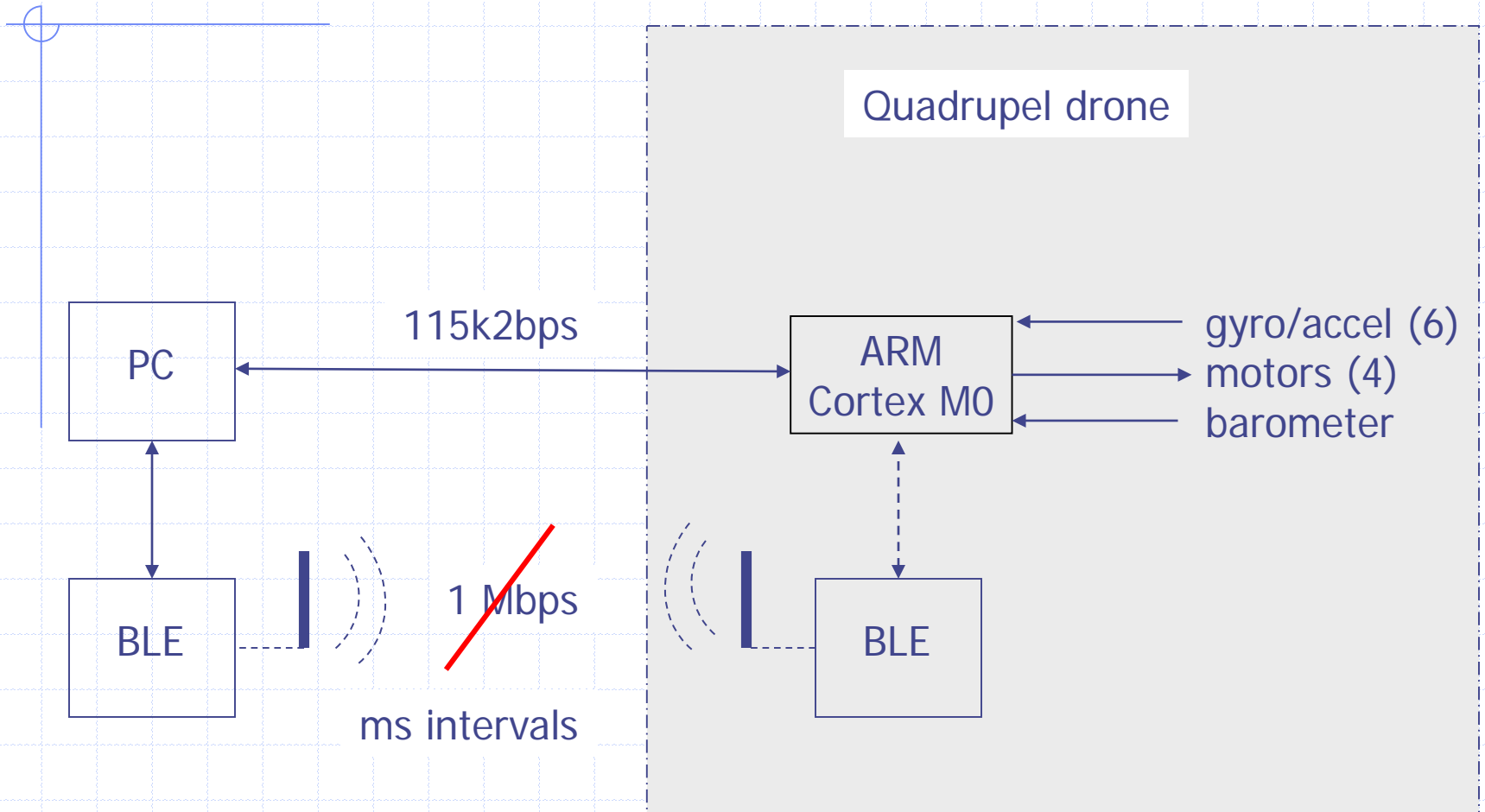
Electrical Model Quad Rotor UAV

