



MATTEO FUMAGALLI

FORCE APPLICATION IN AERIAL MANIPULATION: CHALLENGES AND PERSPECTIVES IN INFRASTRUCTURE INSPECTION



AERIAL MANIPULATORS: THE NEED



- For automating infrastructure inspection and maintenance, AEROWORKS introduces the novel concept for Service Robots: The Collaborative Aerial Robotic Workers (ARWs)

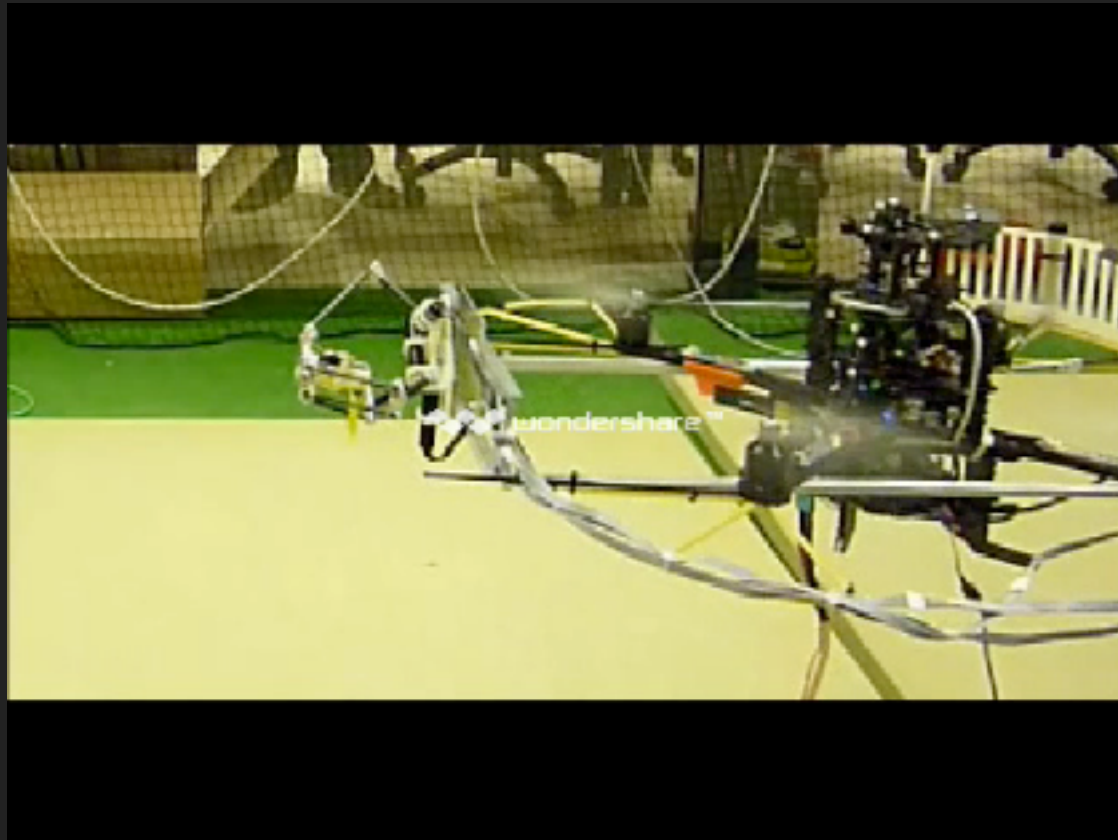
AERIAL MANIPULATORS

- ▶ Why doing so?
 - ▶ To reduce the risk for human operators performing unsafe inspection operations such as:
 - ▶ Ultrasound testing of material
 - ▶ Cleaning surfaces
 - ▶ Applying markers/sensors
- ▶ All these applications require the drone to achieve stable physical interaction with the environment, and apply forces to it!!!

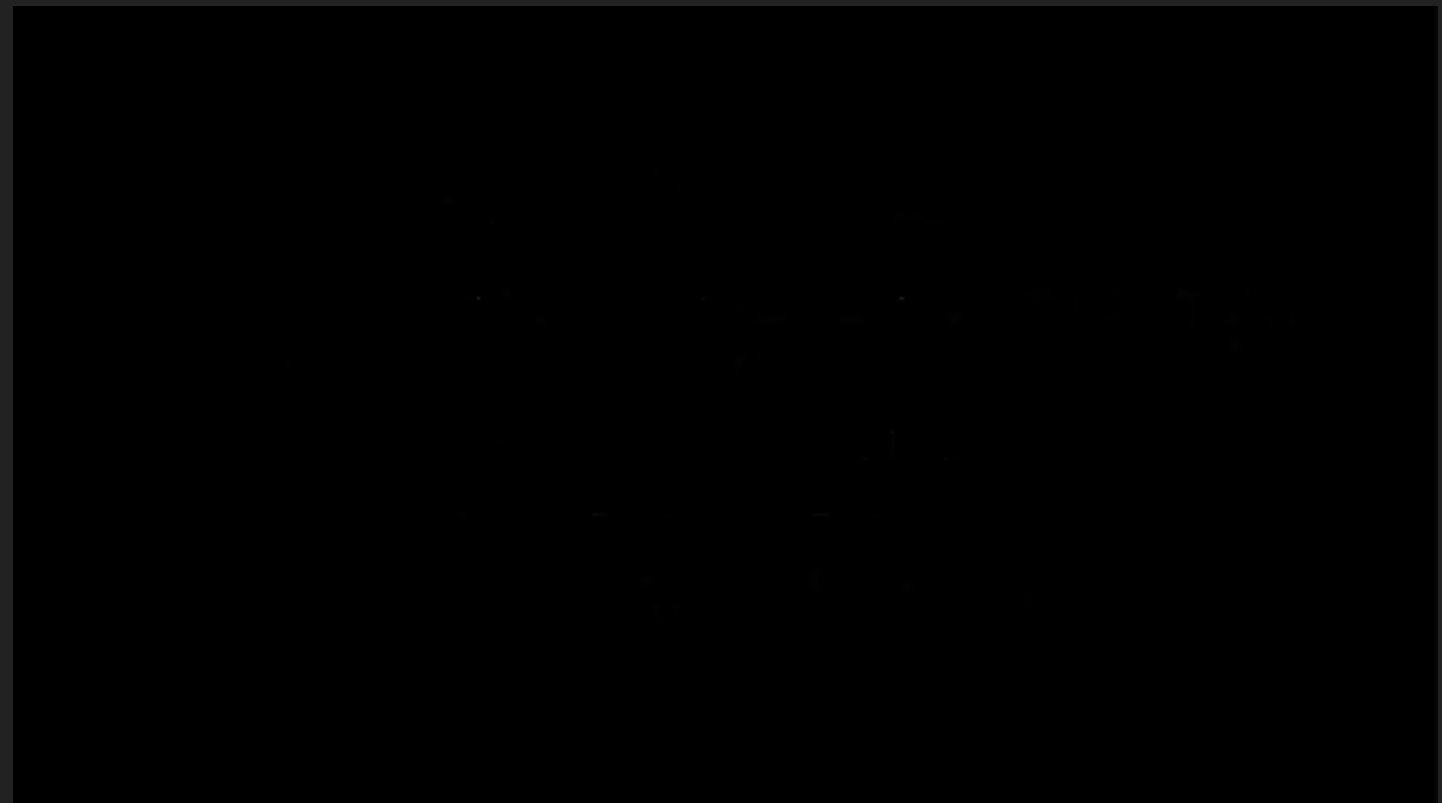
AERIAL MANIPULATORS: SOME OLD RESULTS



Delta manipulator interacting with the environment



Modeling and control of a flying robot for contact inspection, Fumagalli et Al., IROS 2012

