# From **Filippo's car** to **Antonio's drones**


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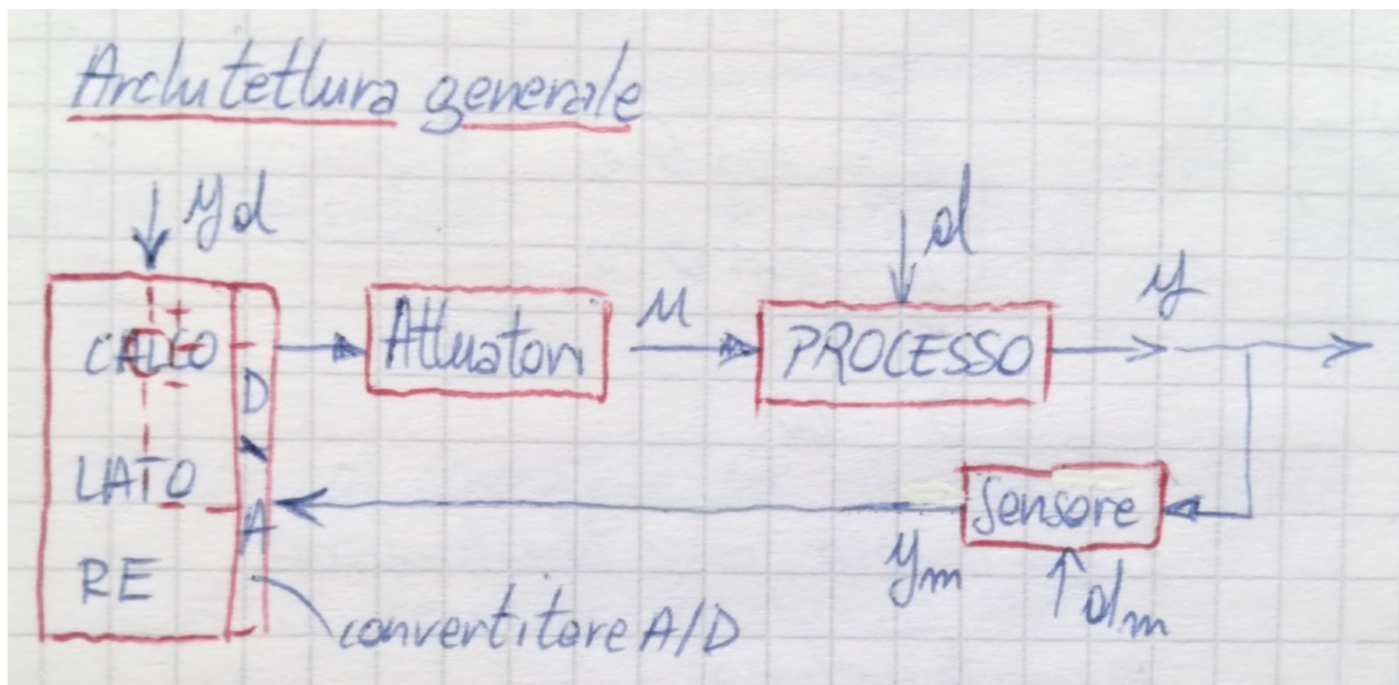
A workshop in honor of Alessandro De Luca
for his 60th birthday

Sapienza University, Rome, January 9th, 2018

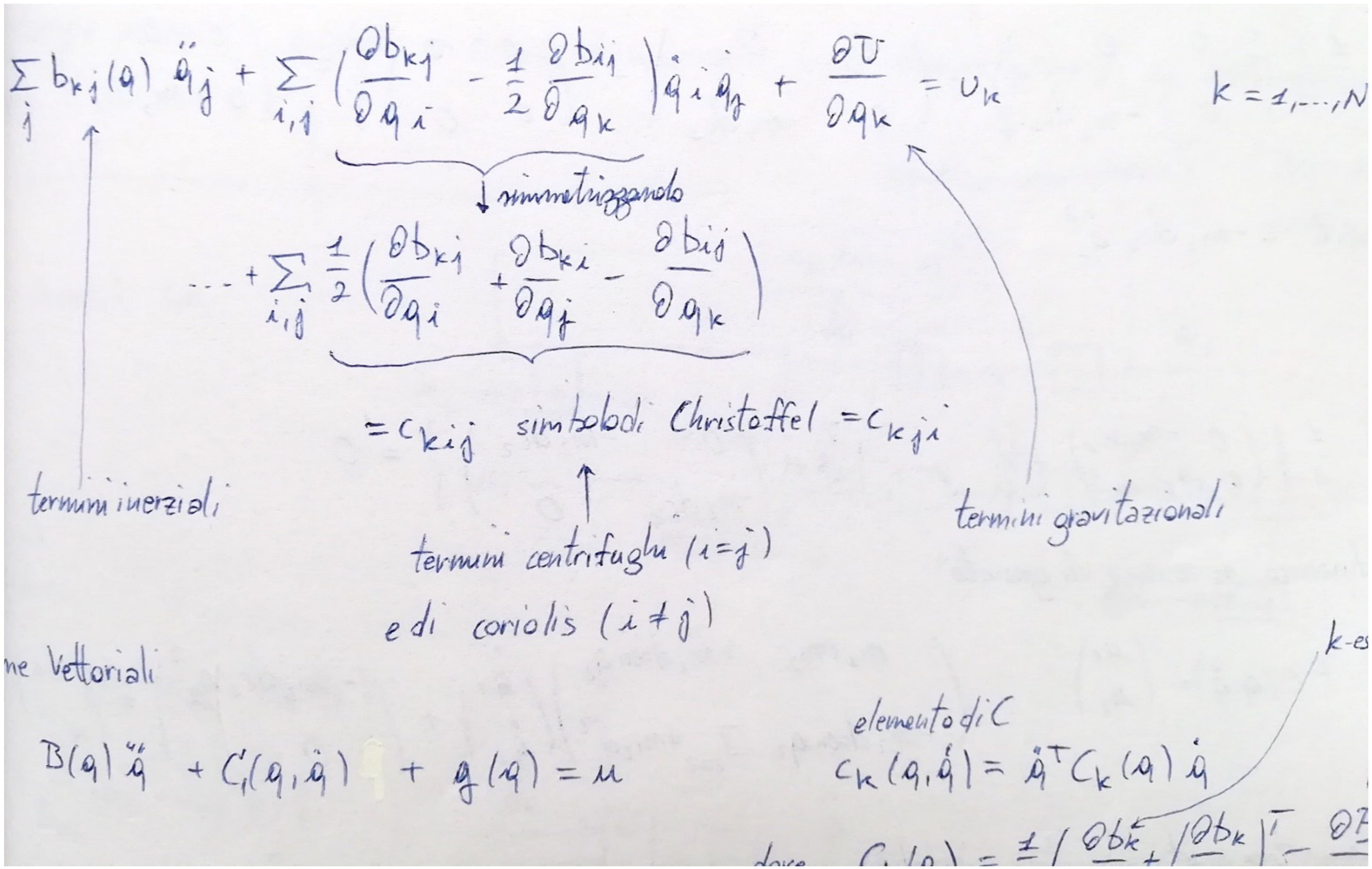
# Automatic Control Class

(2002)




