Ulisses

UNIVERSITY OF LISBON
INTERDISCIPLINARY STUDIES
ON SUSTAINABLE ENVIRONMENT AND SEAS

ulisses.ulisboa.pt

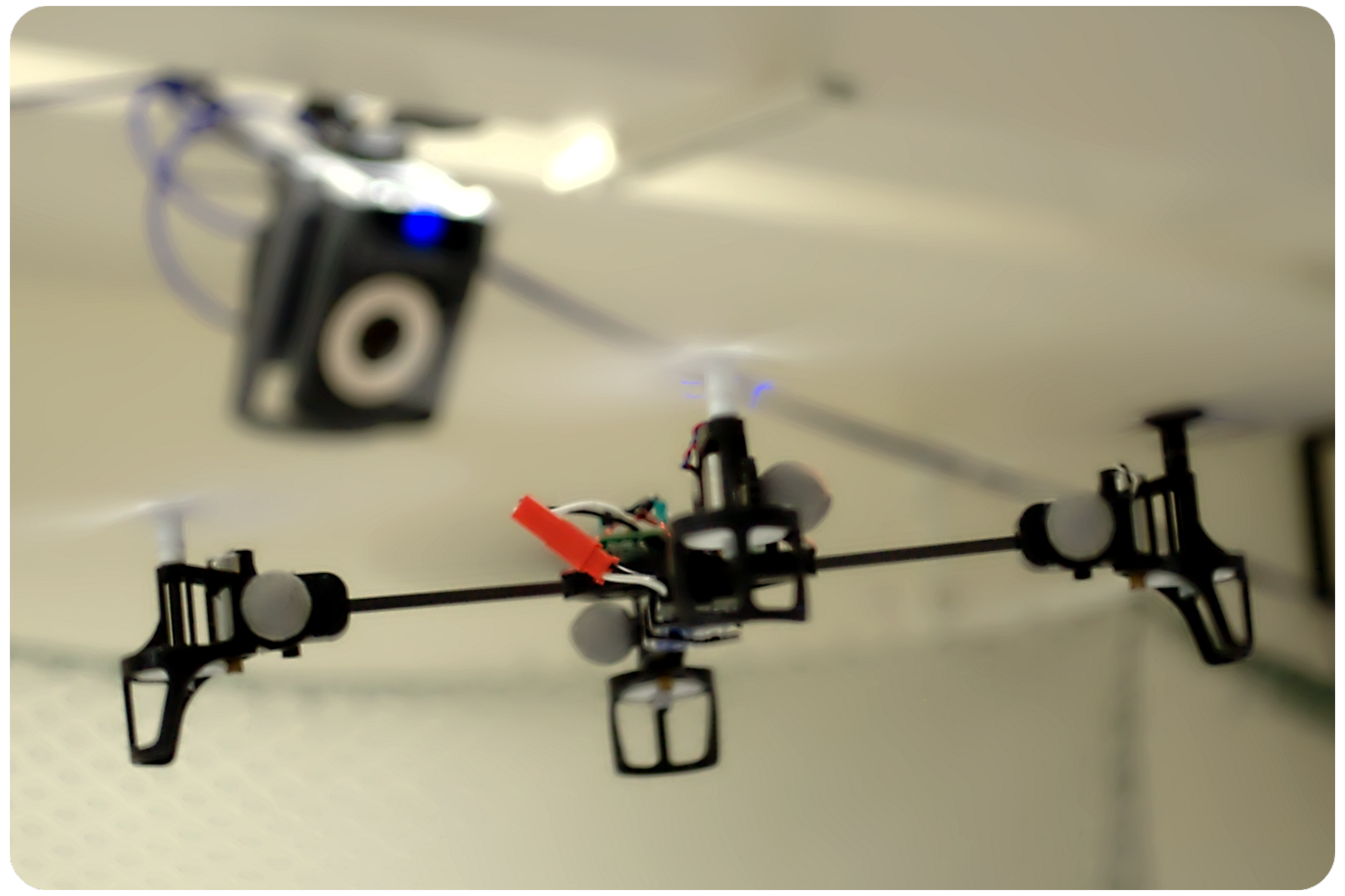
unite! University Network for Innovation, Technology and Engineering

U LISBOA | UNIVERSIDADE DE LISBOA

Co-funded by the Erasmus+ Programme of the European Union

Aerial Vehicles for missions at sea
(Part II)





