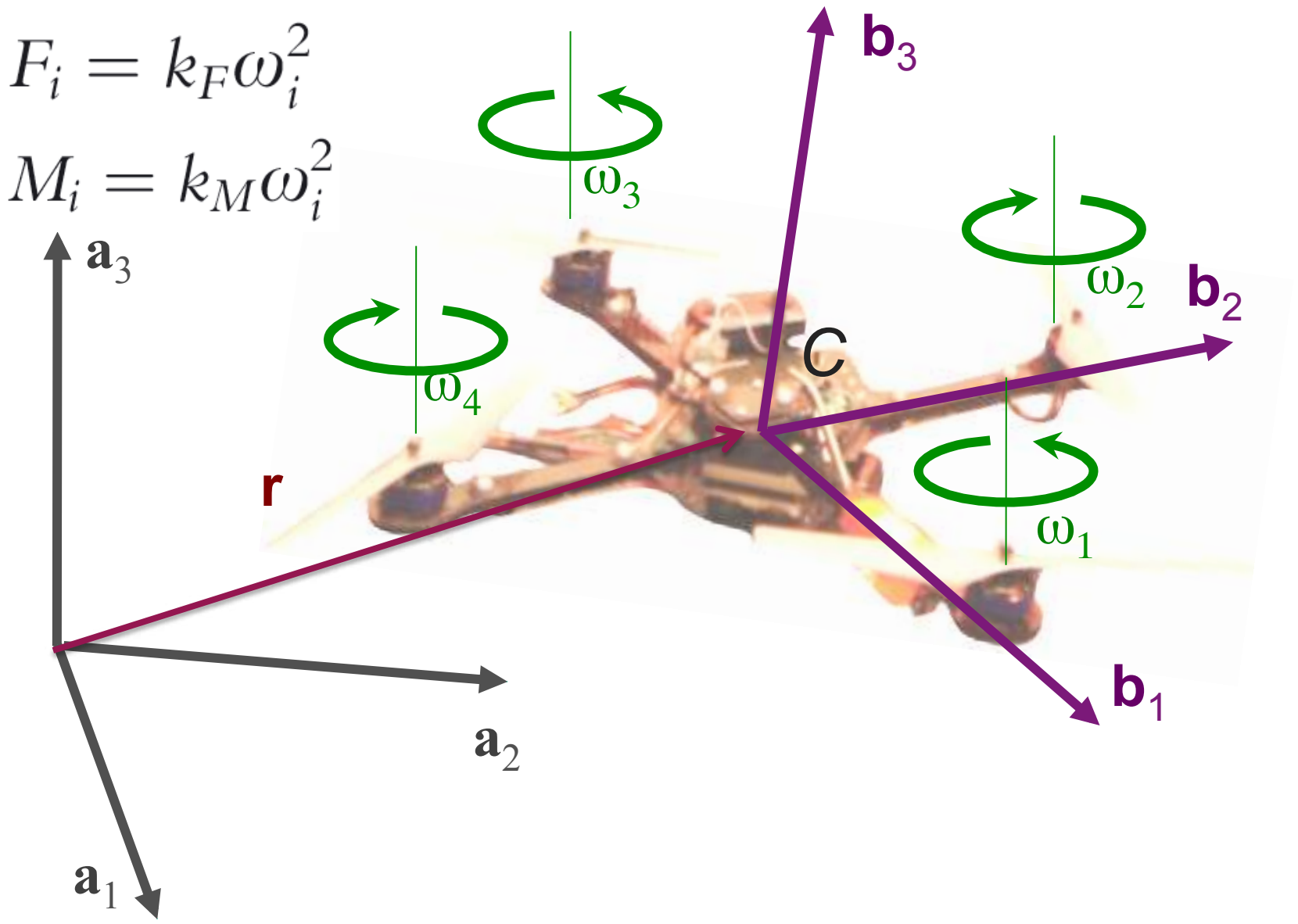