(probably) the first feedback block diagram I wrote

# Robotics Class (2003)




my first derivation of the Lagrangian model

# Alessandro’s Inception (con’t)

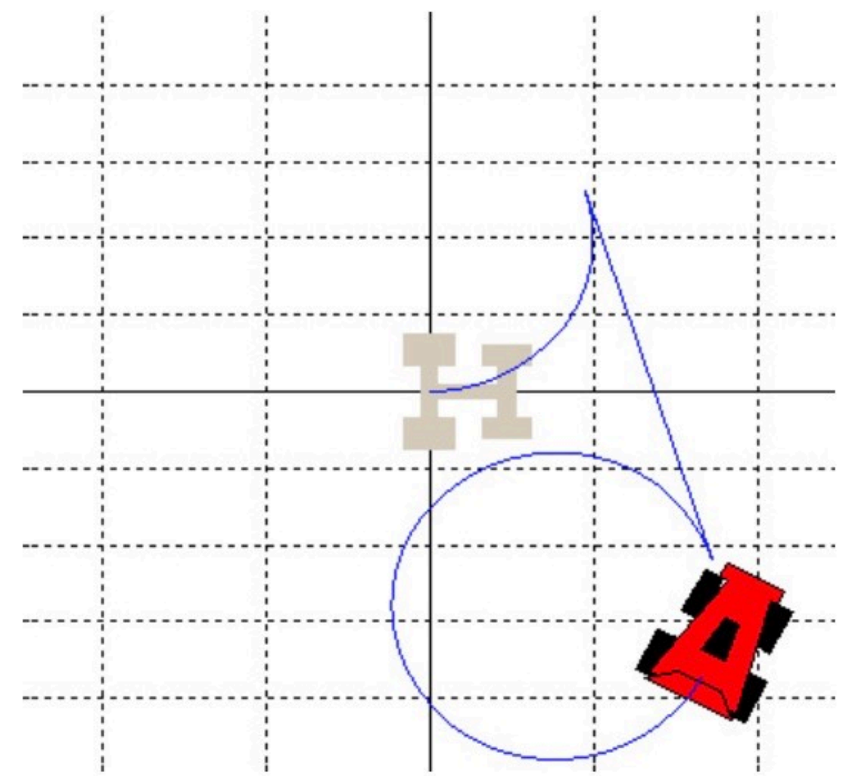
Robotics Class Project

## Motion Planning for the Filippo’s Car


Università di Roma “la Sapienza”
Facoltà di Ingegneria

*Corso di Robotica Industriale*
*Prof. Alessandro De Luca*

PIANIFICAZIONE
DEL MOTO
PER LA
FILIPPO’S CAR

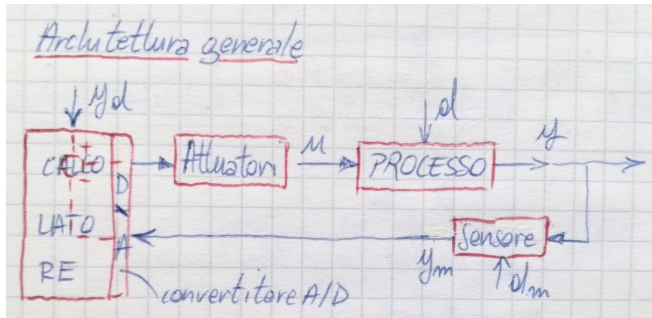


Unicycle

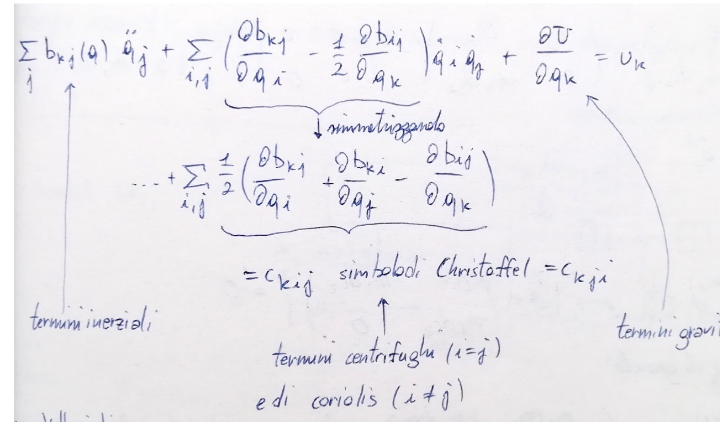
Only two constant inputs:

- Forward straight
- Backward in circle

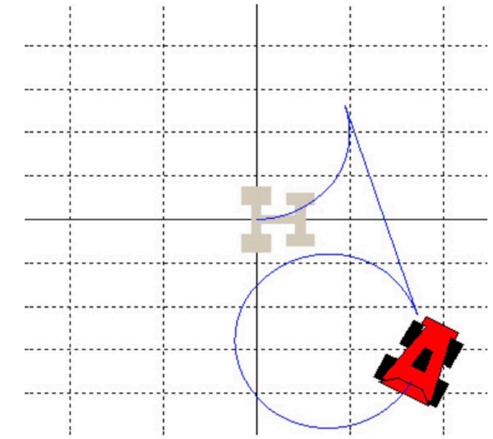
# Alessandro’s Inception (con’t)




Control




Robotics



nonconventional ‘Challenges’

1) Solid **control perspective** to robotics

2) Interest in **nonconventional problems**

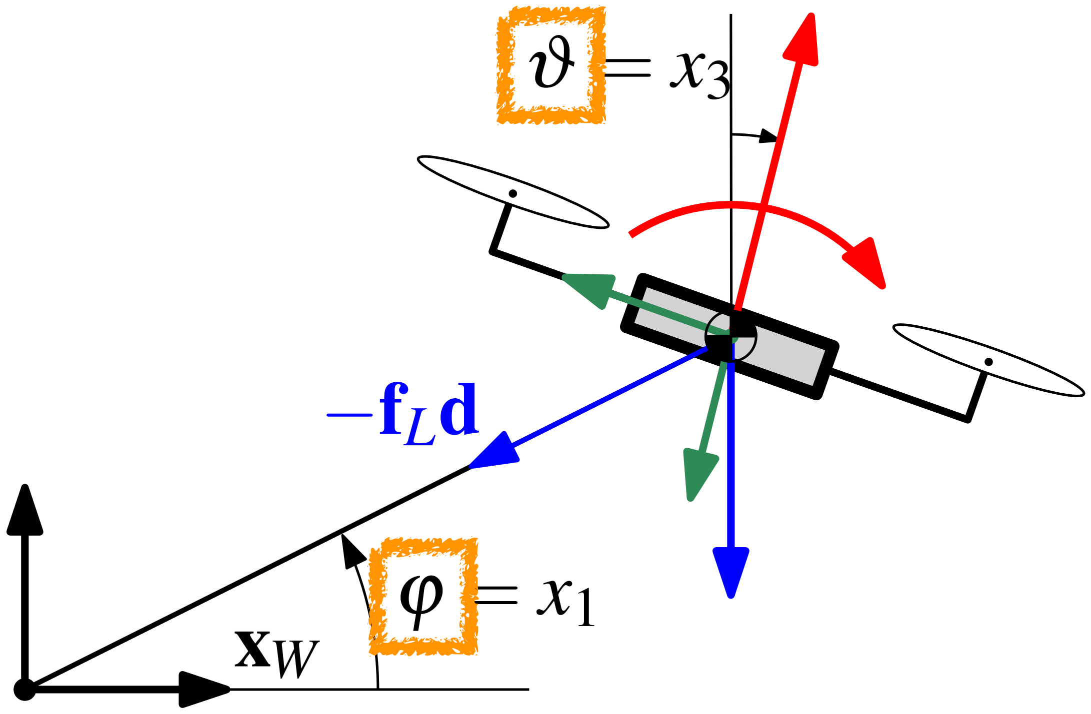
## 'Antonio's' Drones

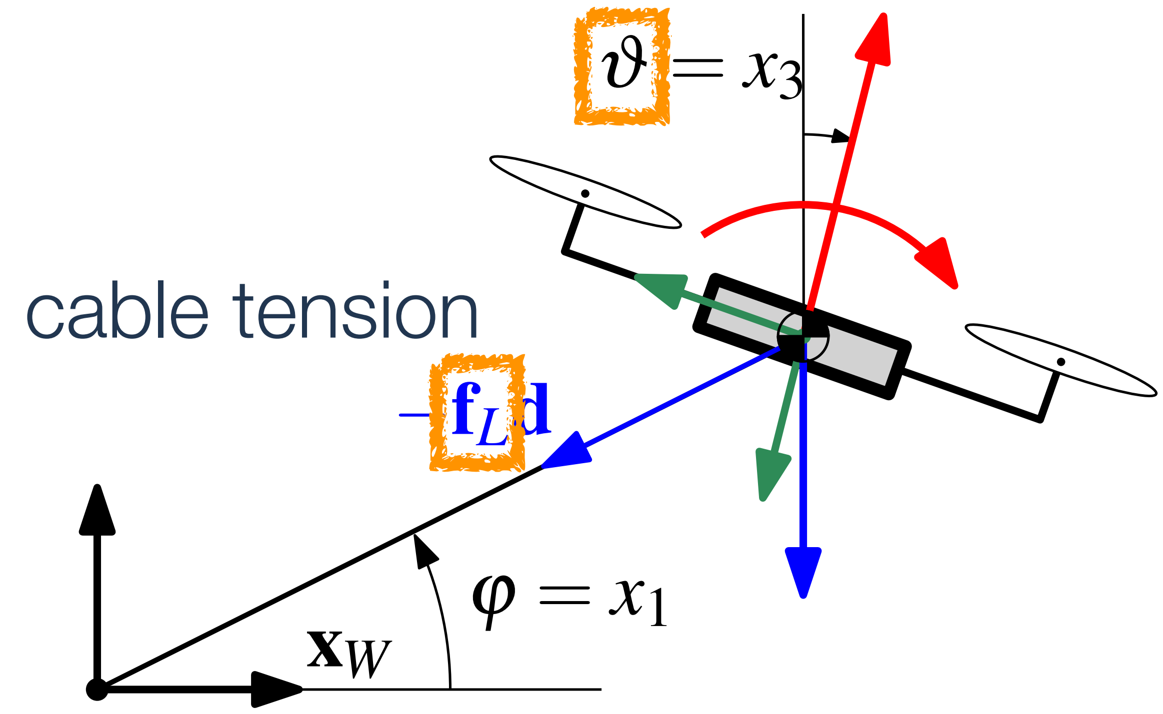
- The **Spider-Rotor**
- The **Protocentric** Aerial Manipulator
- The **Tilt-Hex**
- The **Omni+7**