Rita Cunha

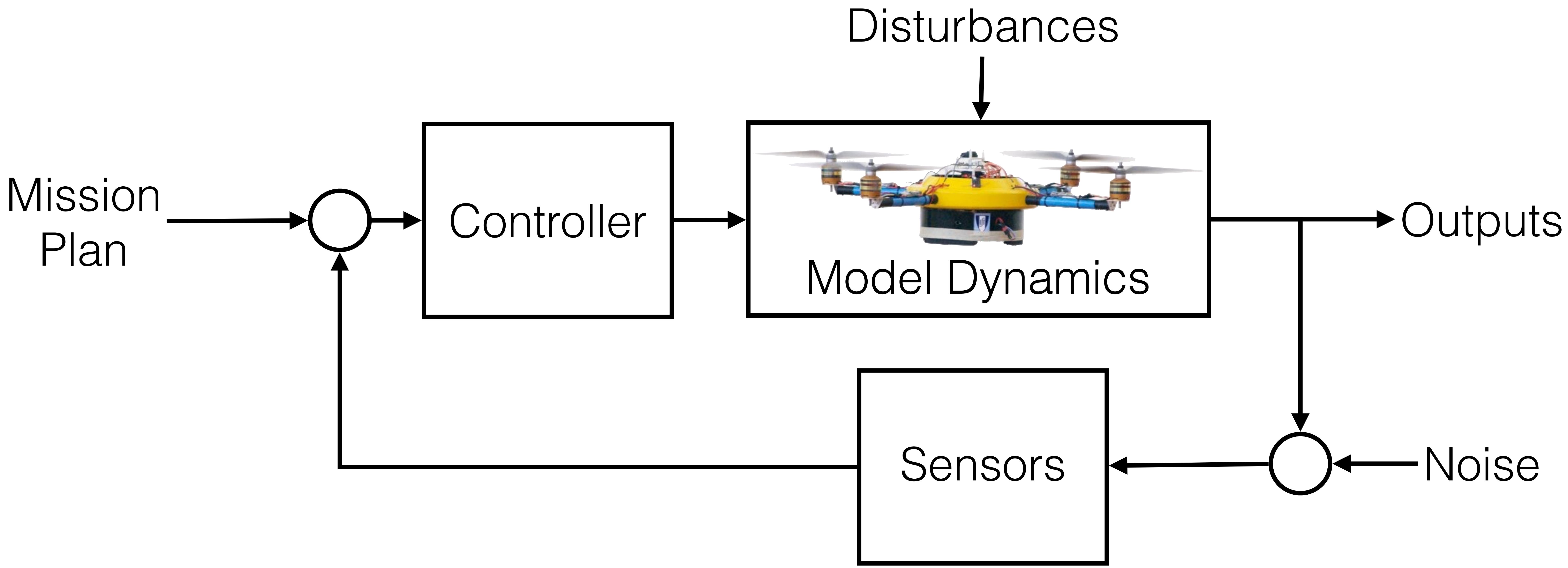
Lisboa, May 2020

unite! University Network for Innovation, Technology and Engineering

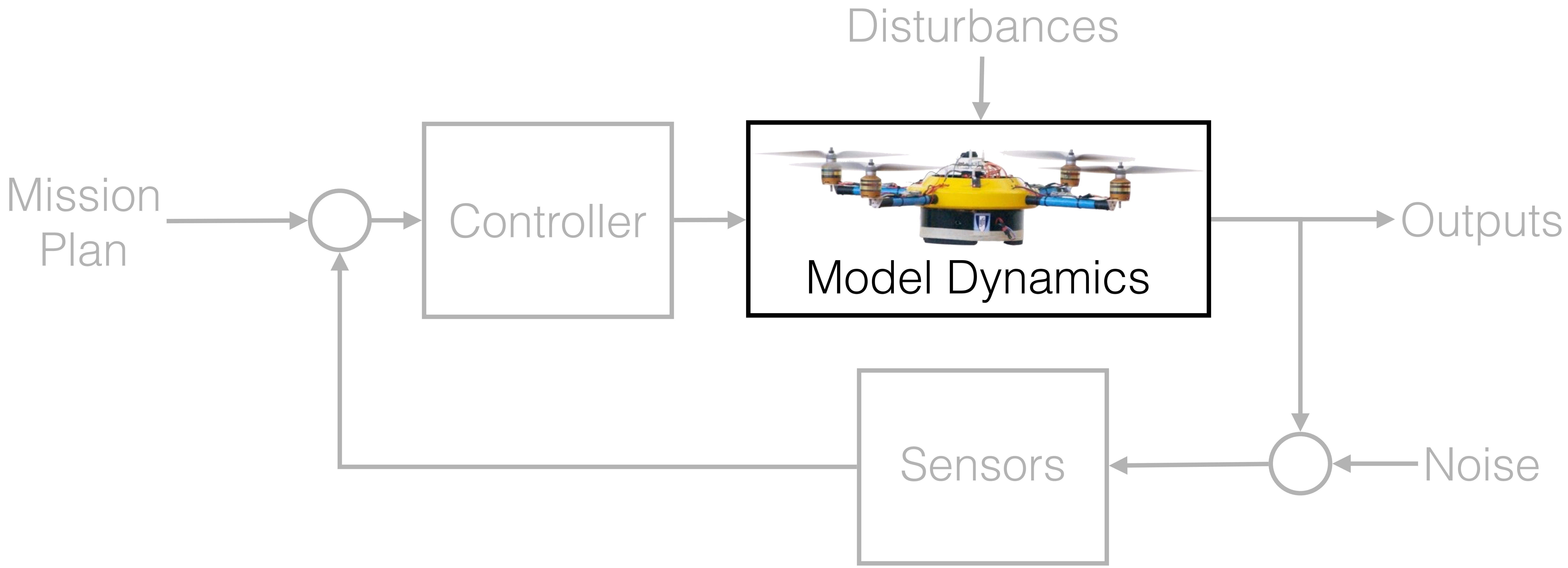
LISBOA UNIVERSIDADE DE LISBOA

Co-funded by the Erasmus+ Programme of the European Union

The quadrotor as a control system



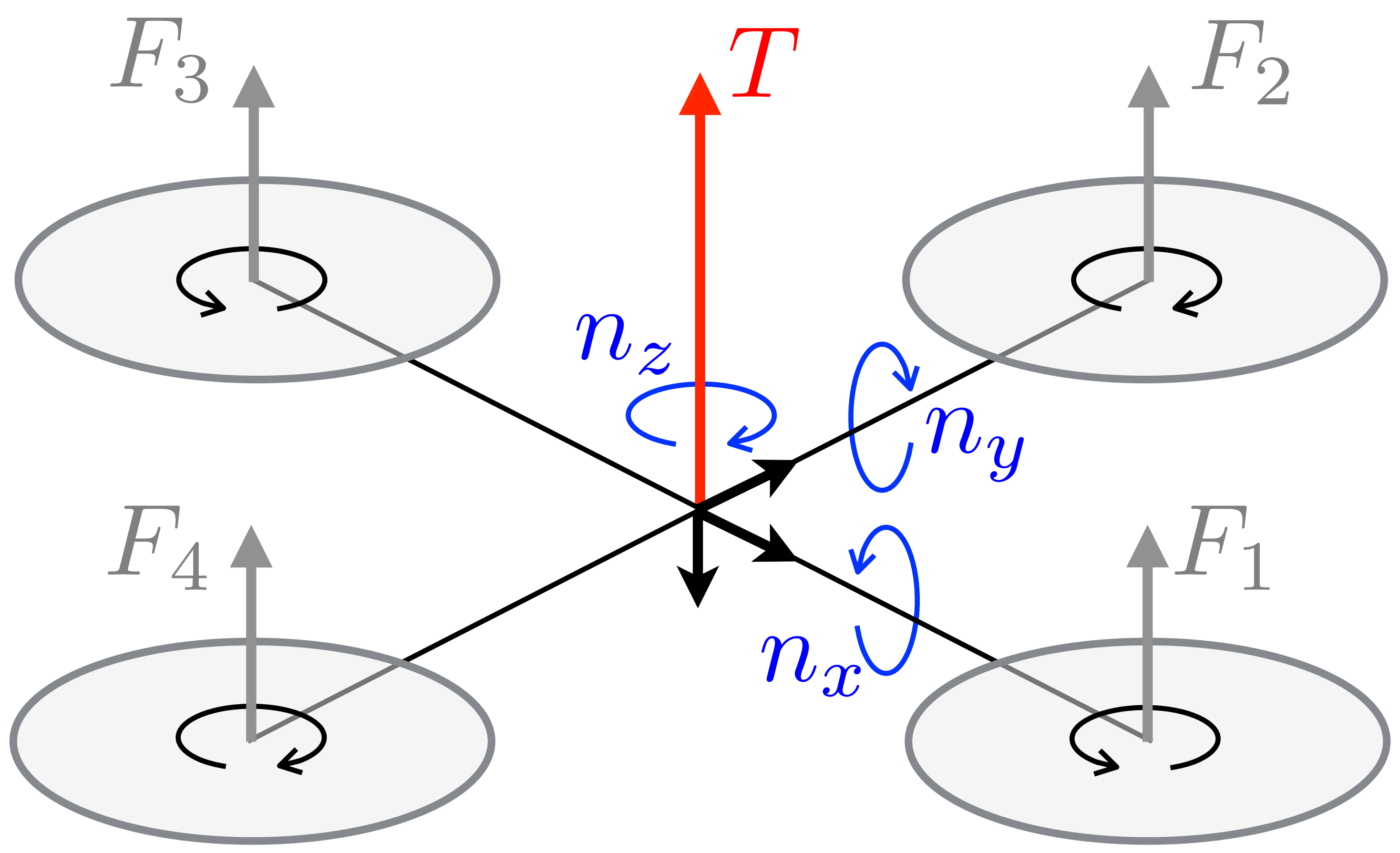
The quadrotor as a control system