System Setup

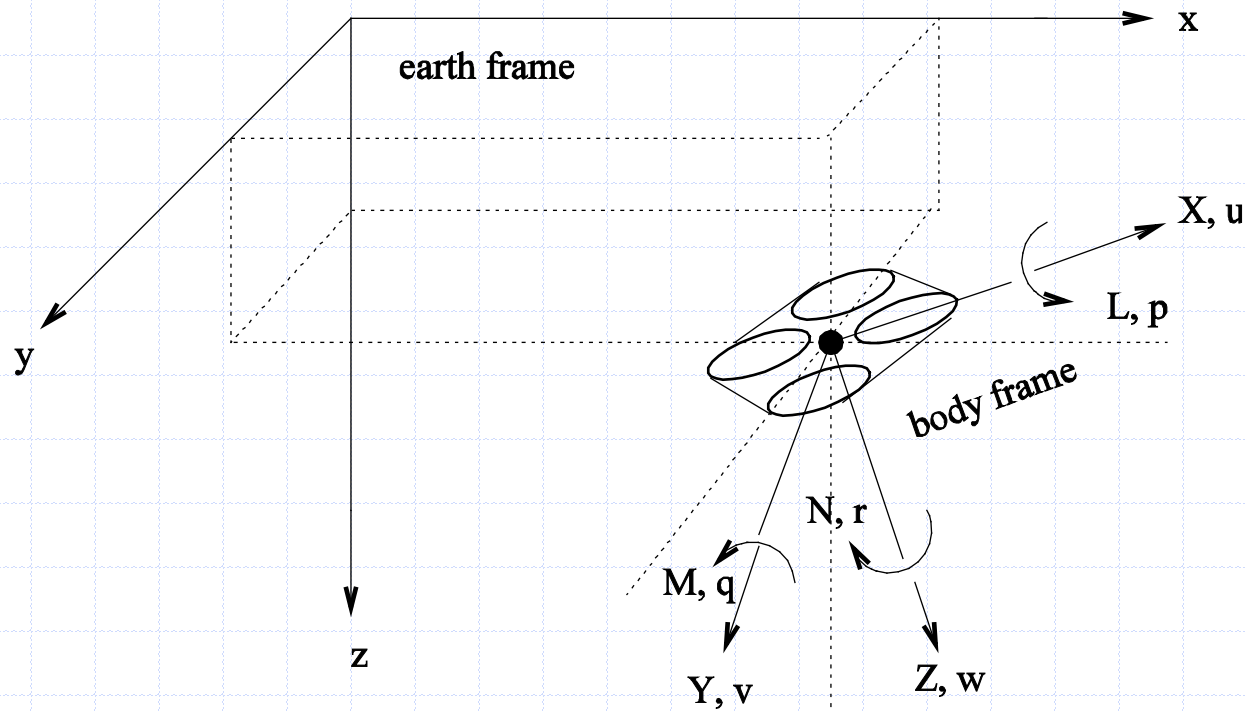


(source: assignment pages)