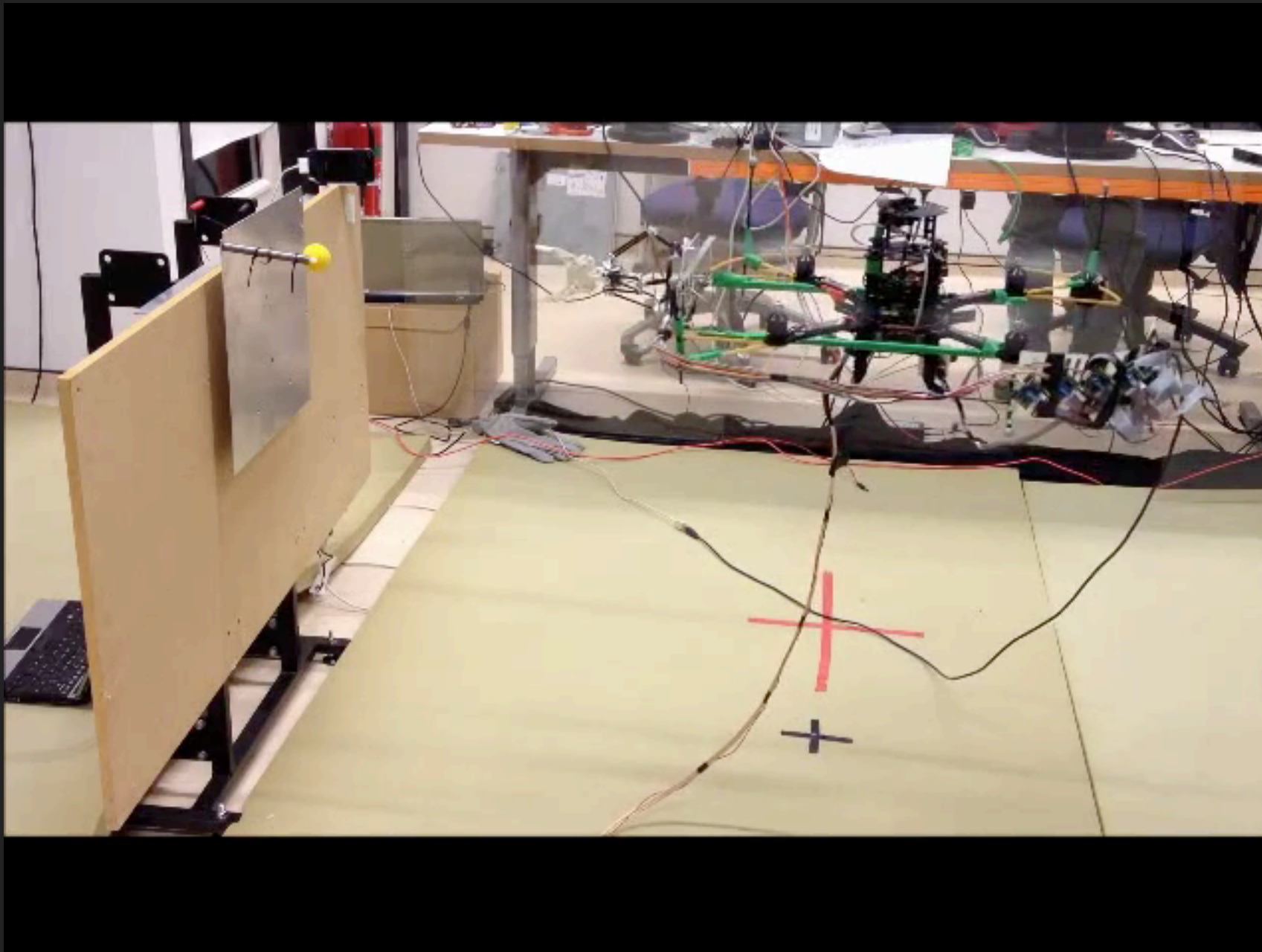


Interaction control of an UAV endowed with a manipulator, Scholten et Al., ICRA 2013

AERIAL MANIPULATORS: SOME OLD RESULTS



Grasping from air



AERIAL MANIPULATORS: THE CHALLENGE

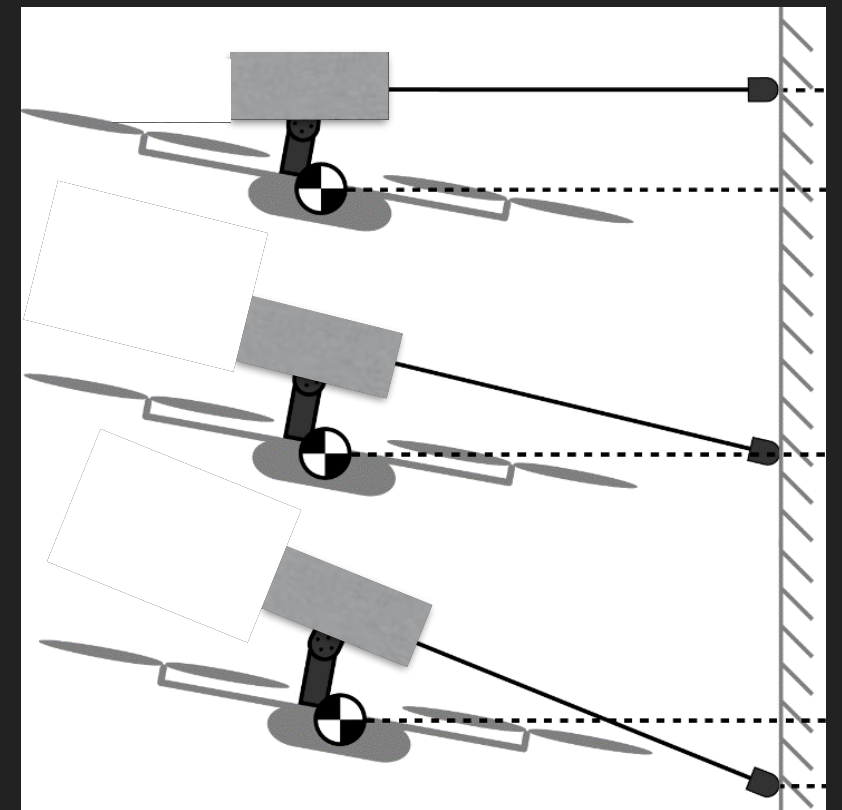
Application of relevant forces on the environment:

- ▶ Active use of tools
- ▶ Cleaning
- ▶ Hammering
- ▶ Application of sensors
(NDT inspection)

How can we use an aerial robots, to apply forces that are meaningful enough to fit the requirements for manipulating tools?