No time for:

- The MAGMaS
- The Monkey-Rotor
- …

# 1) The Spider Rotor




1) Two feedback linearizing (flat) output pairs

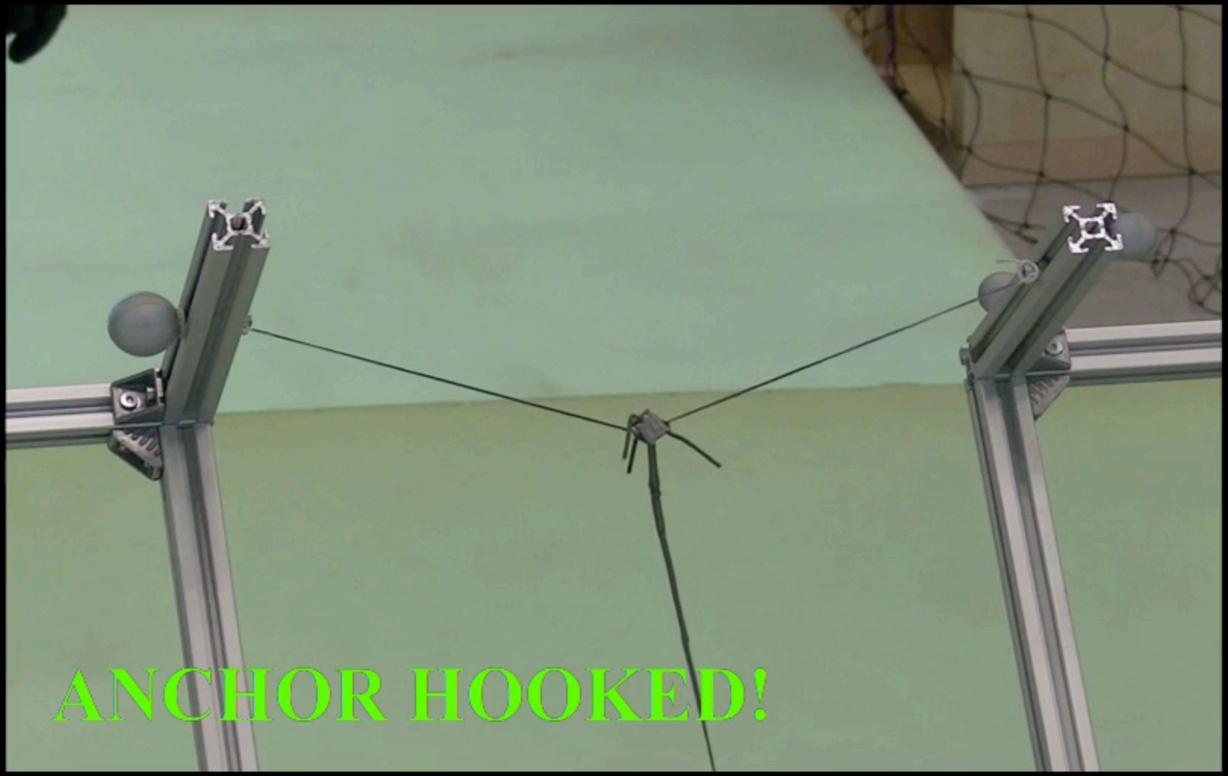
2) Full state observable using
only gyroscope and accelerometer!

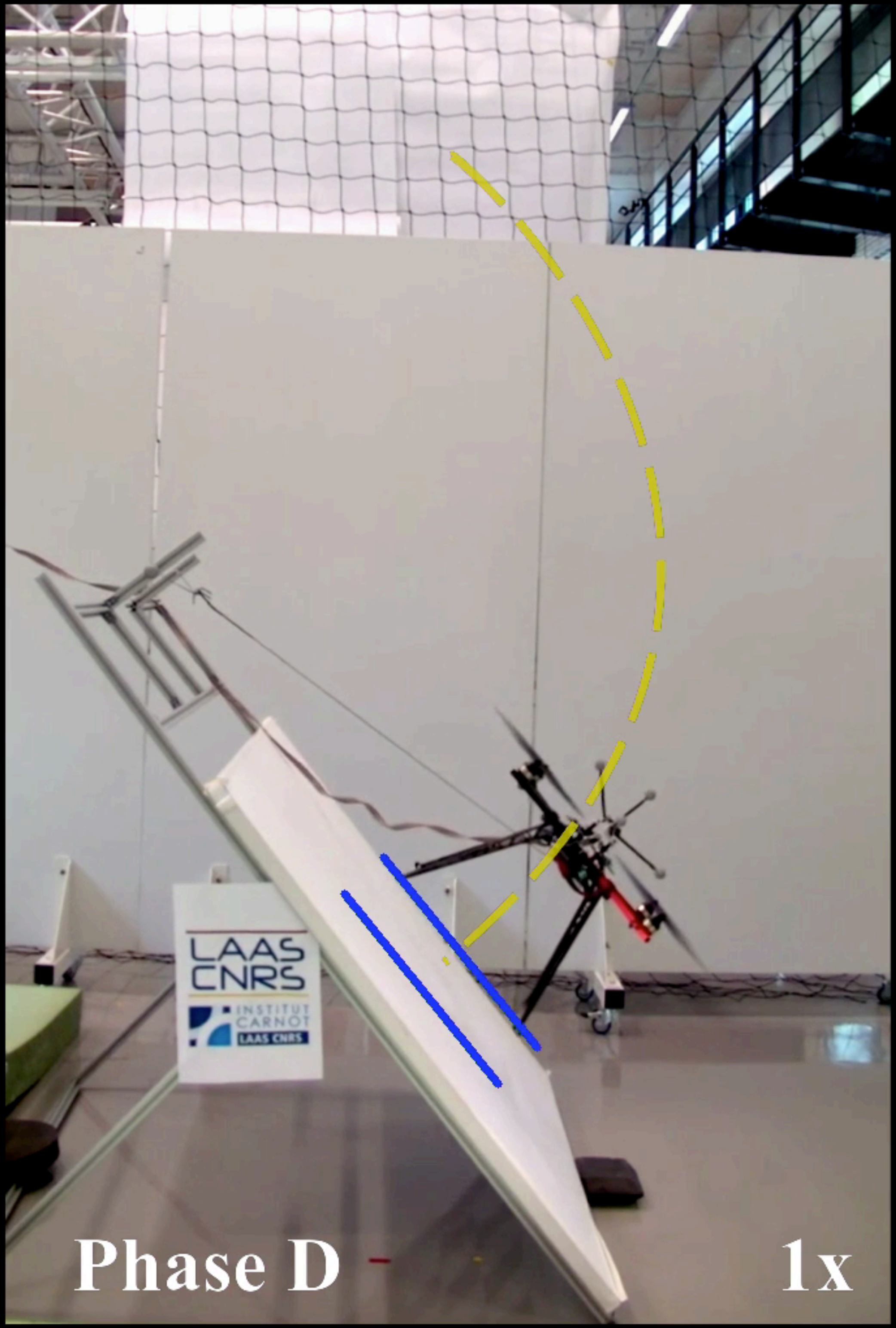
# 1) The Spider Rotor (con't)

Phase D: Landing

While the elevation is decreased:
* the tether is kept taut
* the pitch is steered to the surface angle exploiting the possibility of inclined hovering.