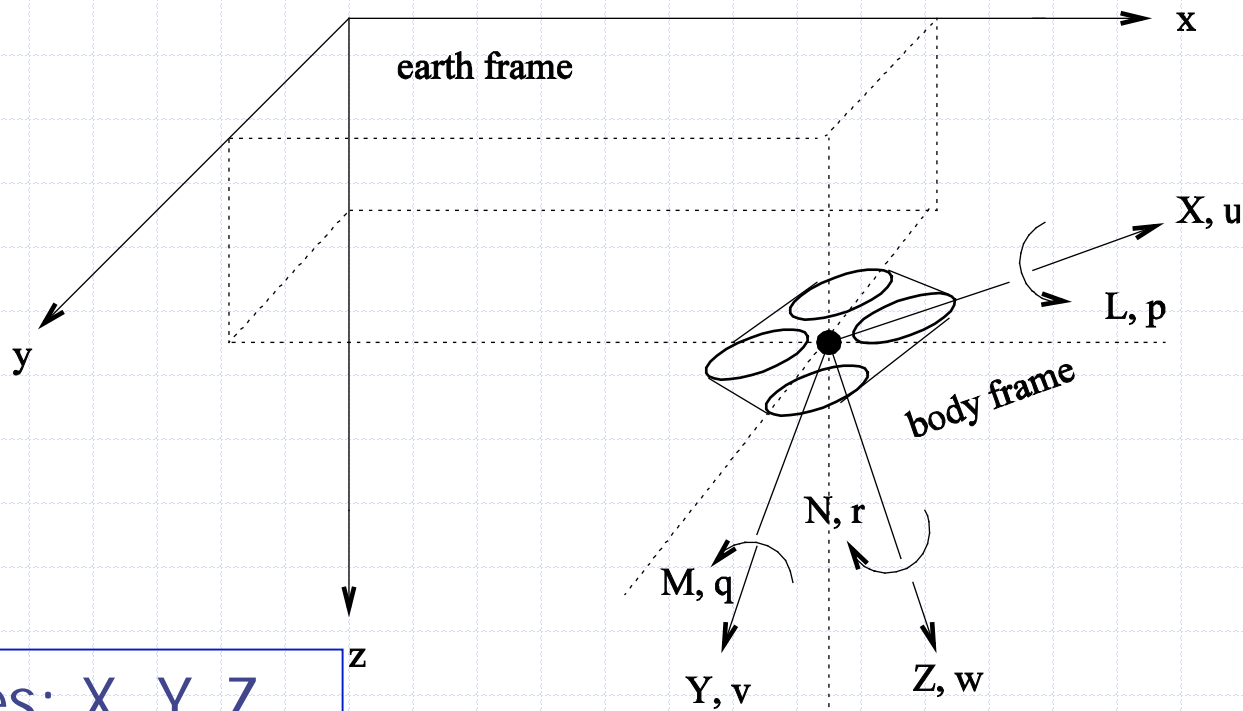
HW view



Drone: Frames & Main Variables



Drone: Forces



Forces: X, Y, Z
Moments: L, M, N

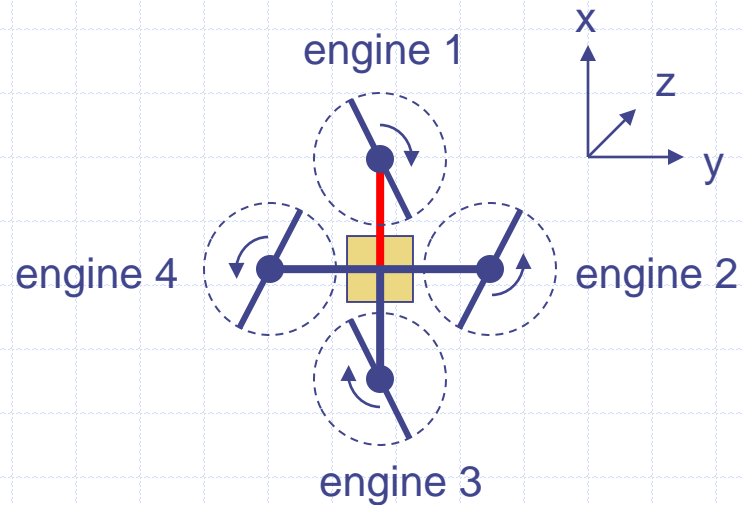
Drone: Actuators

rotor 1 – rotor 4
through RPM,
denoted by Ω

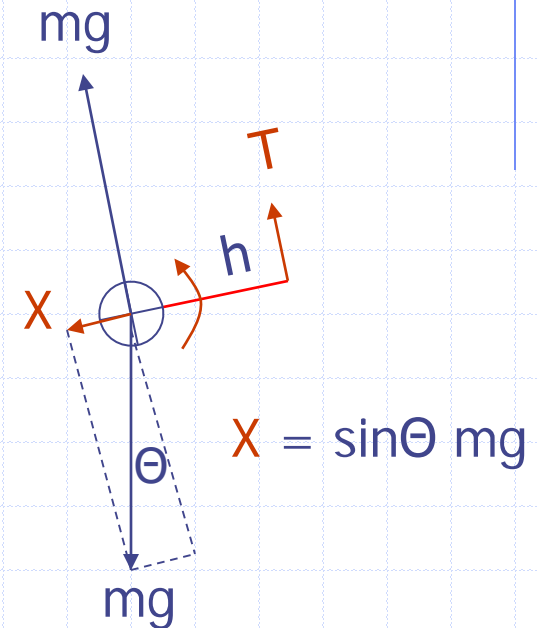
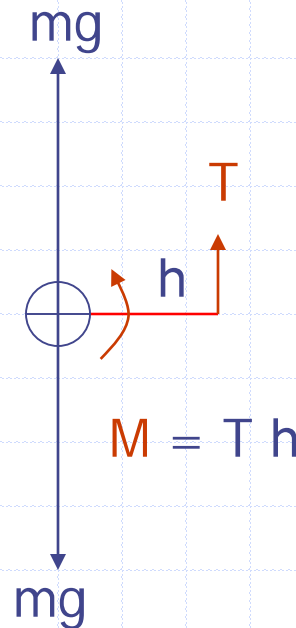
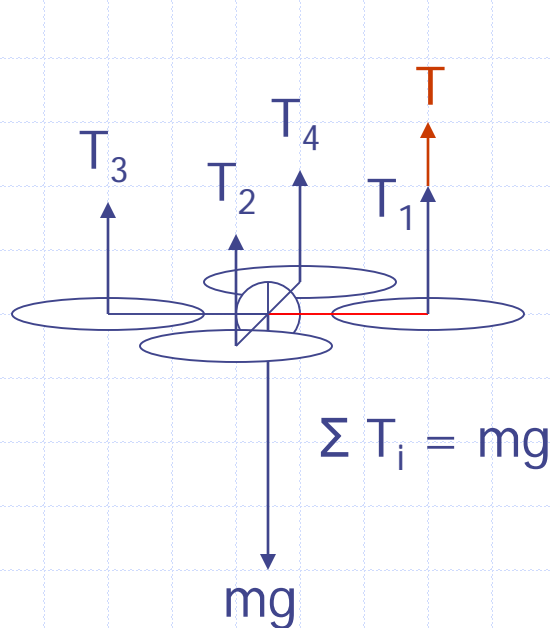
driven by ES signals