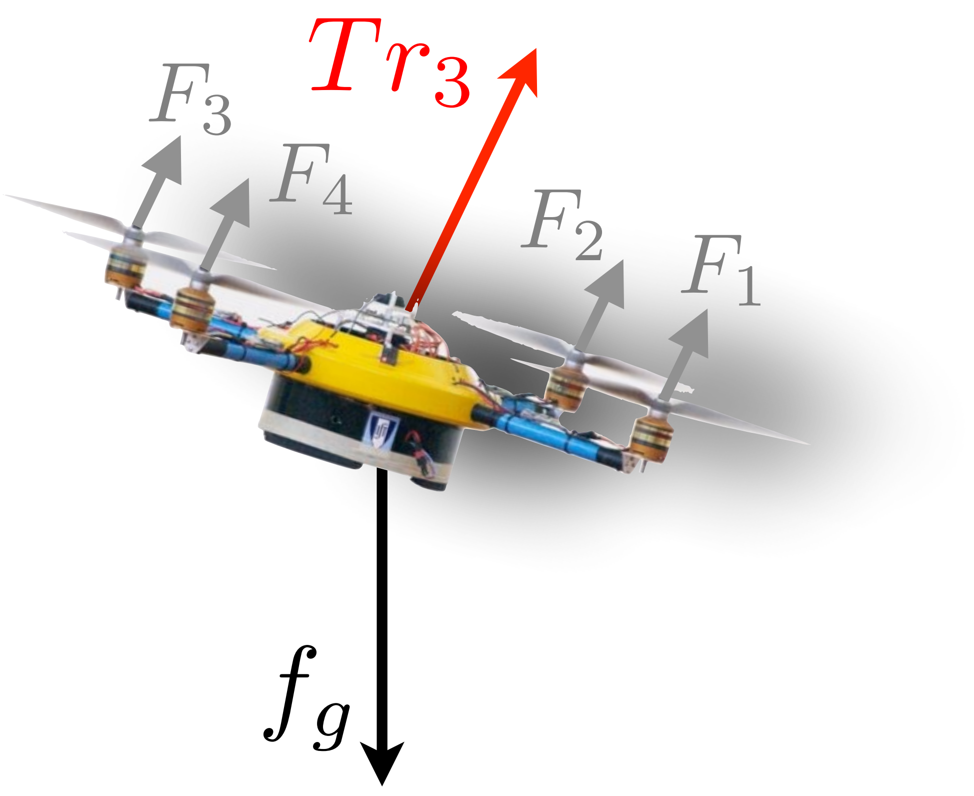
Let's start with the model

Quadrotor forces and moments

Two pairs of counter-rotating rotors



$$\begin{bmatrix} T \\ n_x \\ n_y \\ n_z \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 & 1 \\ 0 & b & 0 & -b \\ -b & 0 & b & 0 \\ c & -c & c & -c \end{bmatrix} \begin{bmatrix} F_1 \\ F_2 \\ F_3 \\ F_4 \end{bmatrix}$$