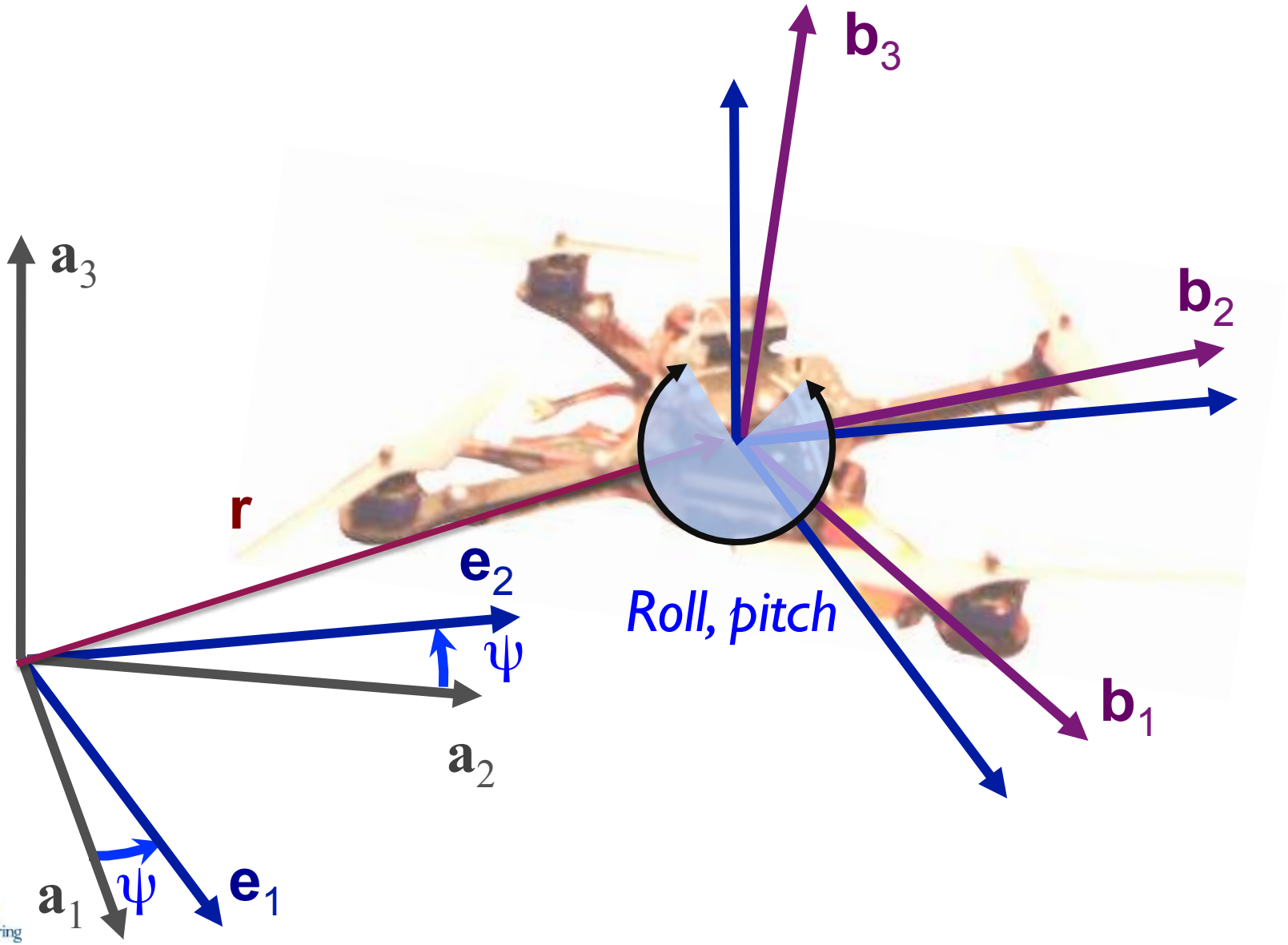
Dynamics of a Quadrotor