 $ae1 - ae4$

$$ae = 0 \rightarrow \Omega = 0$$

$$ae = 1000 \rightarrow \Omega = \max$$



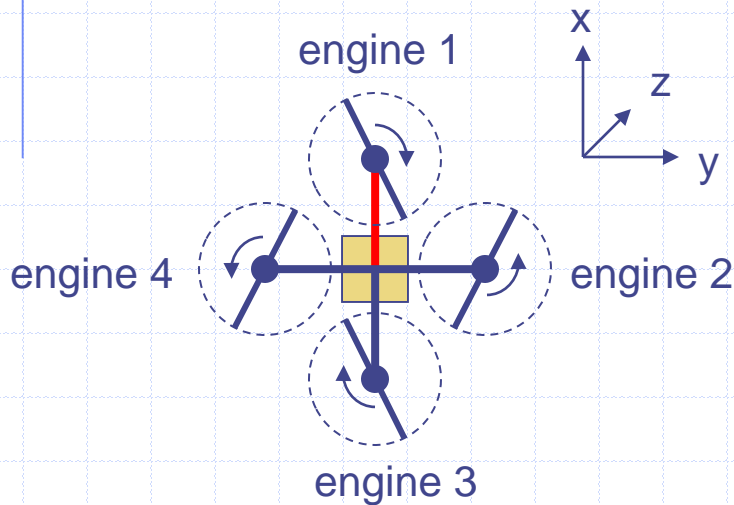
Drone: Dynamics (in hover)



$T_i = \text{rotor thrust} = f(\Omega_i)$
 $mg = \text{gravity}$
 $h = \text{rotor distance ref. center of gravity}$
 $I_Y = \text{heli rotation inertia in Y-axis}$

$dq/dt = M / I_Y$
 $du/dt = X / m$
 accelerated
 rotation & xlation!