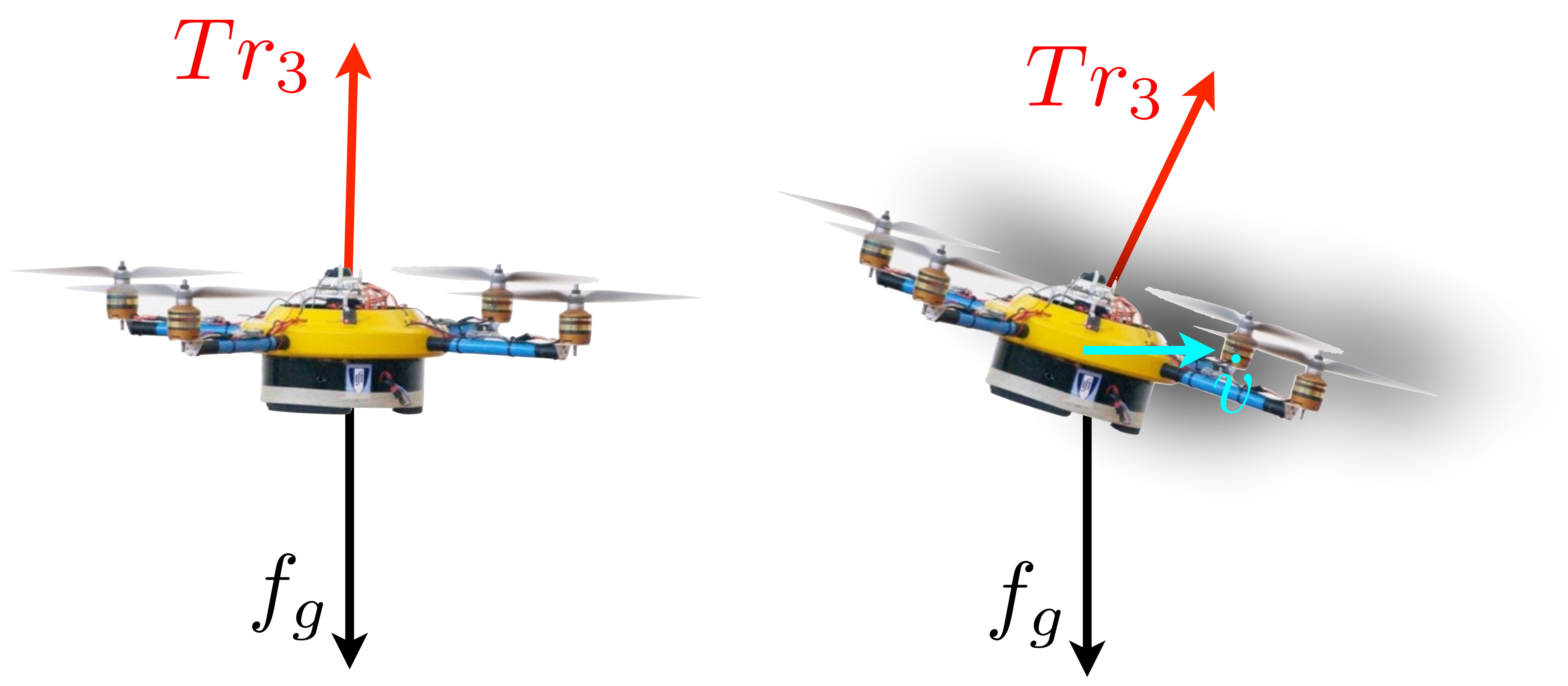
$$r_3 = Re_3 = R \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix}$$

$$f_g = mge_3$$

Quadrotor forces

Underactuated system: 12 states, 4 inputs

At rest | Accelerating



$v = 0$ | $\dot{v} \neq 0$

$Tr_3 = f_g$ | $Tr_3 = f_g - m\dot{v}$

Control objective:

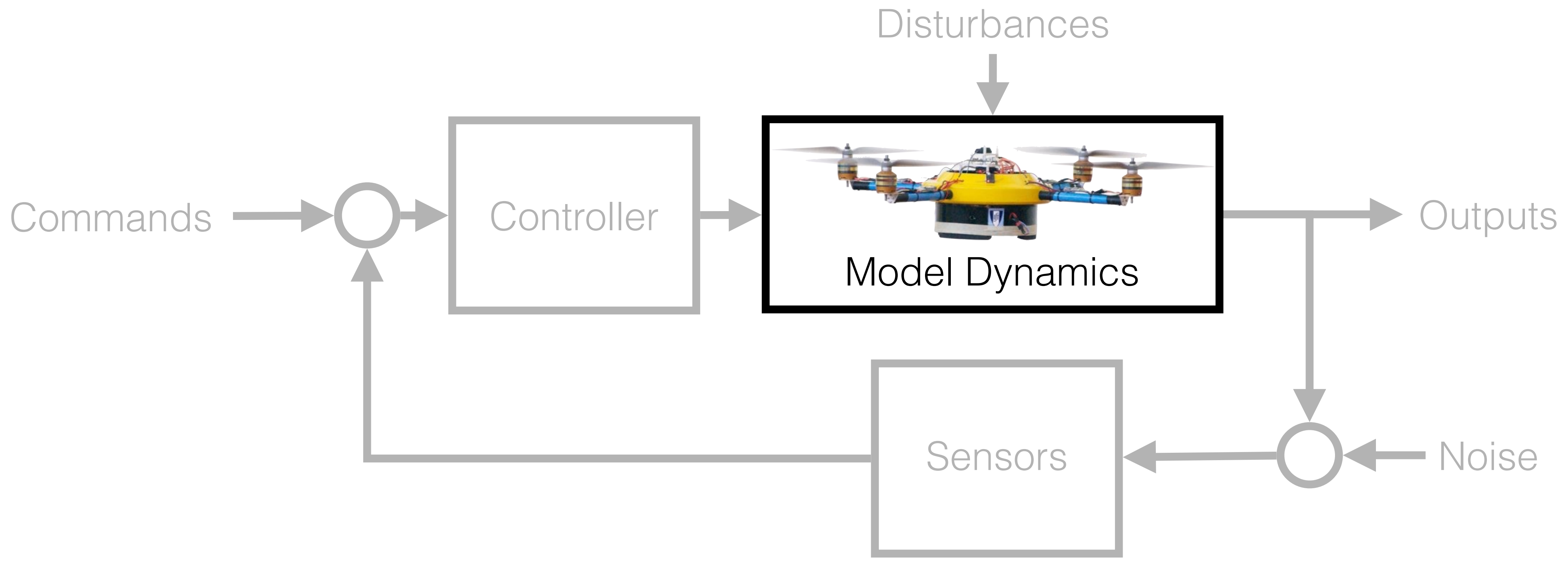
Steer the position to
a desired trajectory