AERIAL MANIPULATORS: ACHIEVING AERIAL IMPACTS

- ▶ Aerial Impacts for High Interaction Force Generation with an UAV
 - ▶ The UAV interacts on its side with an end effector
 - ▶ The end-effector is rigidly connected to the body-fixed frame of the UAV
 - ▶ The interaction force is directed towards the COM of the UAV



AERIAL MANIPULATORS

- ▶ End-Effector above the COM

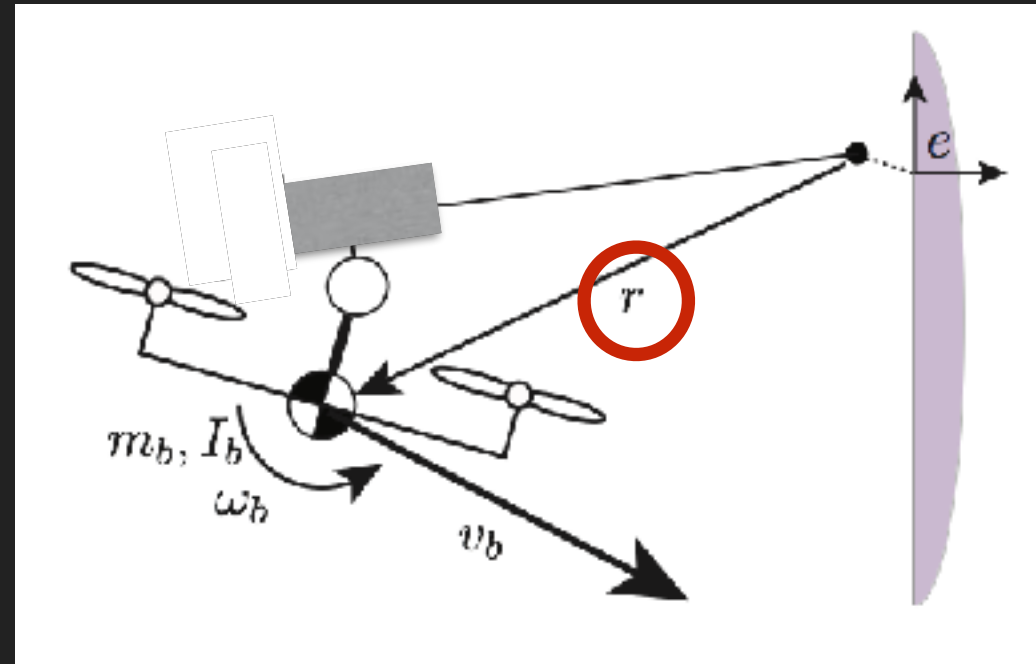


AERIAL MANIPULATORS

- ▶ End-Effector Below the COM



AERIAL MANIPULATORS



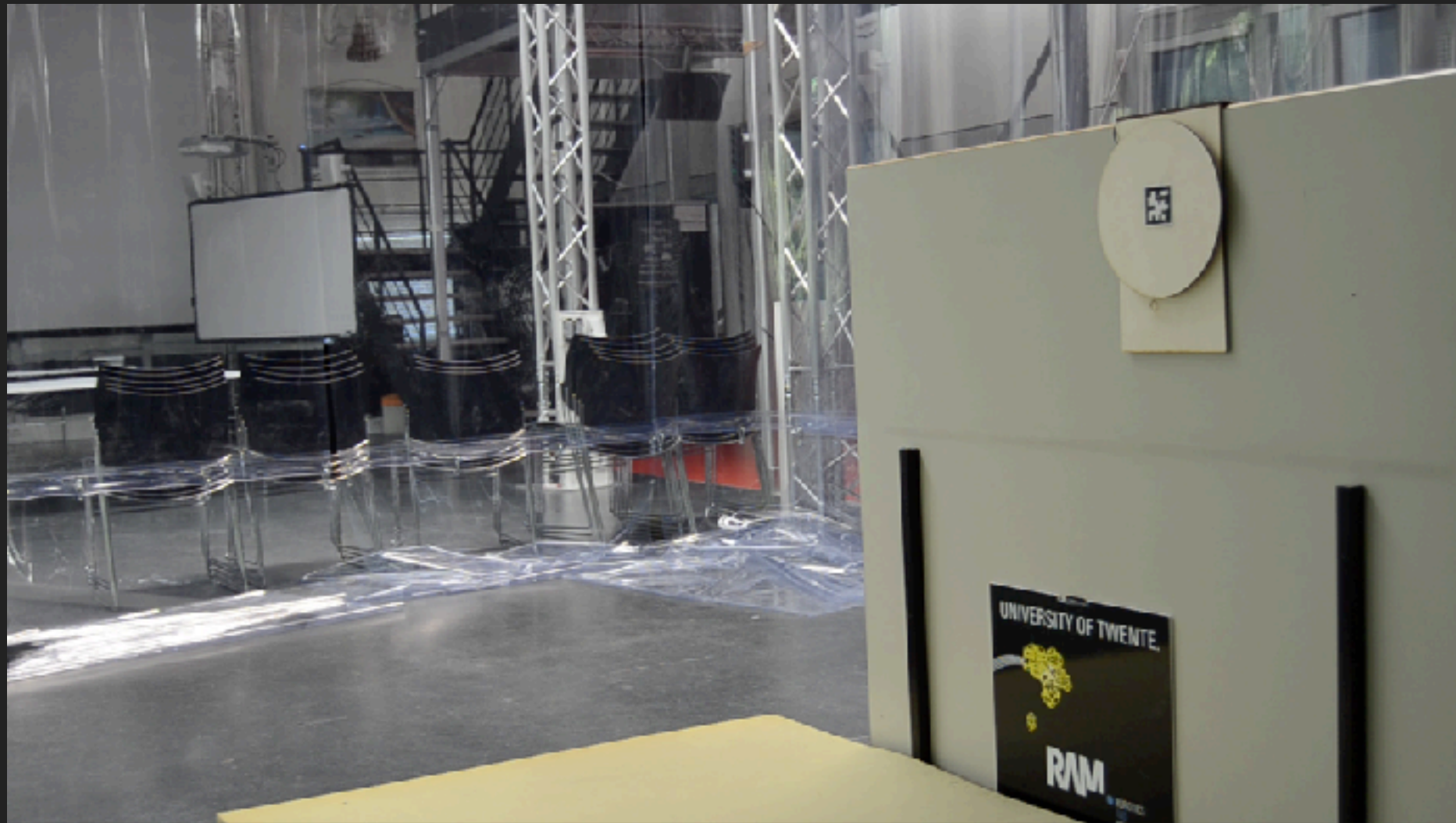
$$\begin{bmatrix} P \\ L \end{bmatrix} = \begin{bmatrix} m_b v_b \\ I_b \omega_b + r \times m_b v_b \end{bmatrix}$$