*Controller: $S^2$-and-attitude controller*



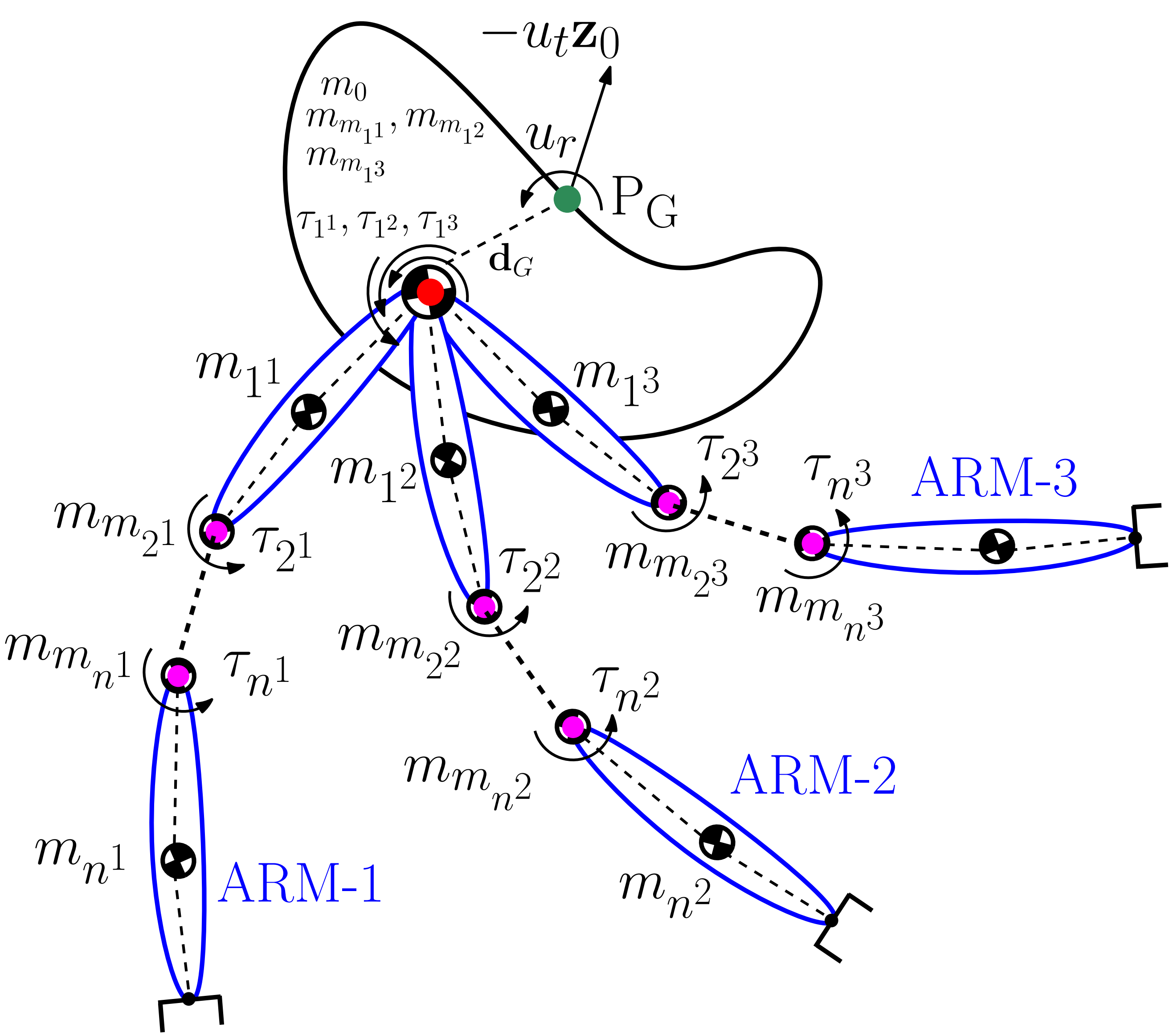



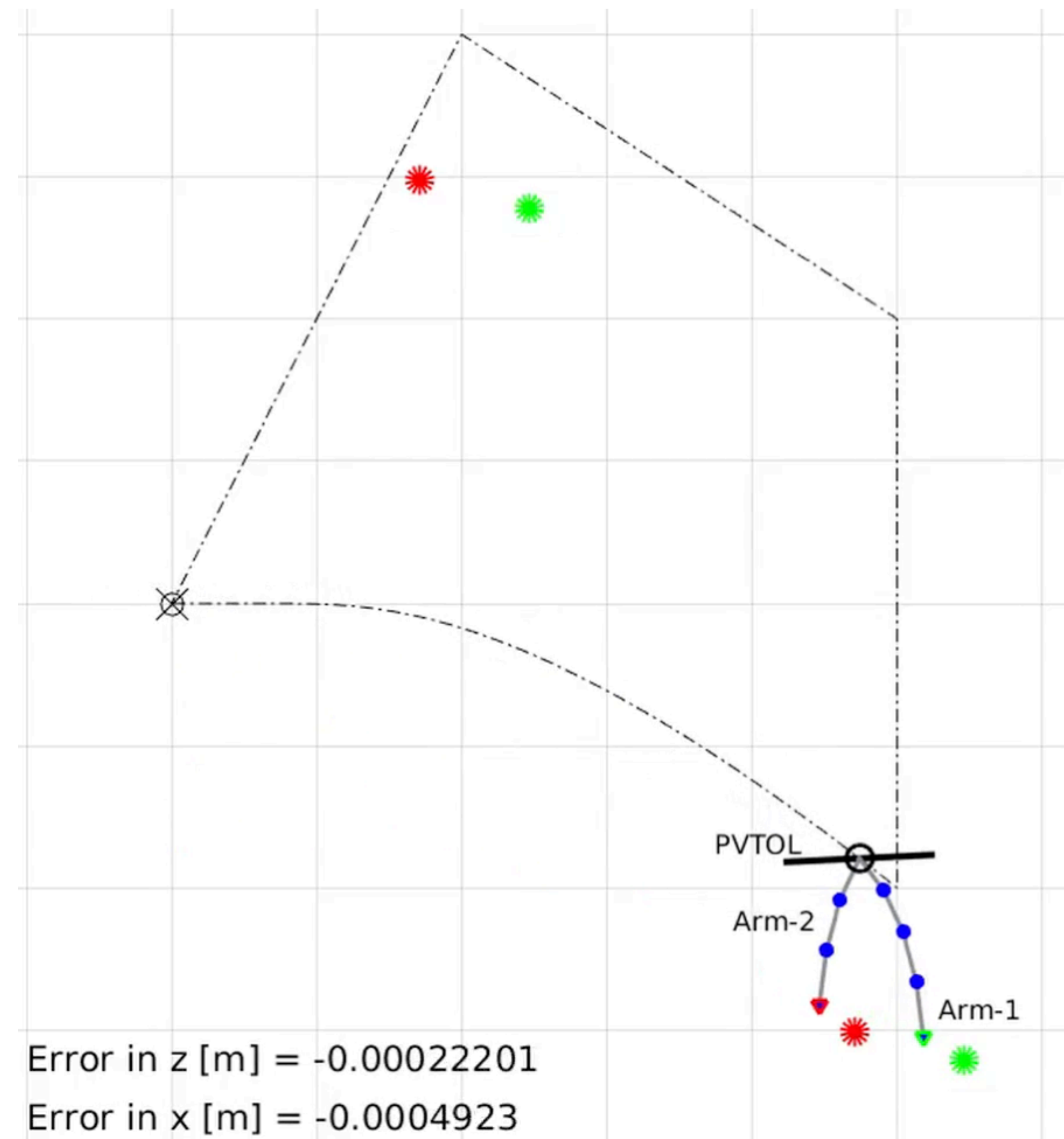

http://homepages.laas.fr/afranchi/robotics/?q=node/293

# 2) Protocentric Aerial Manipulators

## Protocentric = first joints at the