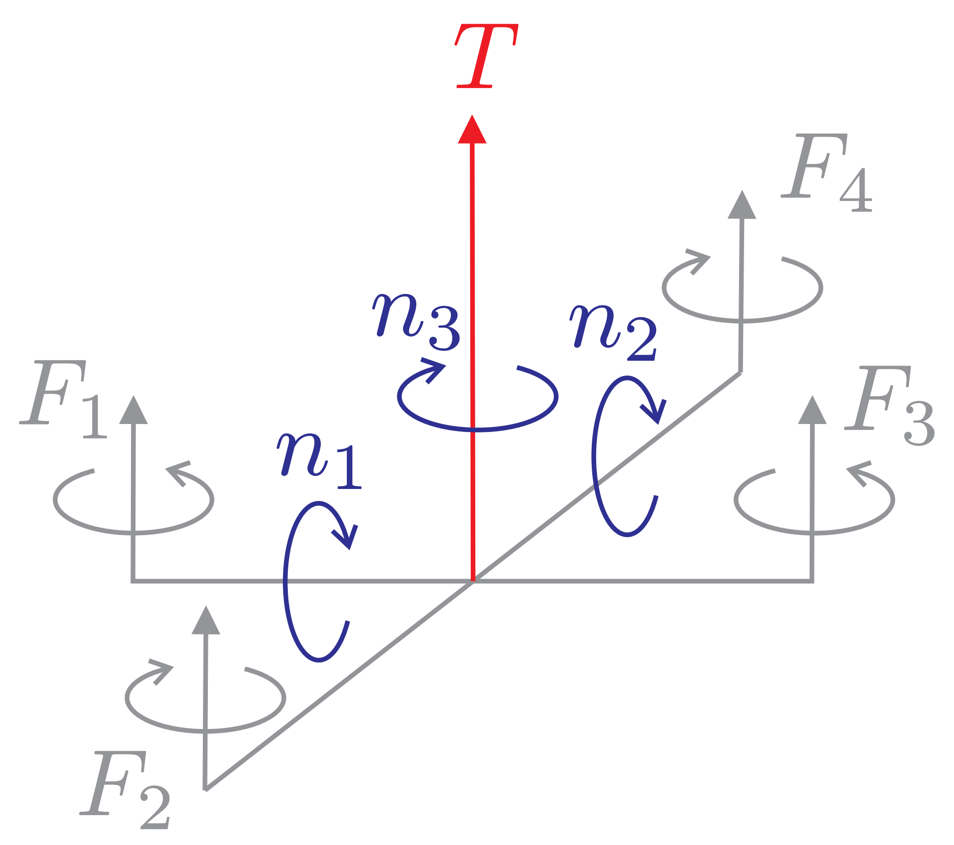
$p(t) \rightarrow p_d(t)$

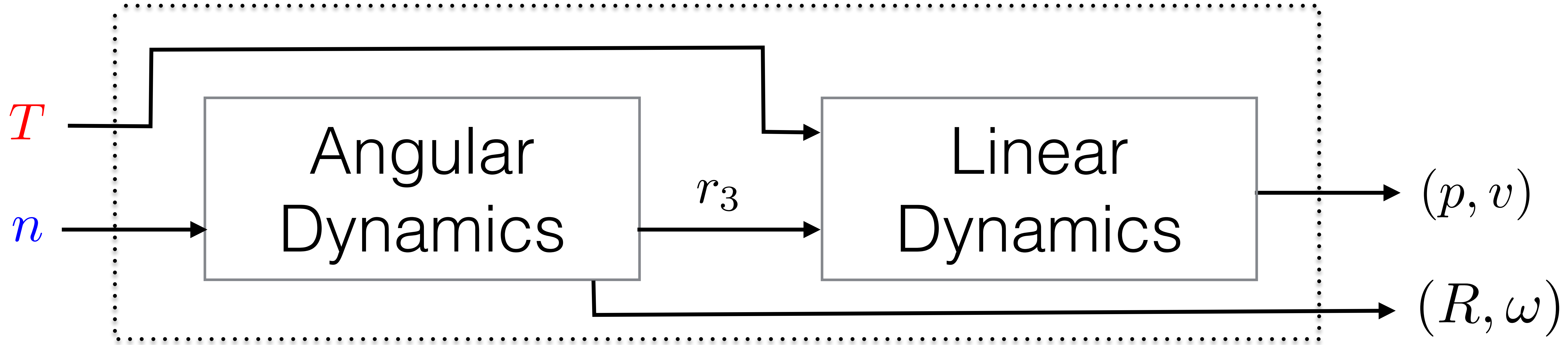
using (T, n) as inputs.