This term generate a change in the angular momenta. We want to keep it to 0

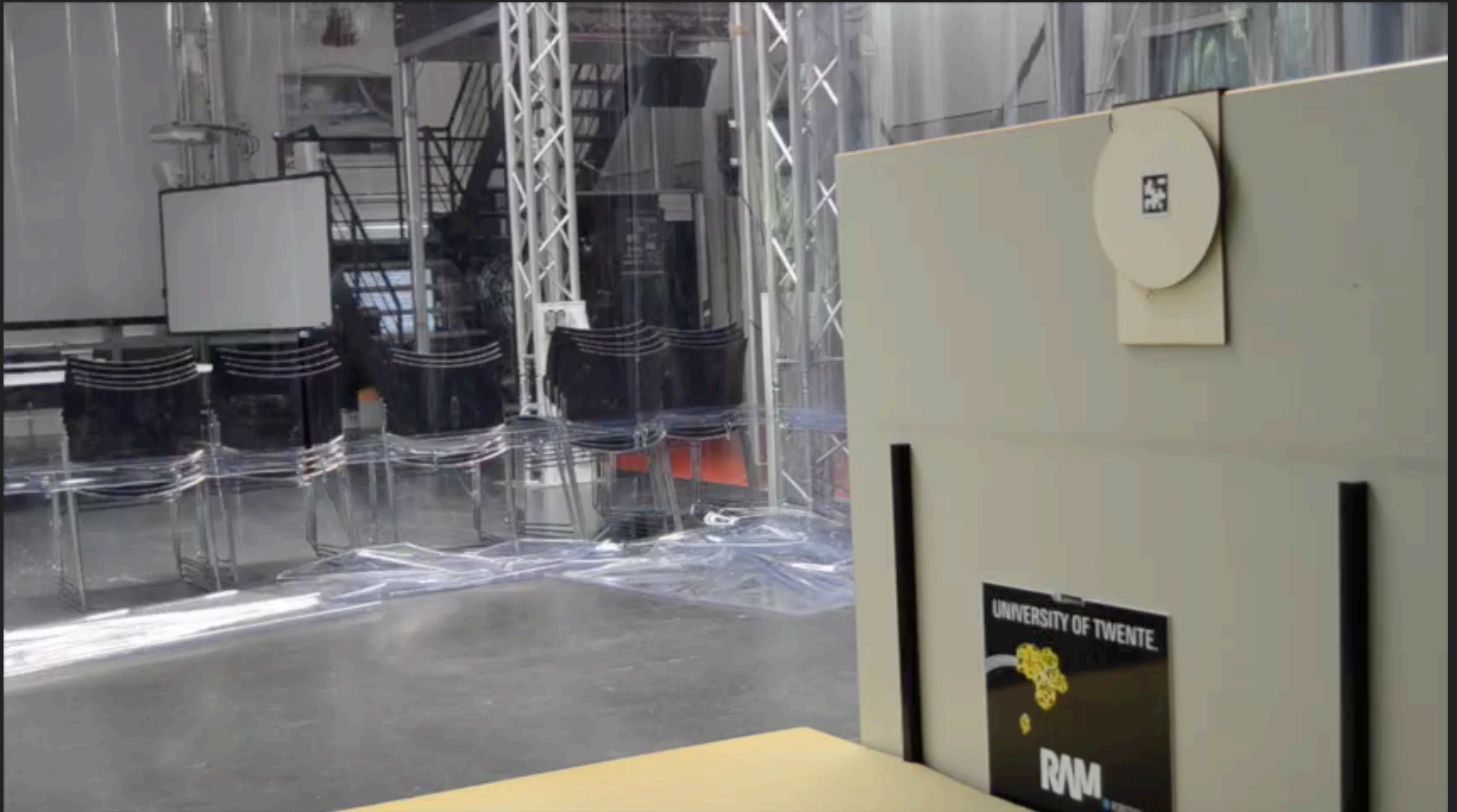
"Compliant Aerial Manipulators: Towards a New Generation of Aerial Robotic Workers," in IEEE Robotics and Automation Letters, January 2016