CoM of the first body

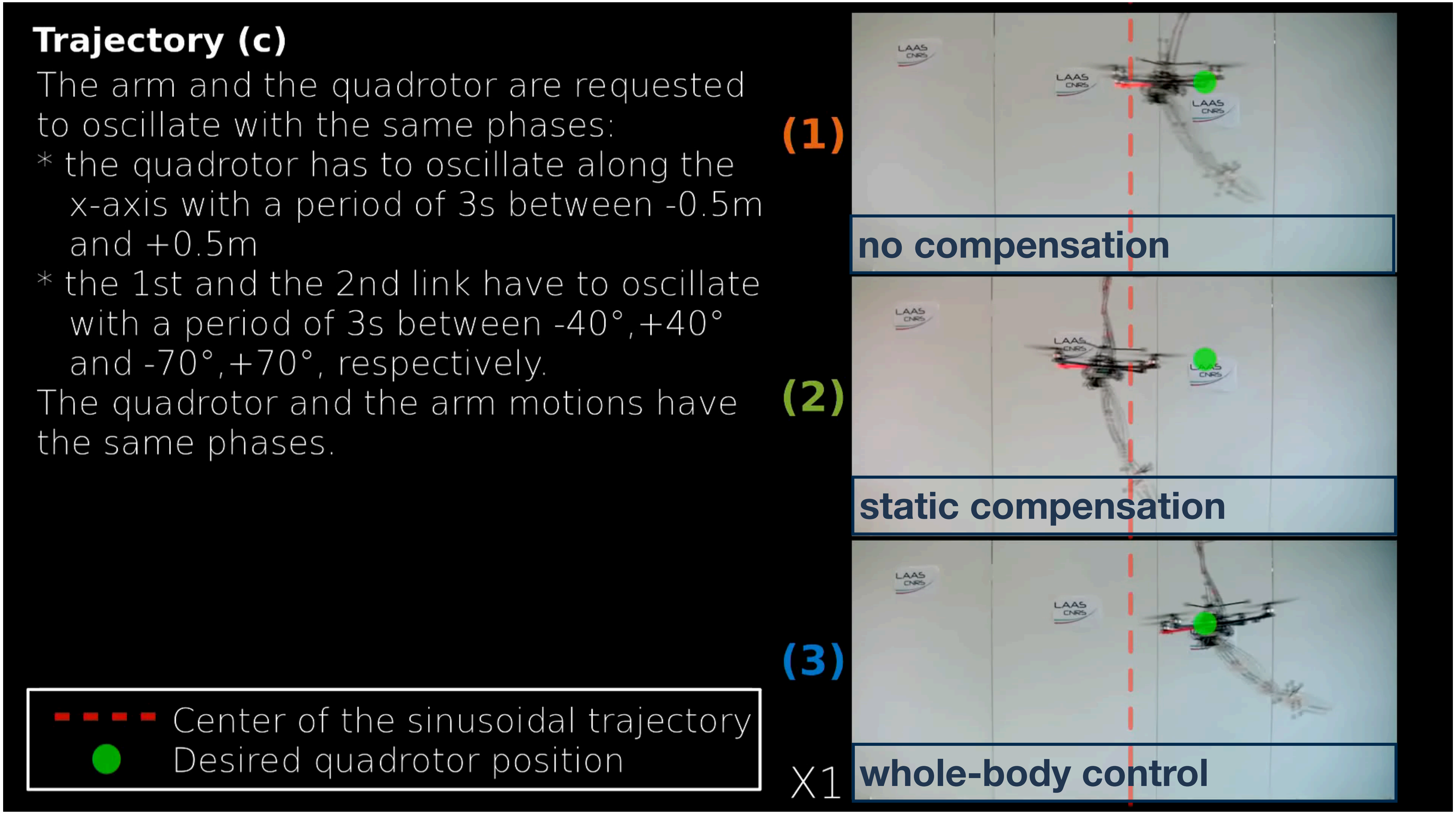
## ⇒EE-position are flat outputs




holds also for elastic joints but relative degree grows quadratically!

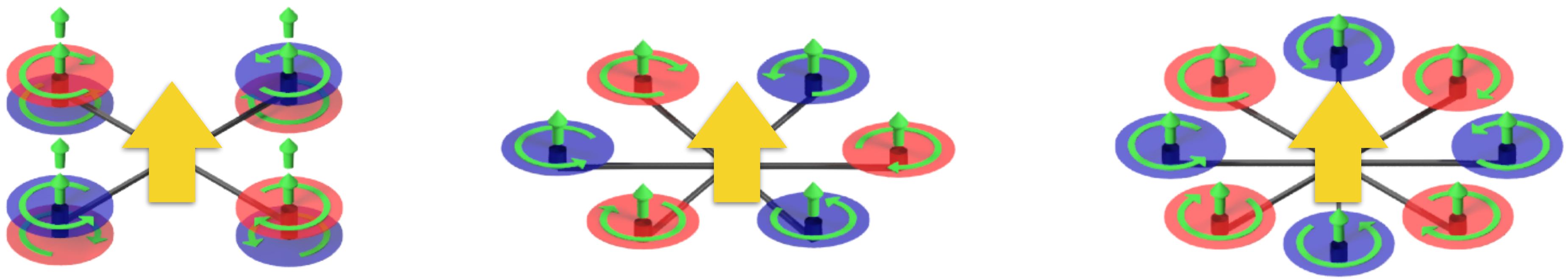
# 2) Protocentric Aerial Manipulators (con’t)