Can only prescribe 4 states:
3D position and rotation about z-axis

Quadrotor dynamic model





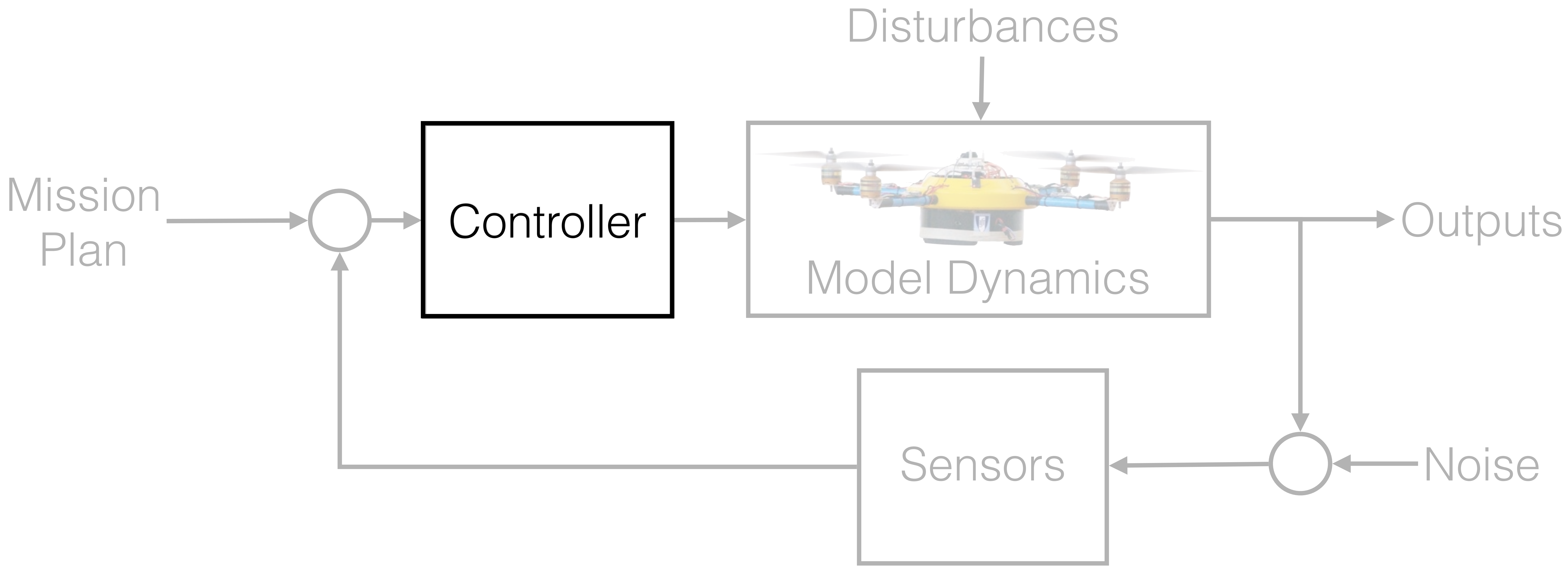


State (p, v, R, ω)

Input (T, n)

Can prescribe $(p,\ \psi) \in \mathbb{R}^4$

The quadrotor as a control system

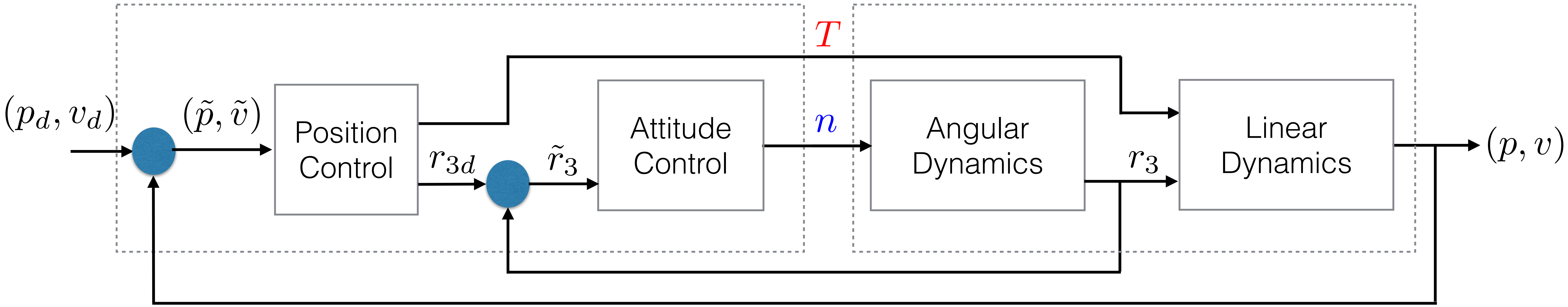


Now the controller

Trajectory Tracking - Control Objectives

- Track a trajectory
- Realistic model
- Robustness to disturbances
- Actuation bounds
- Large basin of attraction