Drone: Rotor Actuators



In general

$$Z = -b(\Omega_1^2 + \Omega_2^2 + \Omega_3^2 + \Omega_4^2)$$

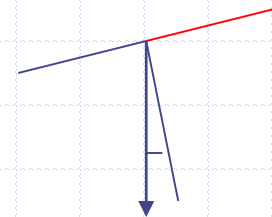
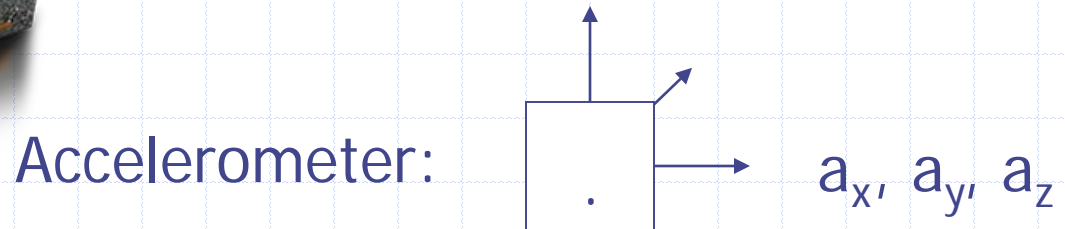
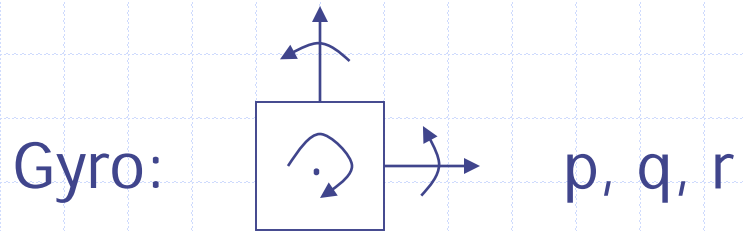
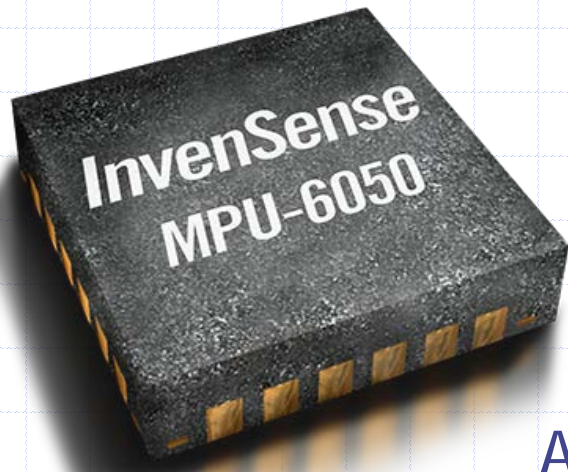
$$L = b(\Omega_4^2 - \Omega_2^2)$$

$$M = b(\Omega_1^2 - \Omega_3^2)$$

$$N = d(\Omega_2^2 + \Omega_4^2 - \Omega_1^2 - \Omega_3^2)$$

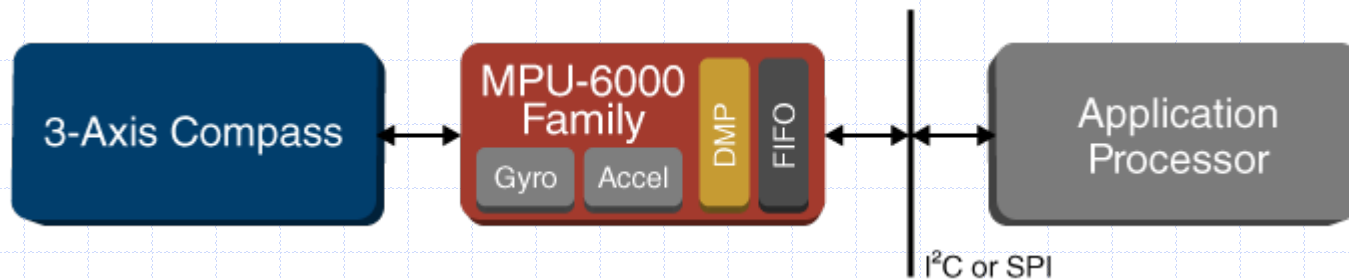
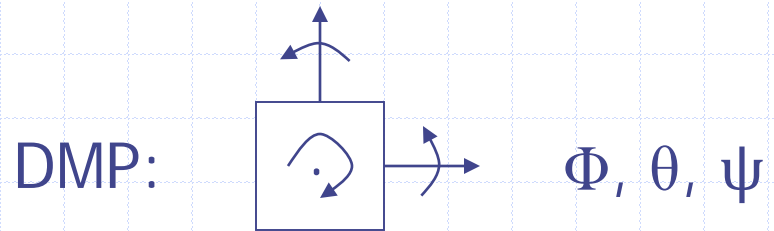
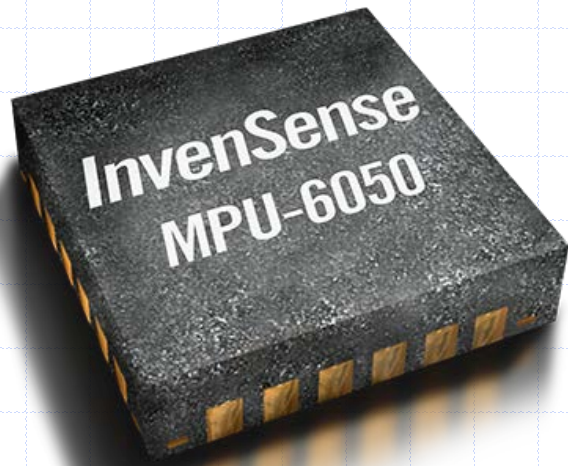
So compute Ω_i (i.e., ae_i) from desired lift (Z), roll rate (L), pitch rate (M), and yaw rate (N)