$$F_i = k_F \omega_i^2$$

$$M_i = k_M \omega_i^2$$

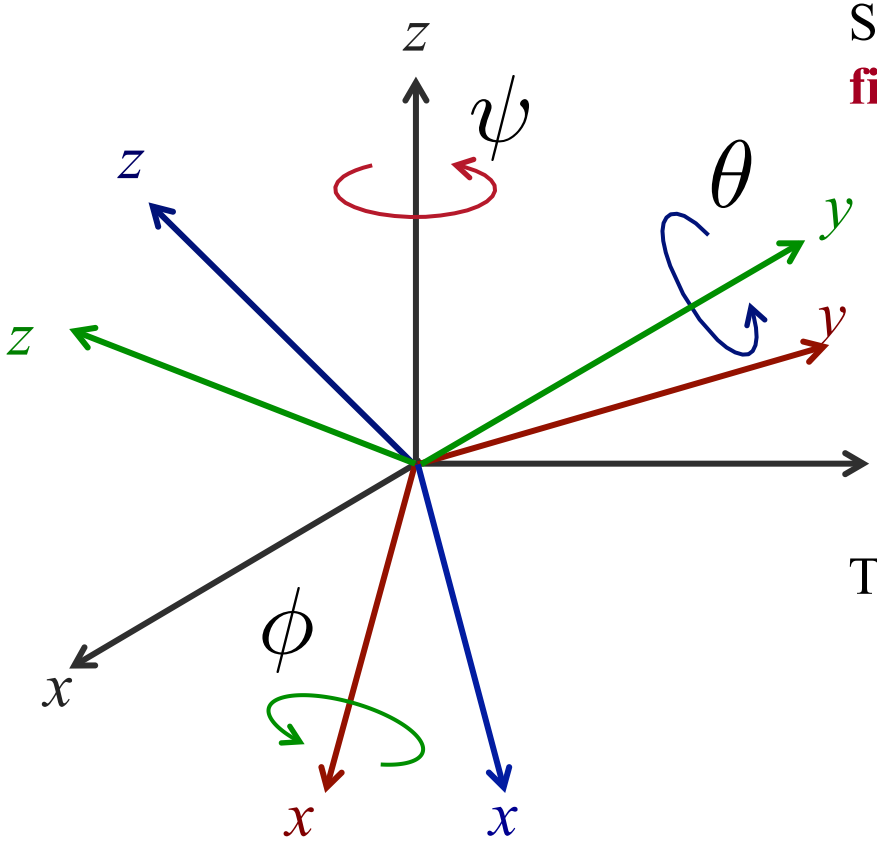


Euler Angles



Penn Engineering

Z-X-Y Euler Angles



Sequence of three rotations about **body-fixed** axes

- Rot(z, ψ)
- Rot(x, ϕ)
- Rot(y, θ)