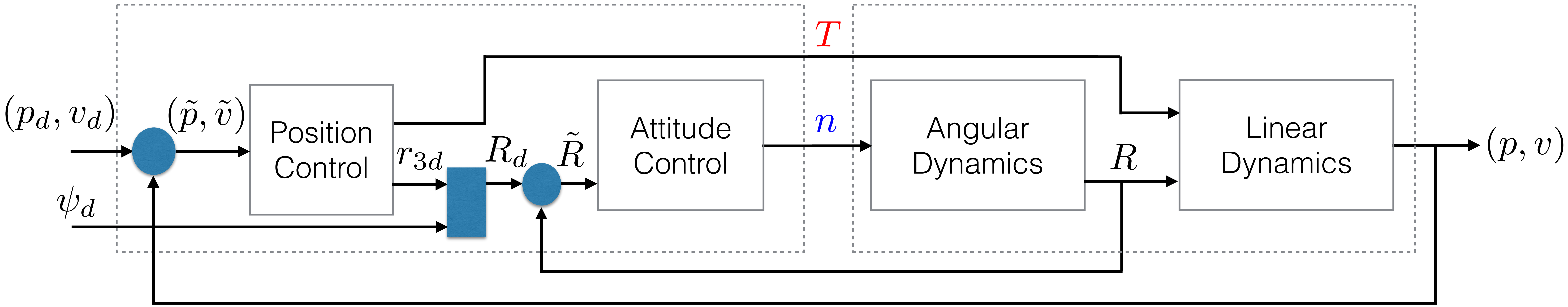
Trajectory Tracking Control



Simplest Position Controller yields a mass-spring-damper system

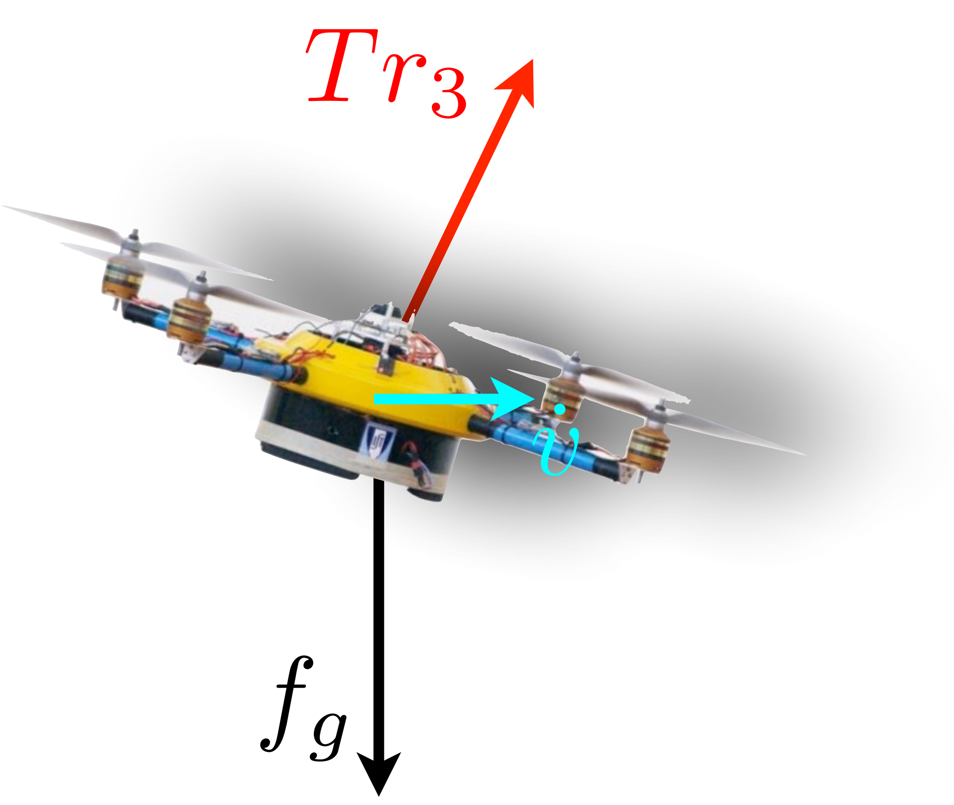
$$m\dot{\tilde{v}} = -k_1\tilde{p} - k_2\tilde{v}$$