AERIAL MANIPULATORS

- ▶ End-Effector Centered w.r.t. the COM

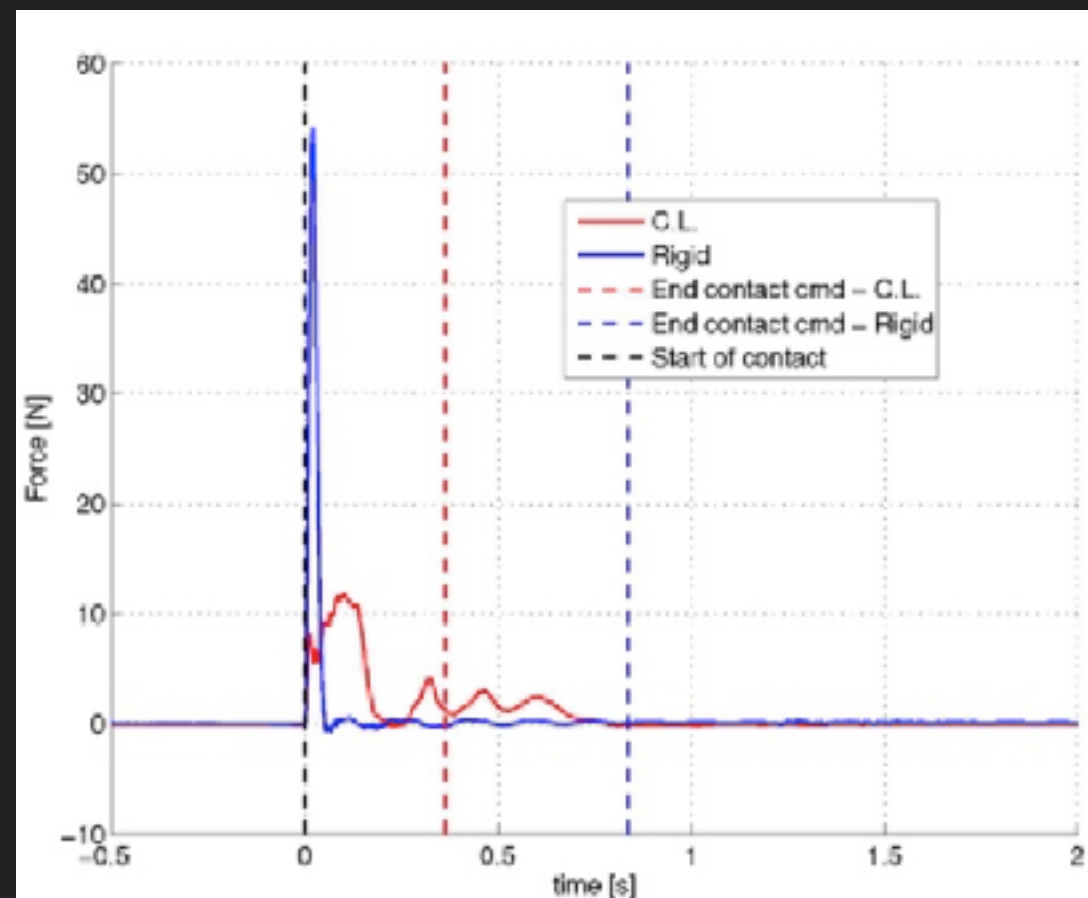
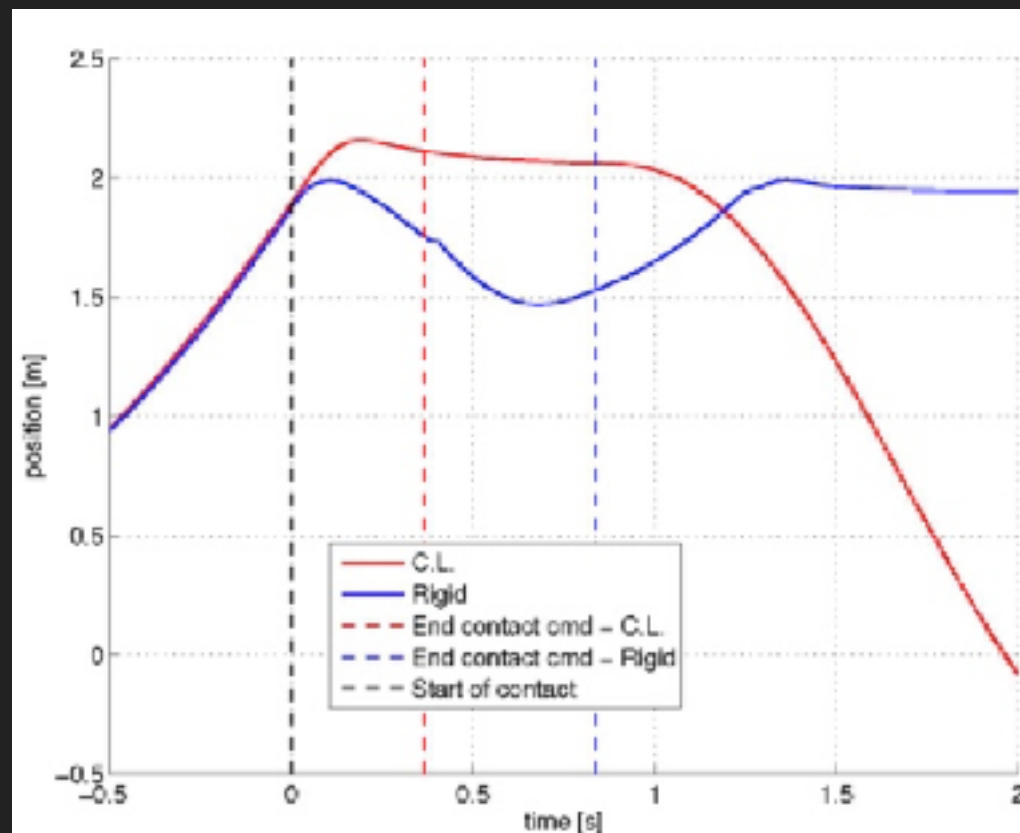


AERIAL MANIPULATORS



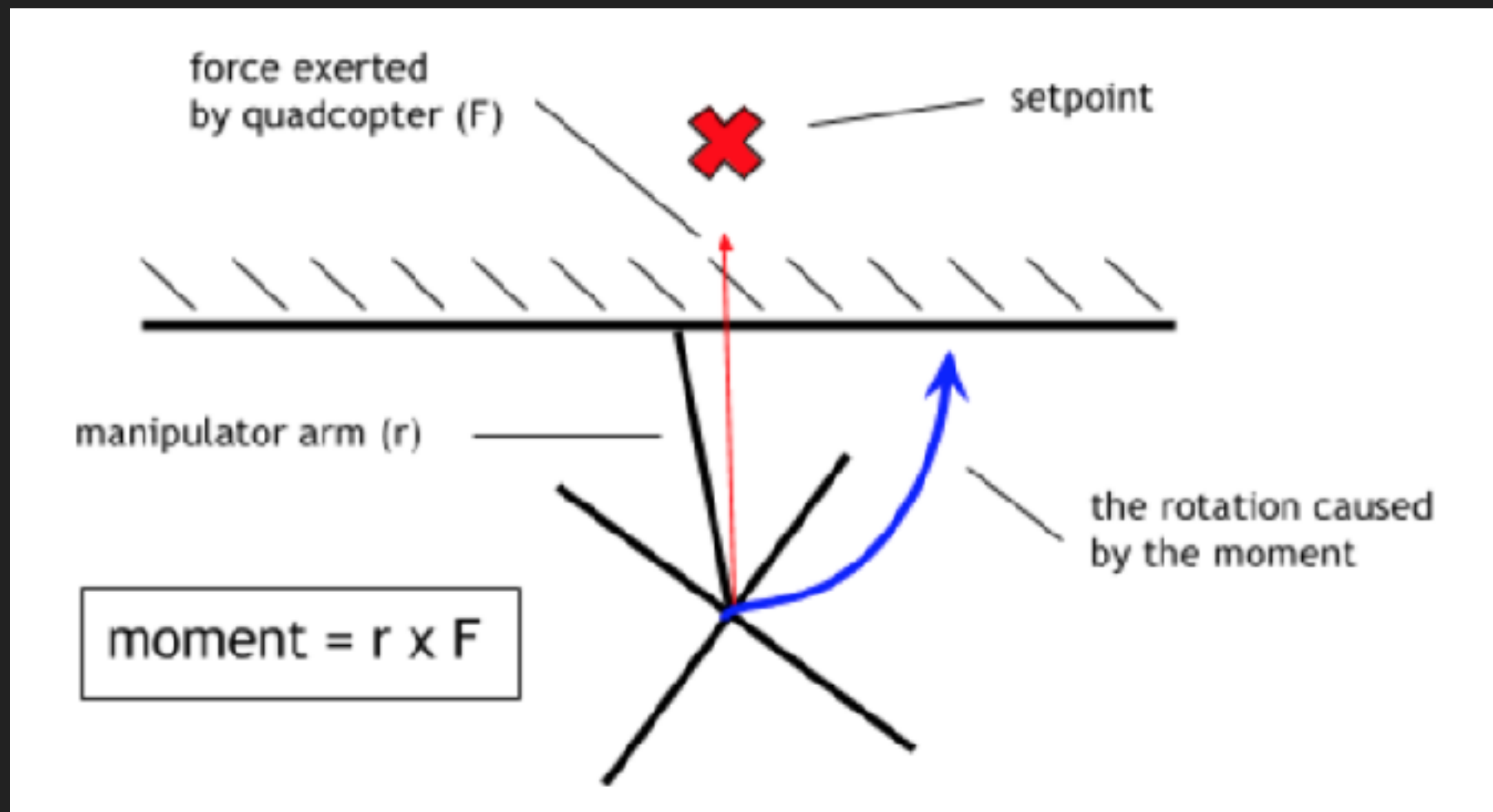
AERIAL MANIPULATORS

- ▶ Application of relevant forces on the environment during a stable impact



HOW CAN WE APPLY FORCES WITH AN AERIAL MANIPULATOR?