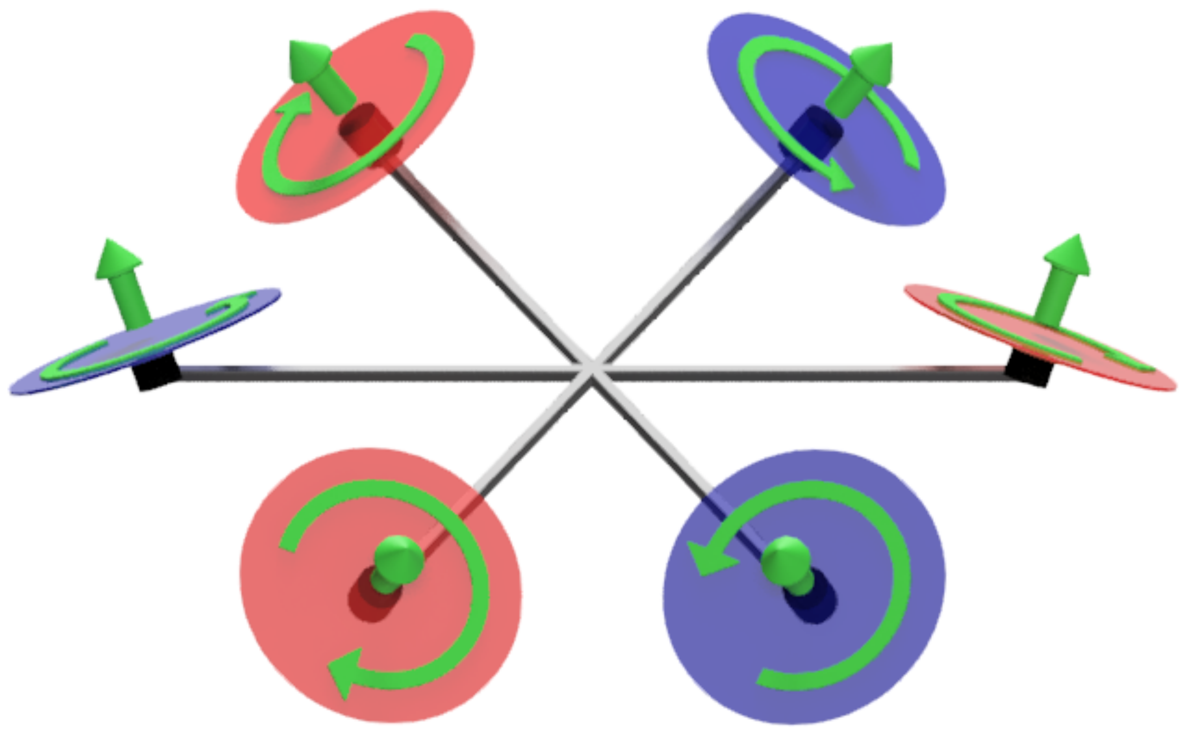

http://homepages.laas.fr/afranchi/robotics/?q=node/416

# 3) The Tilted Hexarotor

Only one total thrust direction

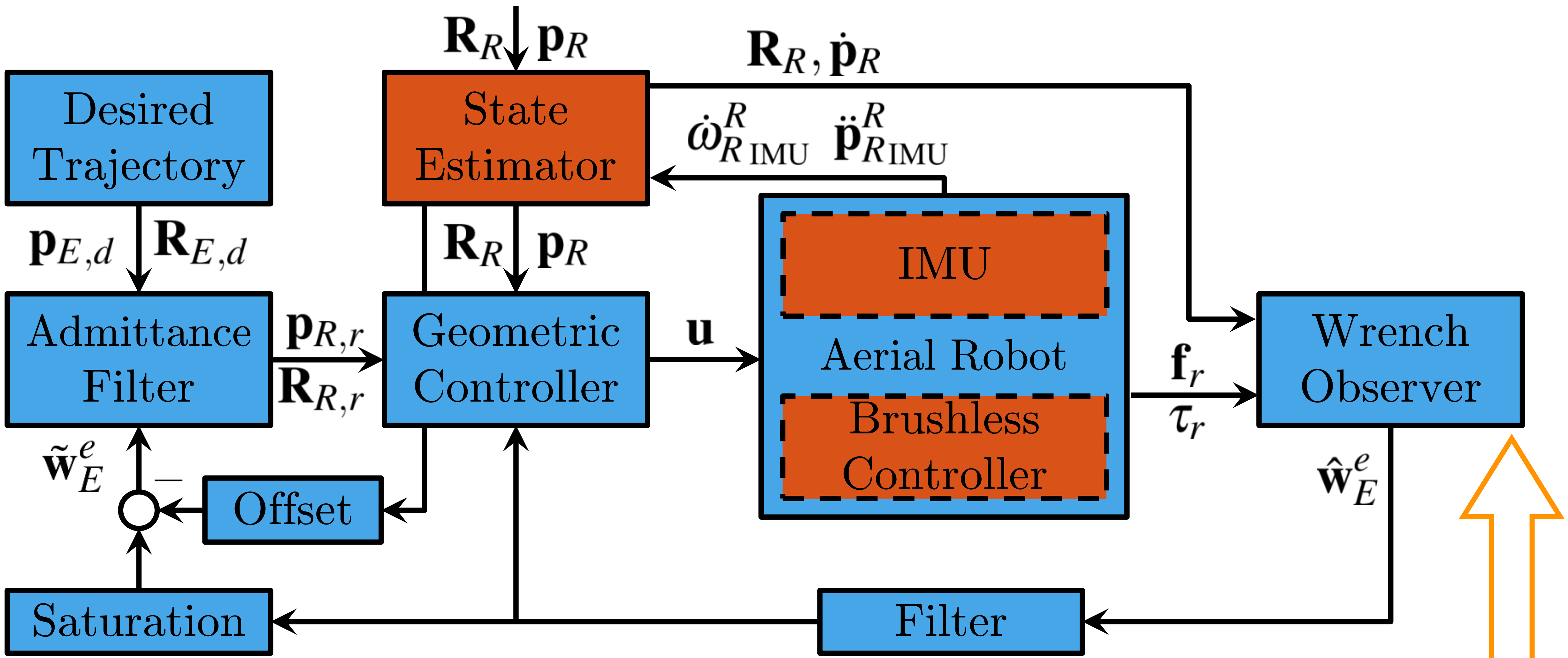


Platforms with **generic** rotor configuration:



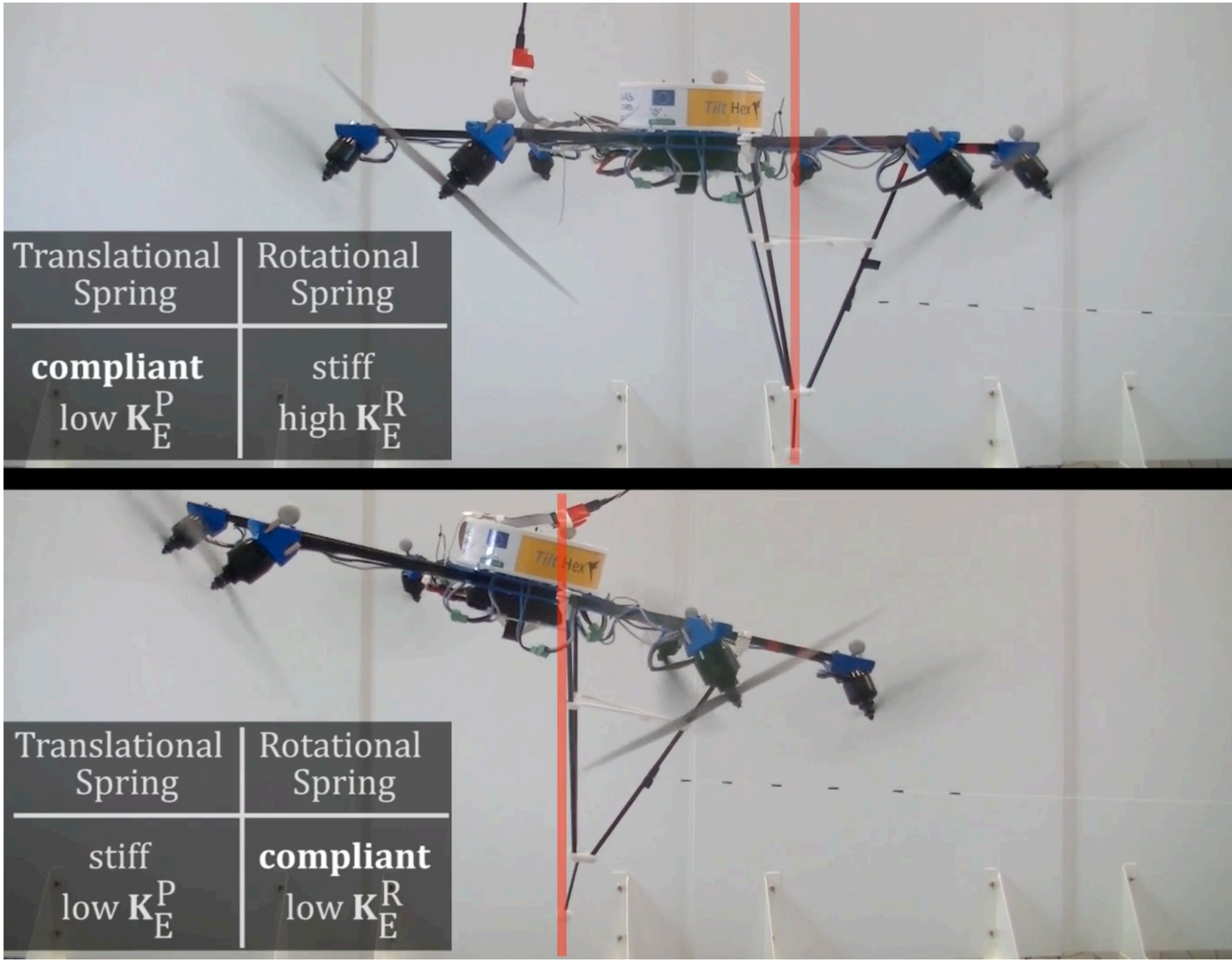
Several total thrust directions become possible

# Interaction Control




(wrench observer: DeLuca&Mattone 2005)