Drone: Sensors (angles)

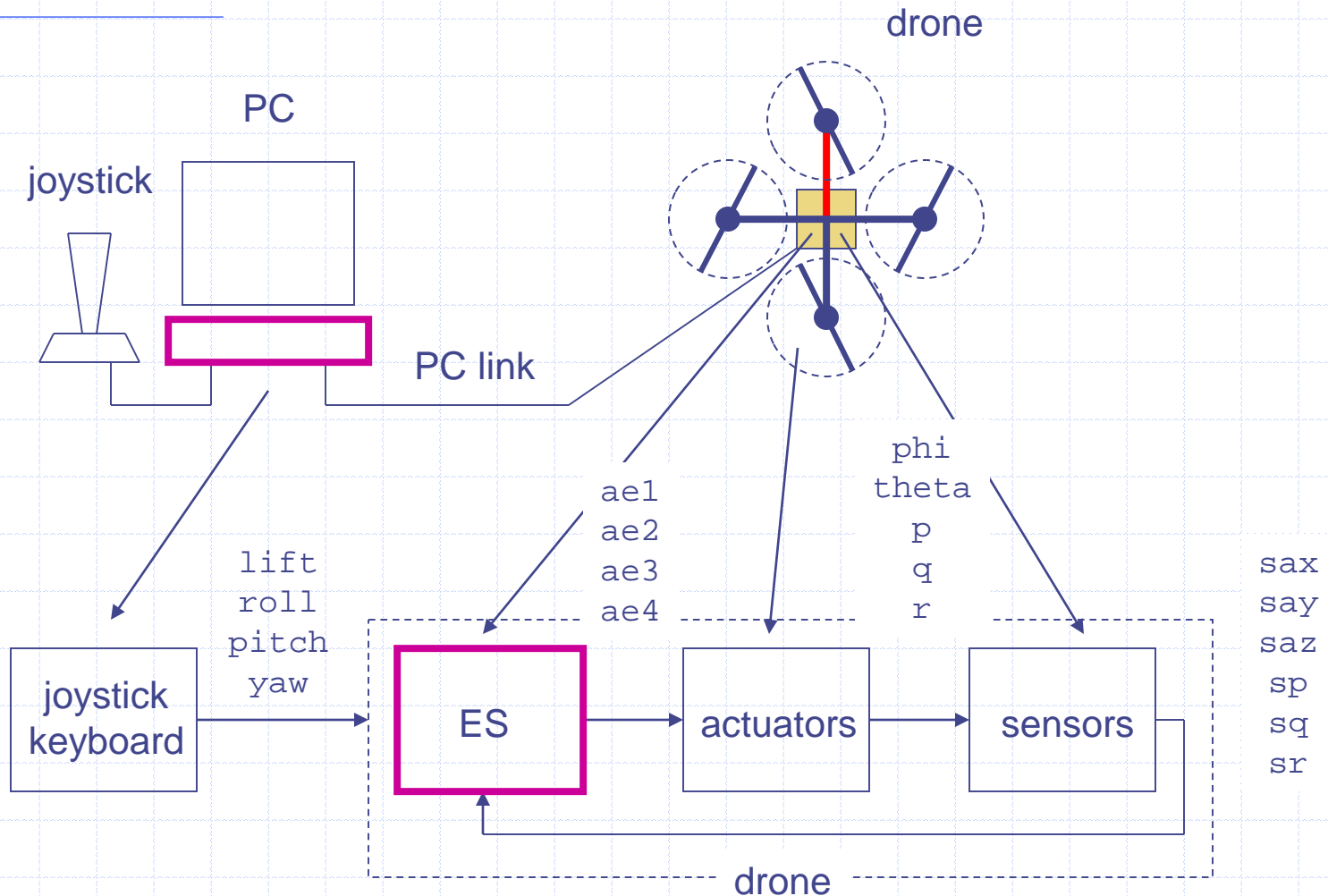


$$a_x = \sin\Theta g \sim \Theta g$$

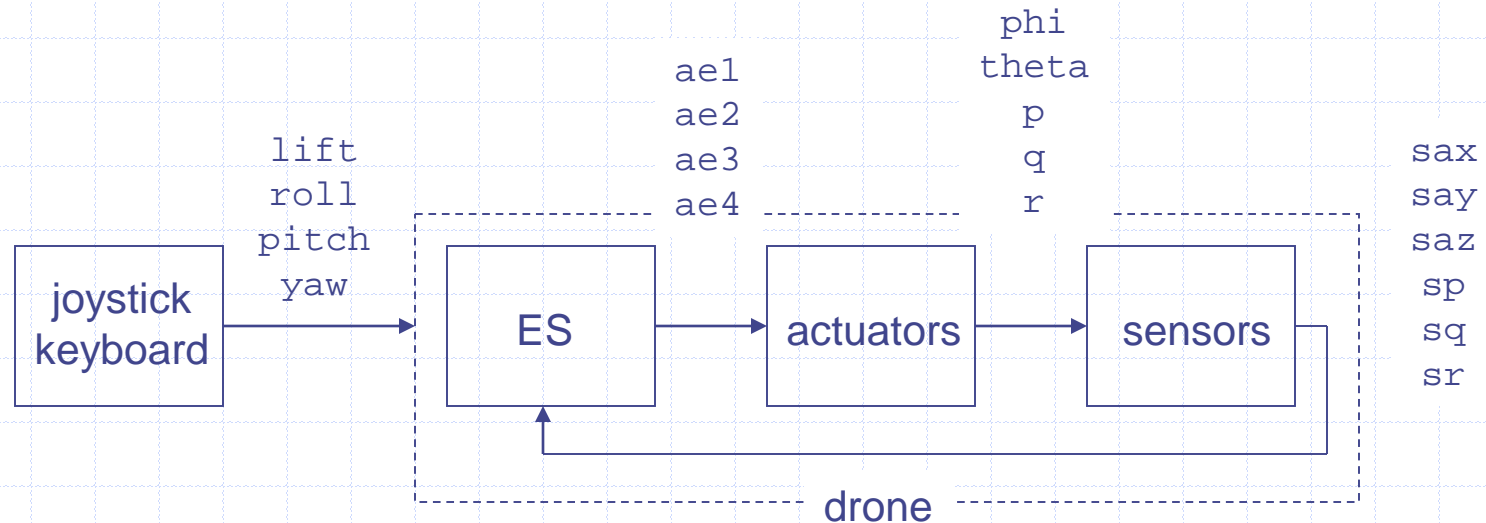
Drone: Sensors (angles)



SW view



Drone: Control Circuit



control loop example (yaw **rate**):

```
eps = yaw - sr;
```

```
N_needed = P * eps;
```

```
ae1 .. ae4 = f(N_needed);
```

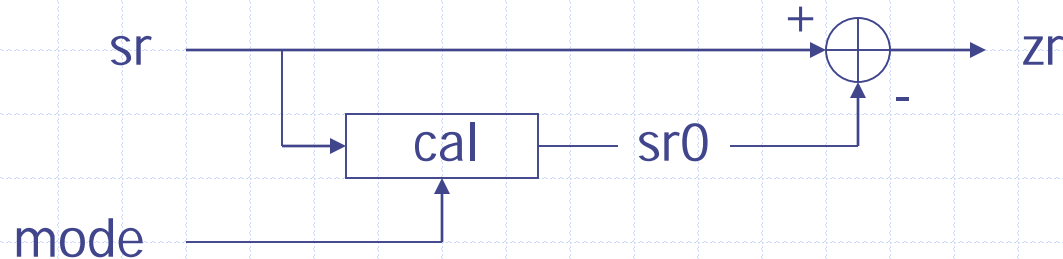
```
// measure deviation
```

```
// compute ctl action
```

```
// actuate, see slide 9
```