A standard cascade controller (attitude and position) using PD on the position, does not allow proper control of the interaction



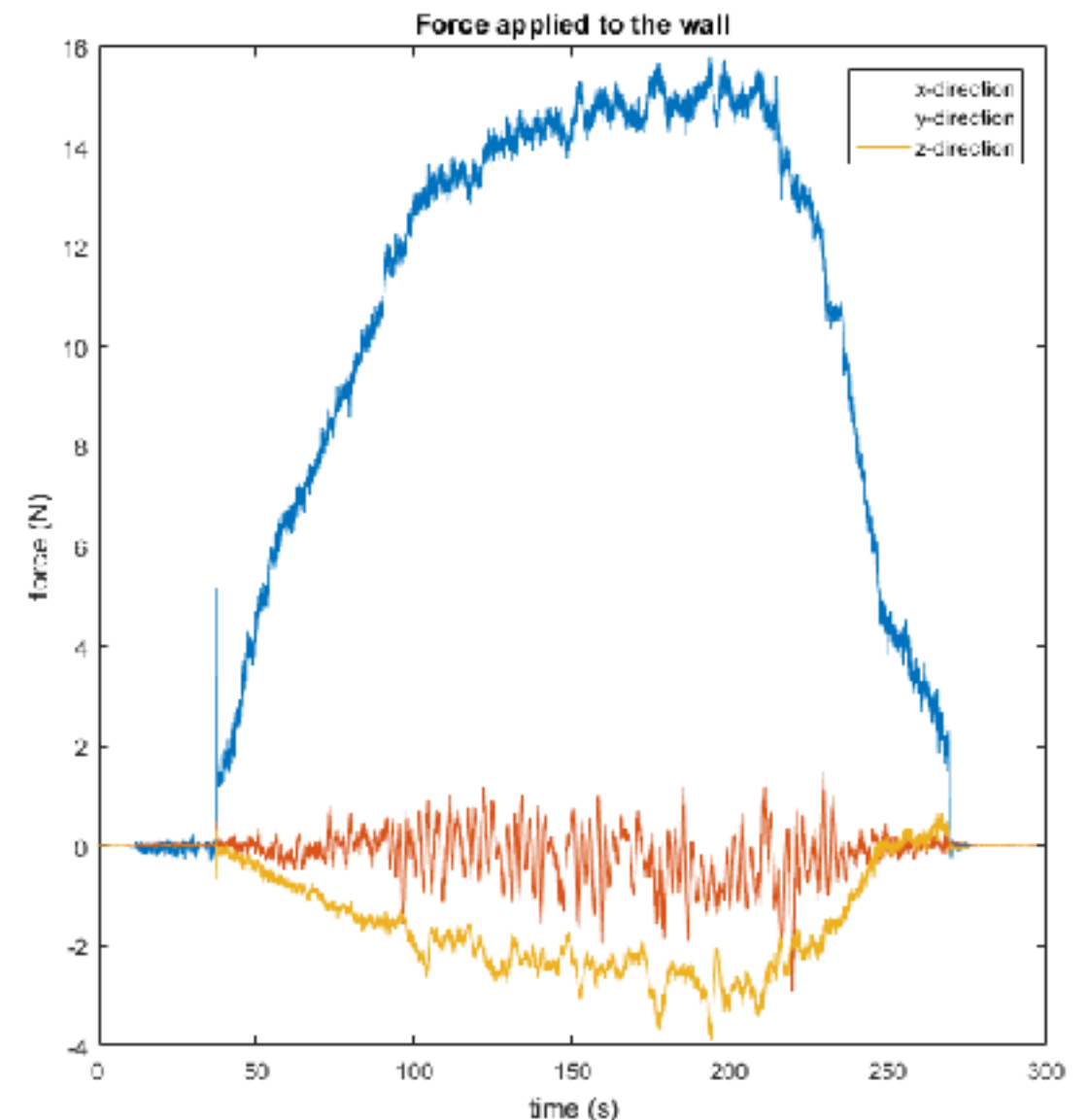
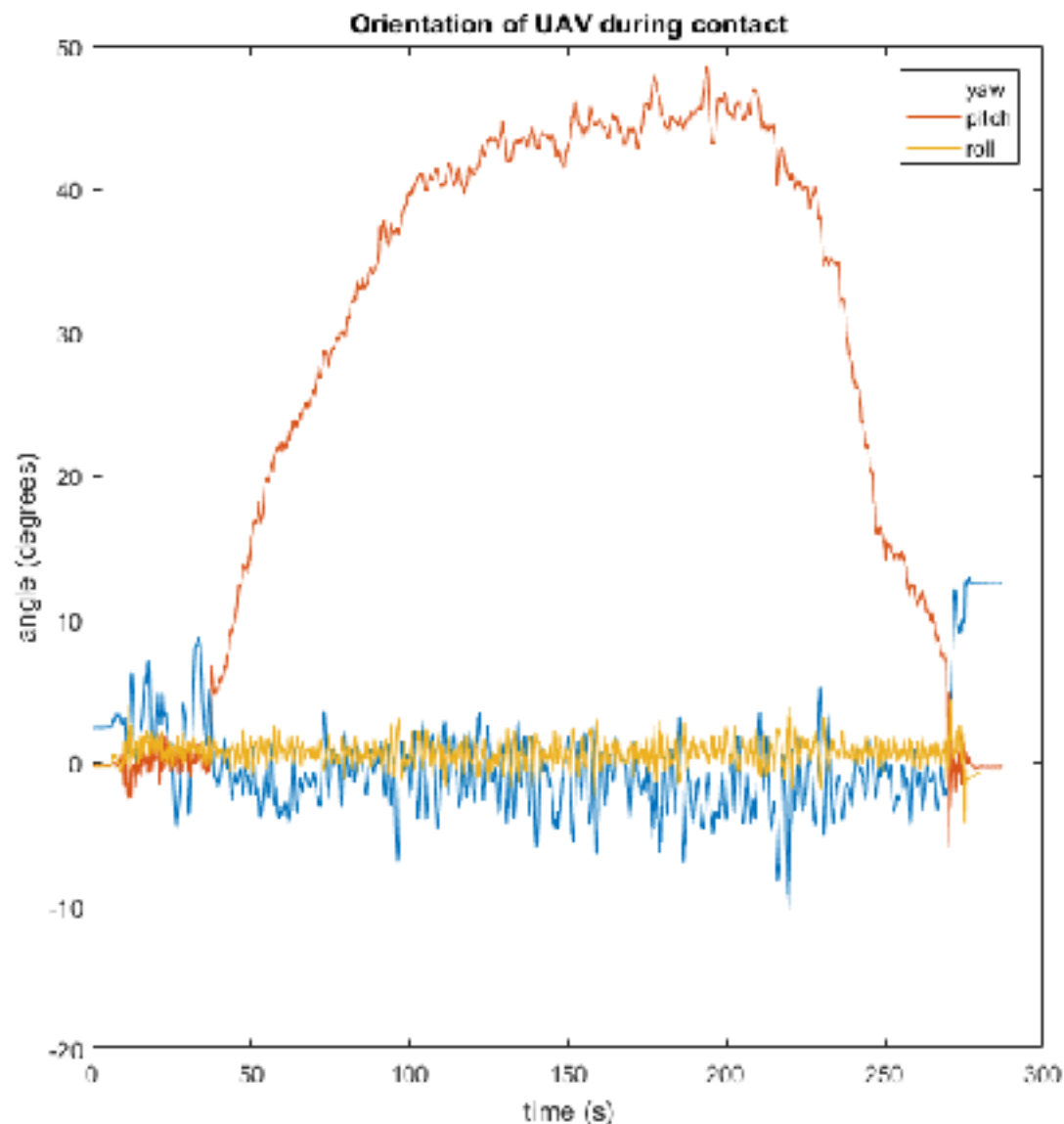
The yaw suffers from instability and the equilibrium position is not the desired one