Trajectory Tracking Control

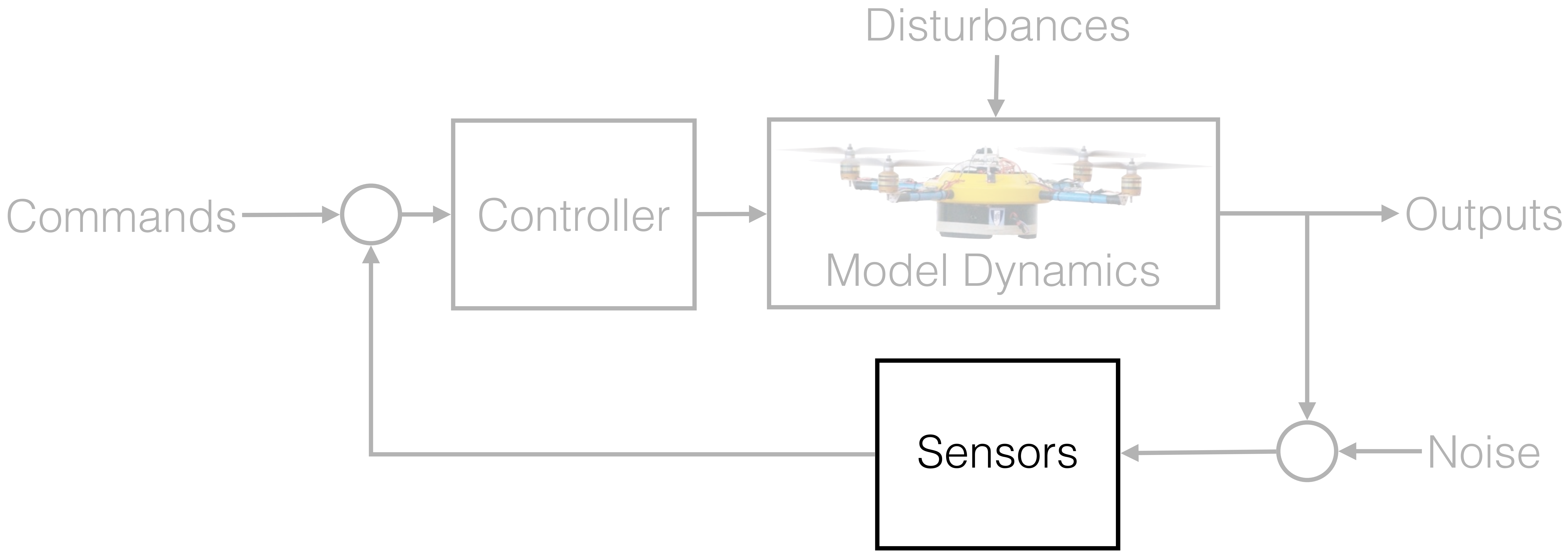


Desired position and yaw angle

(p_d, ψ_d)



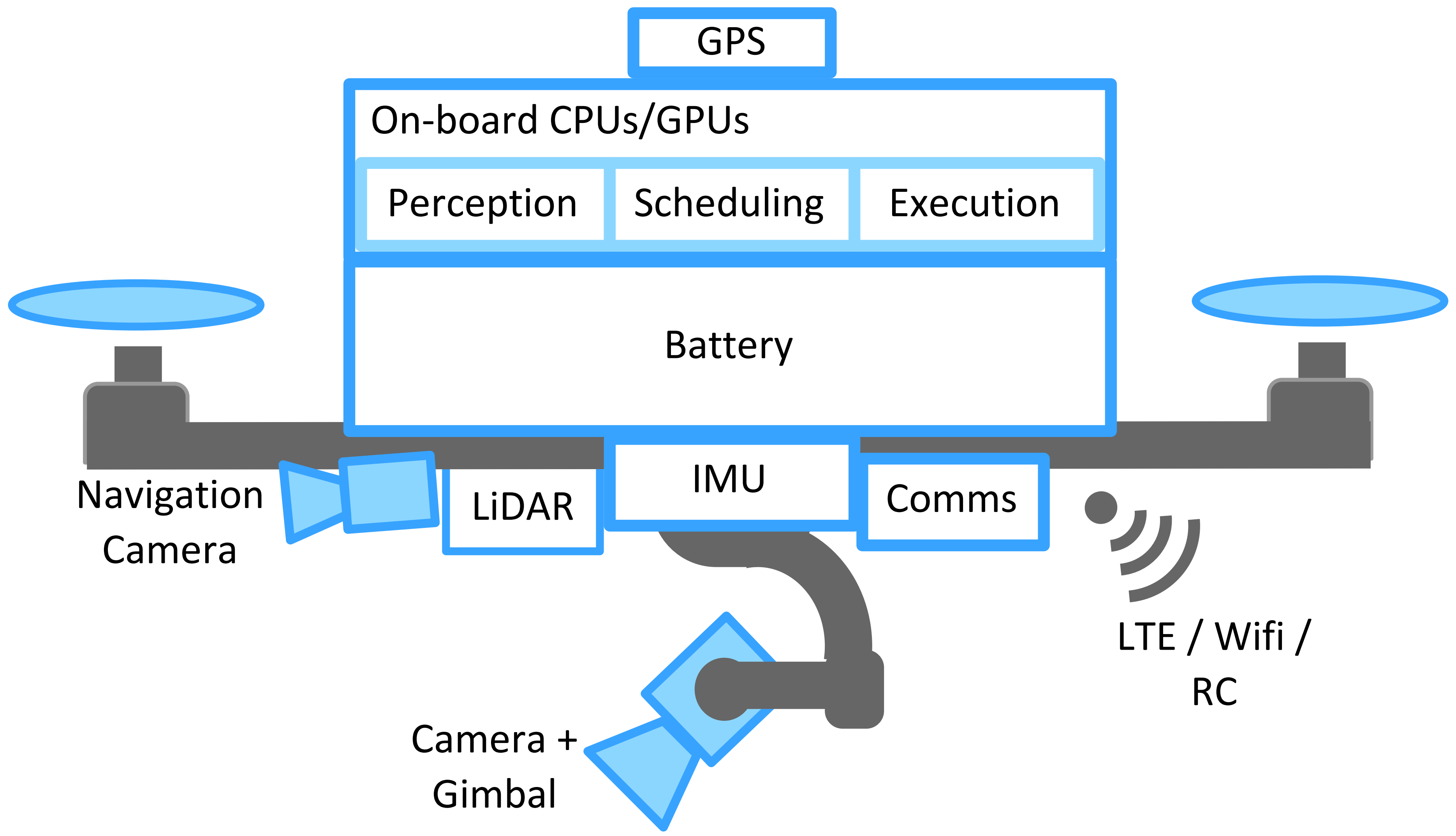
The quadrotor as a control system



Now the sensors

Sensors and Onboard Architecture

- Sensors
    - GPS - position estimates
    - IMU (accelerometers, gyroscopes, magnetometers) - attitude estimates
    - Cameras and LiDARs - mainly used for obstacle avoidance and task execution (surveying, inspection, …)
- Onboard Computers
- Communication Systems
- Batteries



Biggest limitation to enhanced autonomy

- Flight time *vs.* available payload

unite! University Network for Innovation, Technology and Engineering

U LISBOA | UNIVERSIDADE DE LISBOA

Co-funded by the Erasmus+ Programme of the European Union