Three Euler Angles

- ϕ, θ, and ψ
- Parameterize rotations

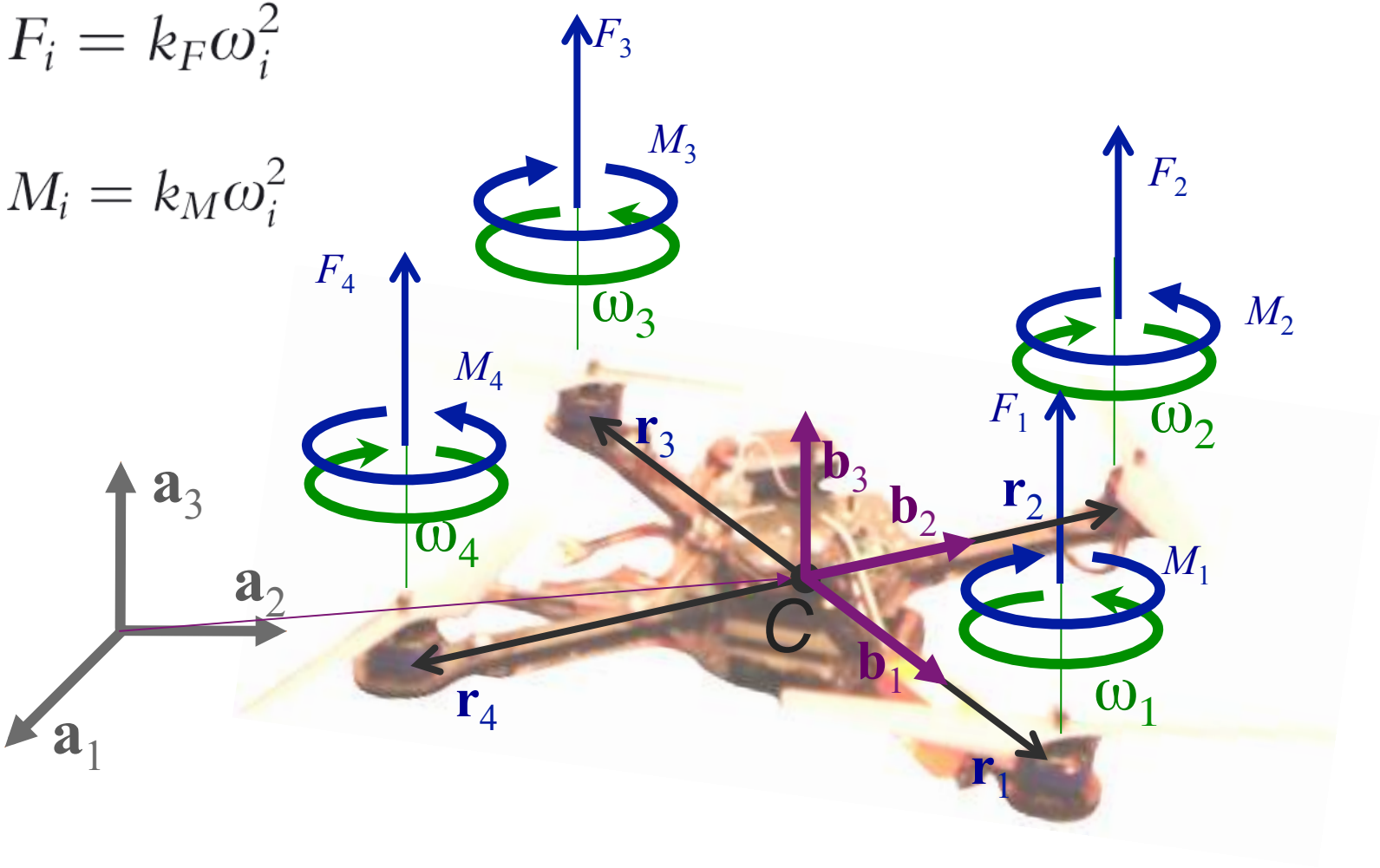
Note there are singularities!

$$\mathbf{R} = \text{Rot}(z, \psi) \times \text{Rot}(x, \phi) \times \text{Rot}(y, \theta)$$

External Forces and Moments

$$F_i = k_F \omega_i^2$$

$$M_i = k_M \omega_i^2$$



$$\mathbf{F} = \mathbf{F}_1 + \mathbf{F}_2 + \mathbf{F}_3 + \mathbf{F}_4 - mg\mathbf{a}_3$$

$$\mathbf{M} = \mathbf{r}_1 \times \mathbf{F}_1 + \mathbf{r}_2 \times \mathbf{F}_2 + \mathbf{r}_3 \times \mathbf{F}_3 + \mathbf{r}_4 \times \mathbf{F}_4 + \mathbf{M}_1 + \mathbf{M}_2 + \mathbf{M}_3 + \mathbf{M}_4$$

Newton-Euler Equations

System of Particles

Rigid Body