AERIAL MANIPULATORS

This video demonstrates a newly designed controller, capable of controlling the attitude of a quadrotor while applying a substantial force to a vertical surface.

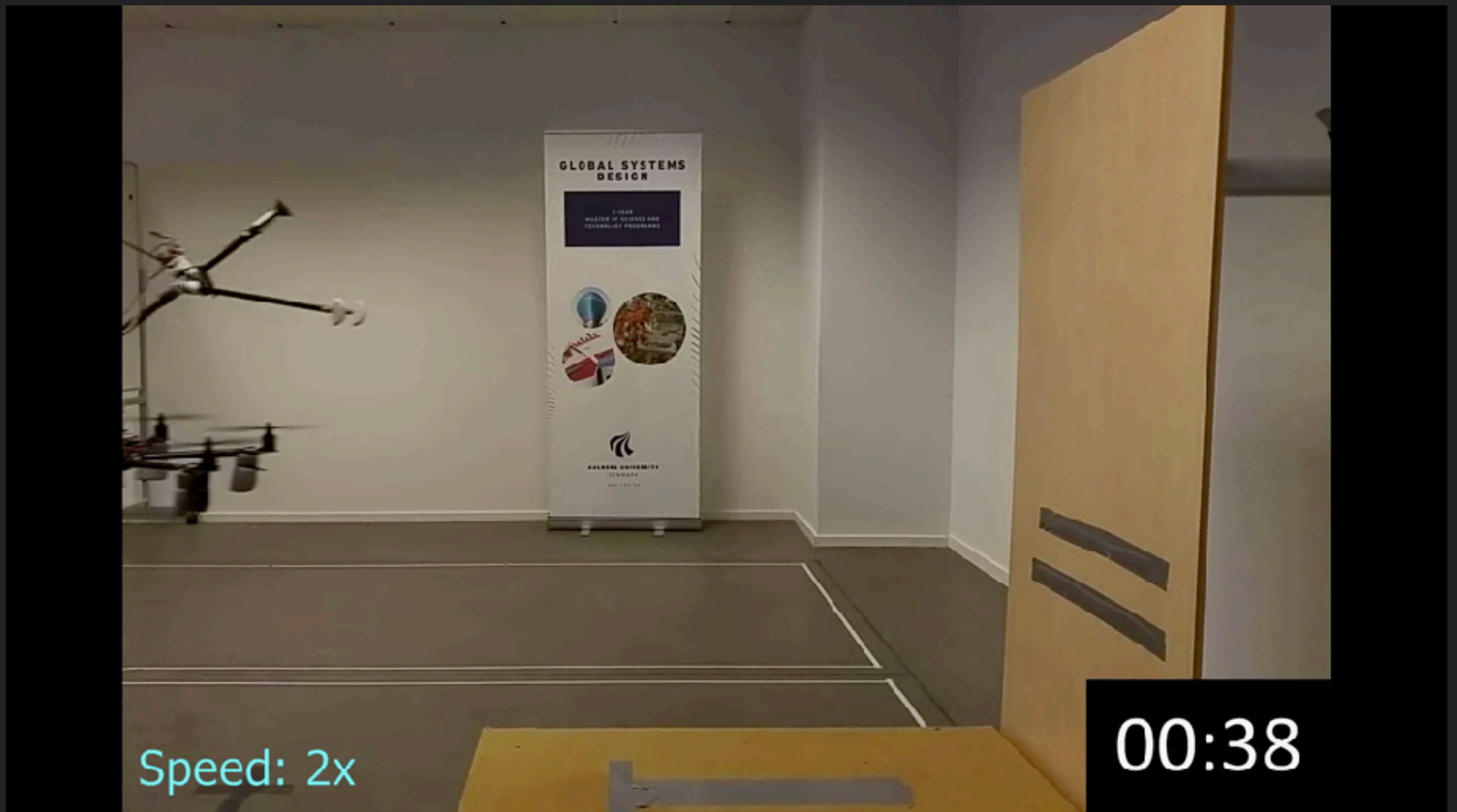
AERIAL MANIPULATORS: PUSH WITH END EFFECTOR

- ▶ Application of static forces by exploiting the aerial manipulator's rotational DoFs