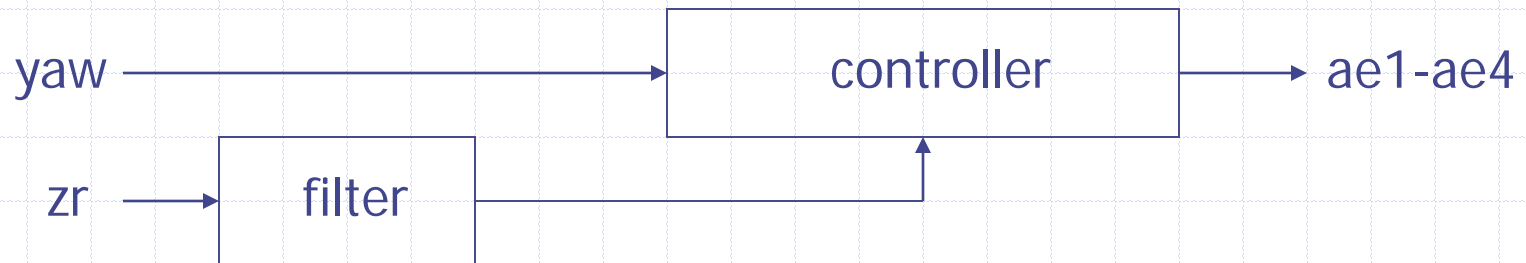
Calibration

- real p, q, r, \dots are sensed in terms of sp, sq, sr, \dots
 - sp, sq, \dots have a (voltage) bias (are not zero at rest)
 - so need to calibrate all 6 sensors at rest:
 - let $sr0$ be sensor output at rest
 - real estimate of r are given by (z for zeroed)
- $$zr = sr - sr0$$



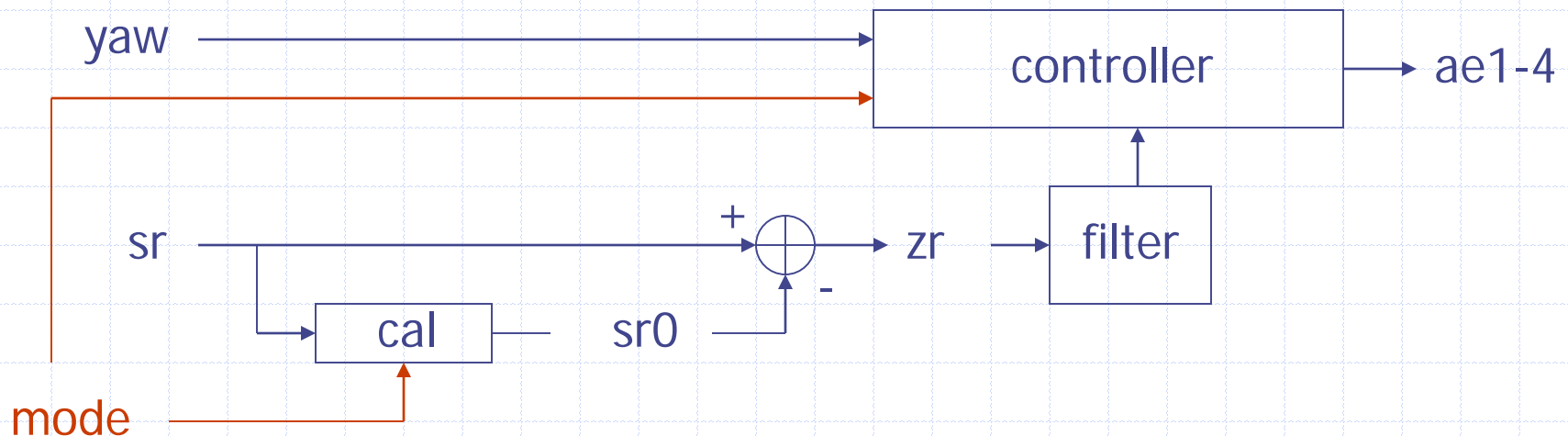
Filtering

- signals also need to be *filtered* to remove noise
- filtered signal input to embedded controller



Controller Modes

- controller mode: manual
- controller mode: calibrate
- controller mode: control (yaw, pitch, roll)



Lab logistics

- ◆ team assignments
 - Wednesday
- ◆ FCB pickup
 - Thursday
- ◆ Labs
 - wk 3.2 – safety briefing