# 3) The Tilted Hexarotor (con't)

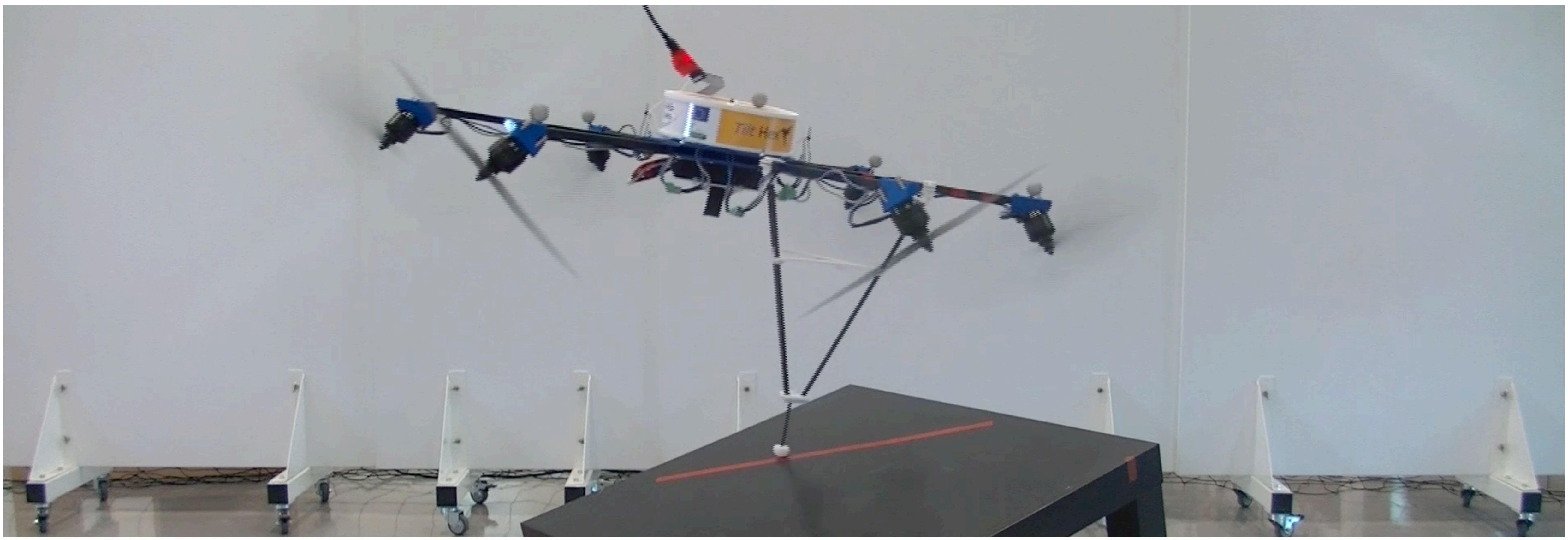


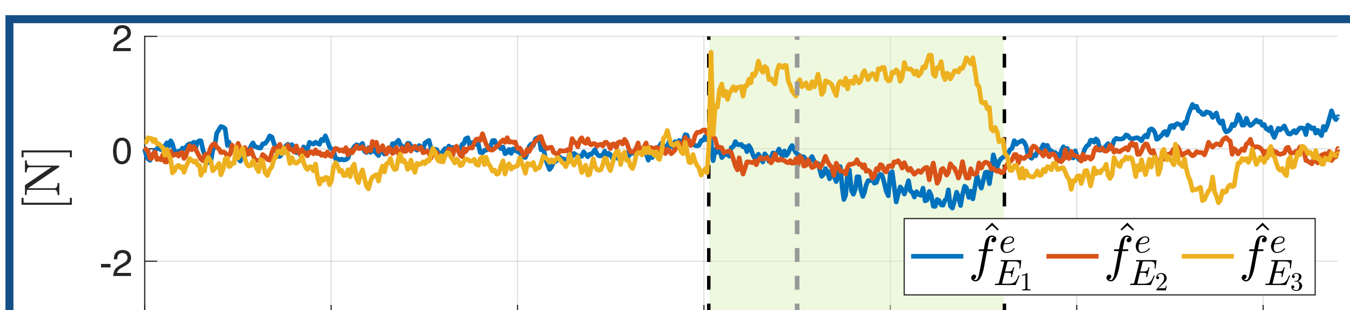

- Low position gain -> only translation
- Low orientation gain-> only rotation
- Aerial vehicle rotates about tool-tip position -> not about center of mass

## Independent Position/Orientation Response

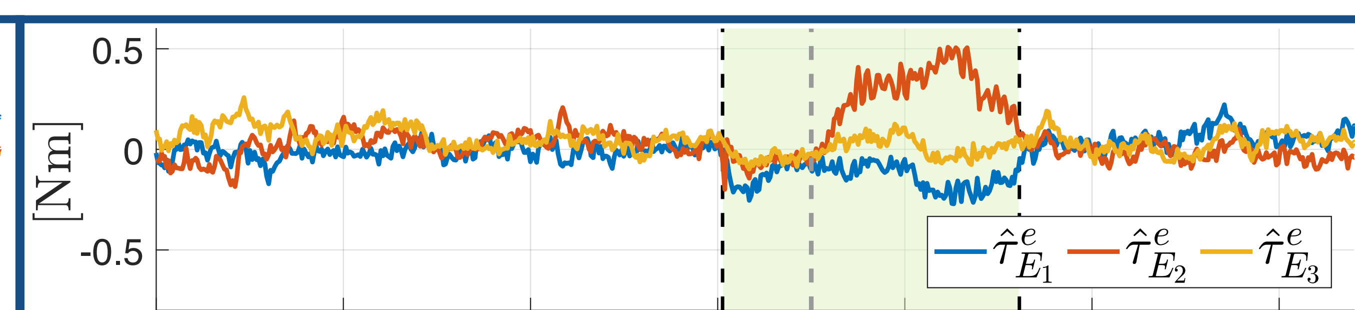
## Compliance:

## the robot is told the surface is horizontal



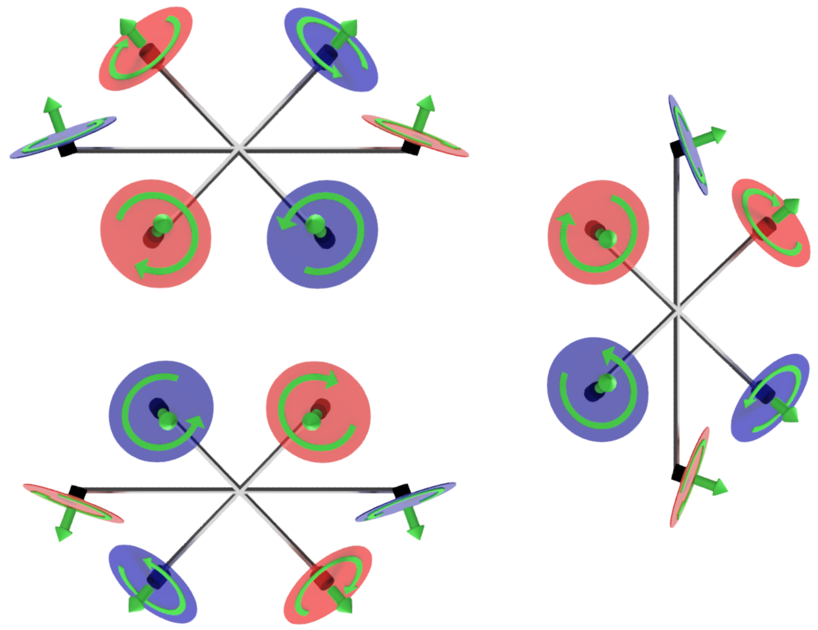



Ext. Force at Tip




Ext. Moment at Tip

# Can 'omnidirectionality' stem from unidirectional rotors?



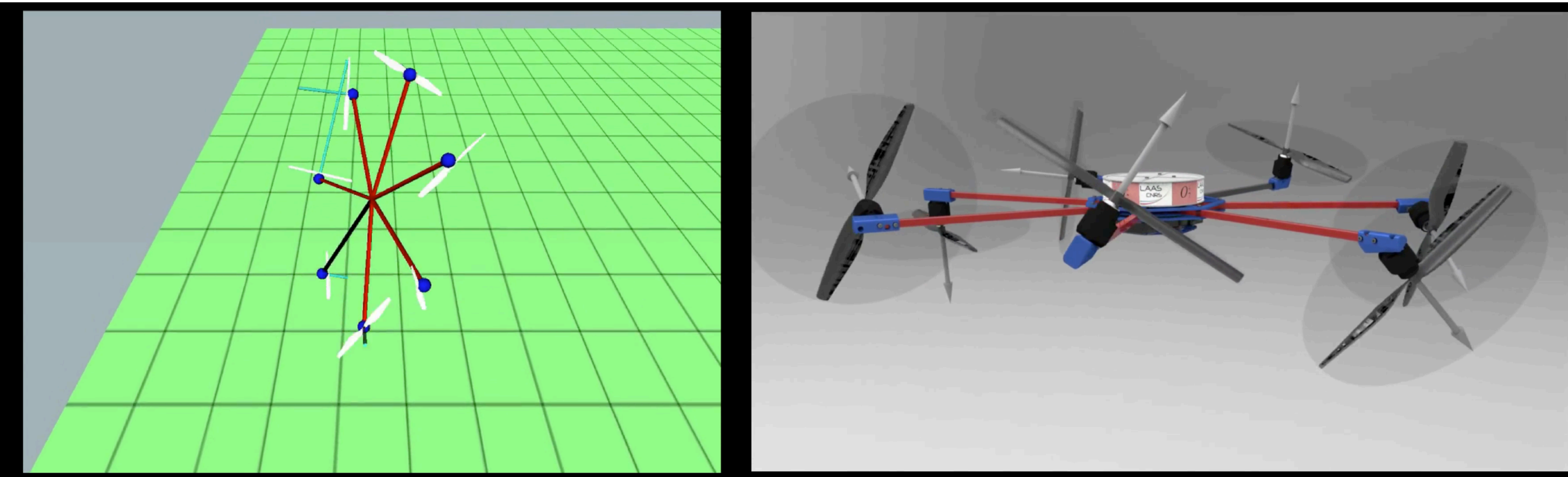
$$\forall \mathbf{w} \in \mathbb{R}^6 \;\; \exists \mathbf{u} \geq \mathbf{0} \; s.t. \; \mathbf{F}\mathbf{u} = \mathbf{w}$$

$$\Updownarrow$$

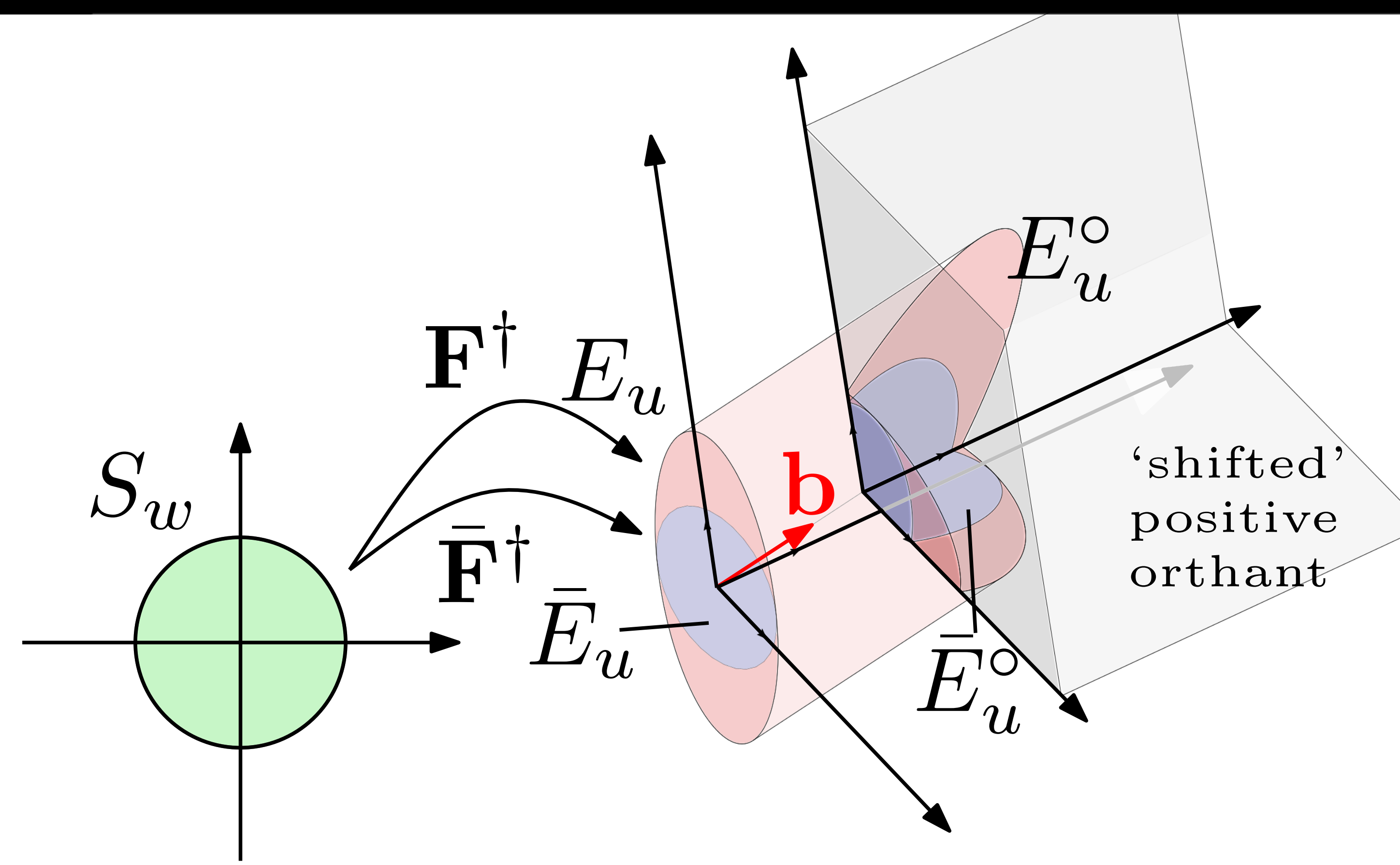
$$\text{rank}(\mathbf{F}) = 6 \quad and \quad \exists \mathbf{b} > \mathbf{0} \; s.t. \; \mathbf{F}\mathbf{b} = 0$$

$\Rightarrow$ at least 7 rotors needed

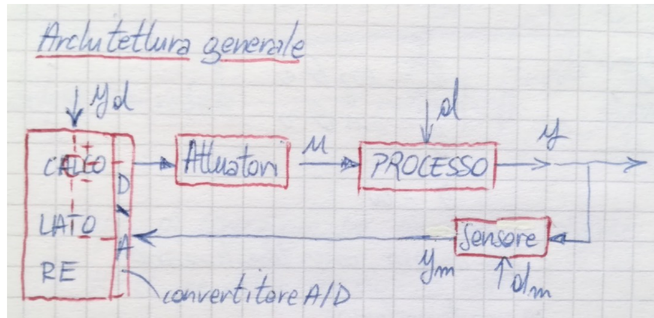
connection with grasping [Bicchi&Kumar 2000]



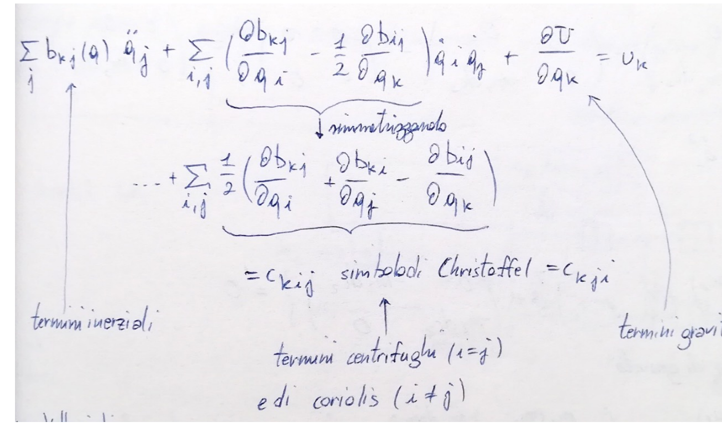
optimization of condition number (similar to a manipulability index)



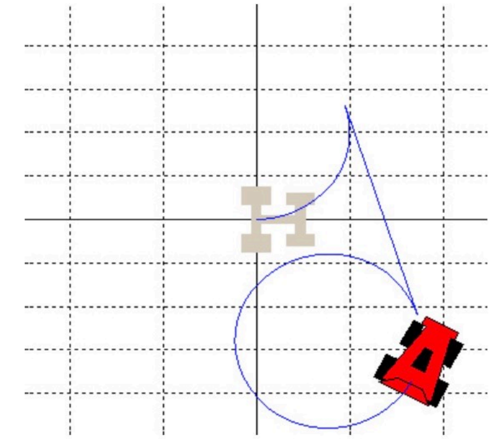
# Alessandro’s Inception




Control




Robotics



nonconventional ‘Challenges’