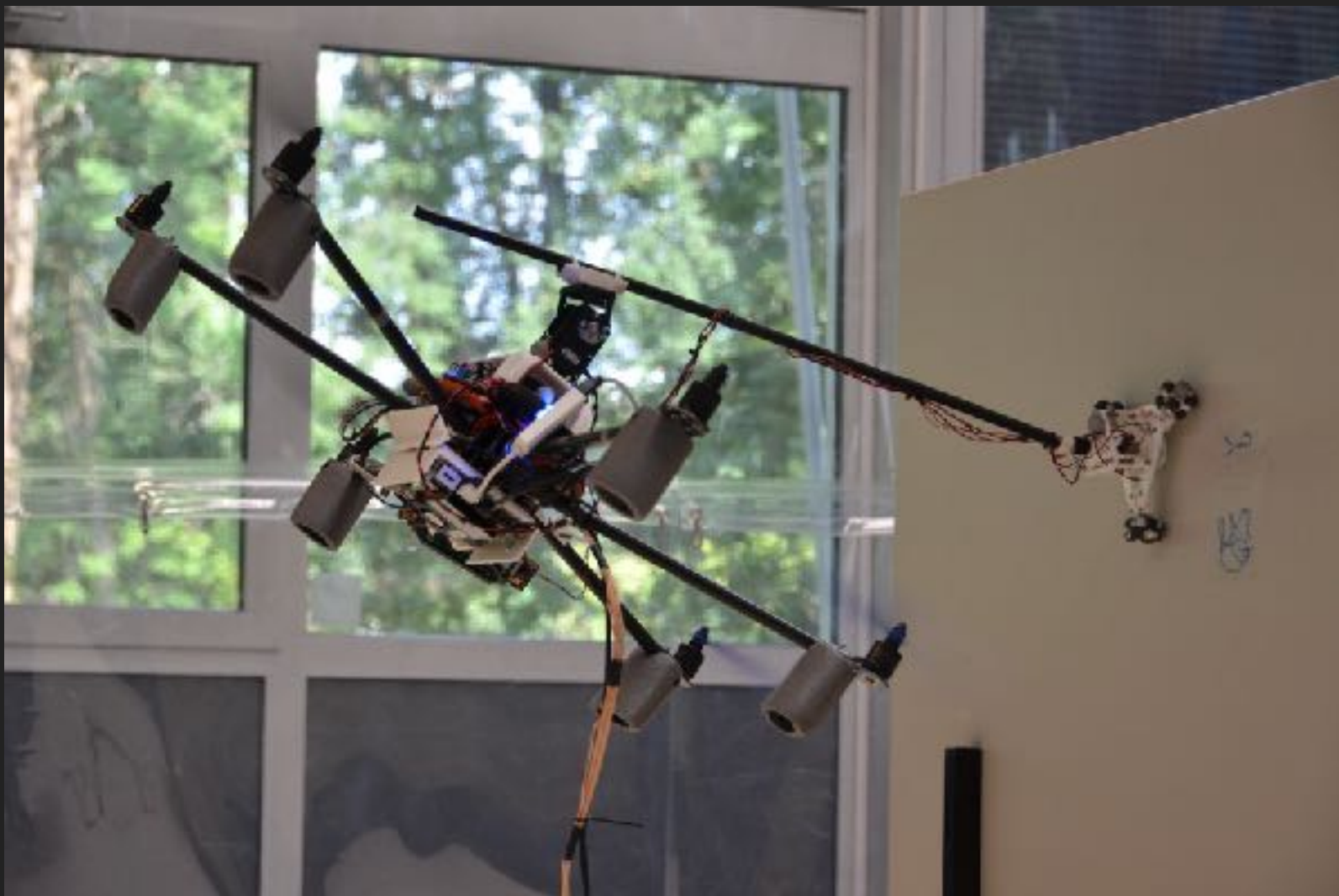
HOW CAN WE EXPLOIT THESE RESULTS?

AERIAL MANIPULATORS: PERCHING ON SURFACES

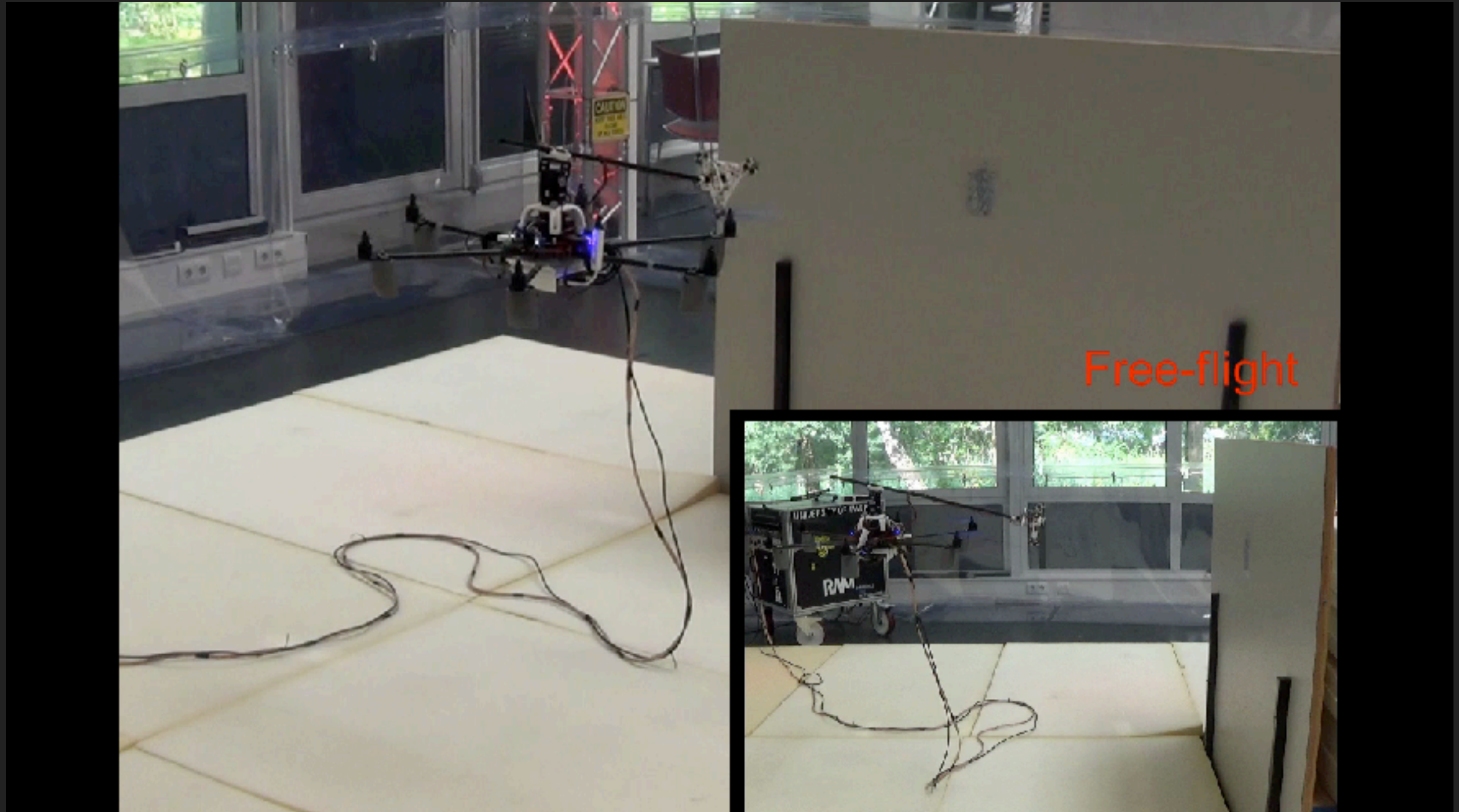


AERIAL MANIPULATORS: MULTI-MODAL LOCOMOTION

- ▶ An active end effector for cleaning surfaces



AERIAL MANIPULATORS: MULTI-MODAL LOCOMOTION



THANKS FOR YOUR ATTENTION

Collaborators from the University of Twente

Han Wopereis

Stefano Stramigioli

Willem Van Ridder

Johan Hengler