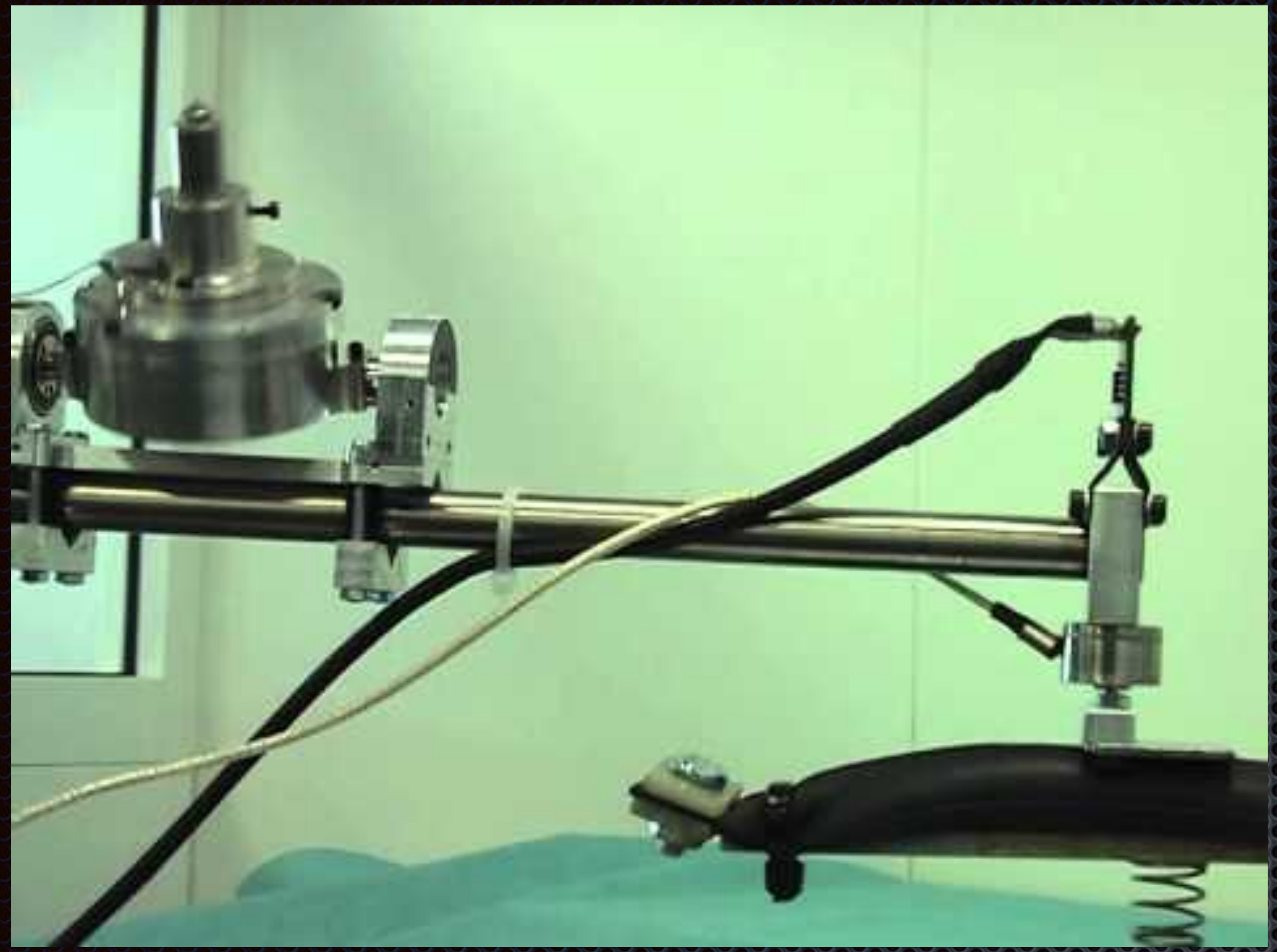
dextAIR Project

Genesis, Recent Developments and Future Work

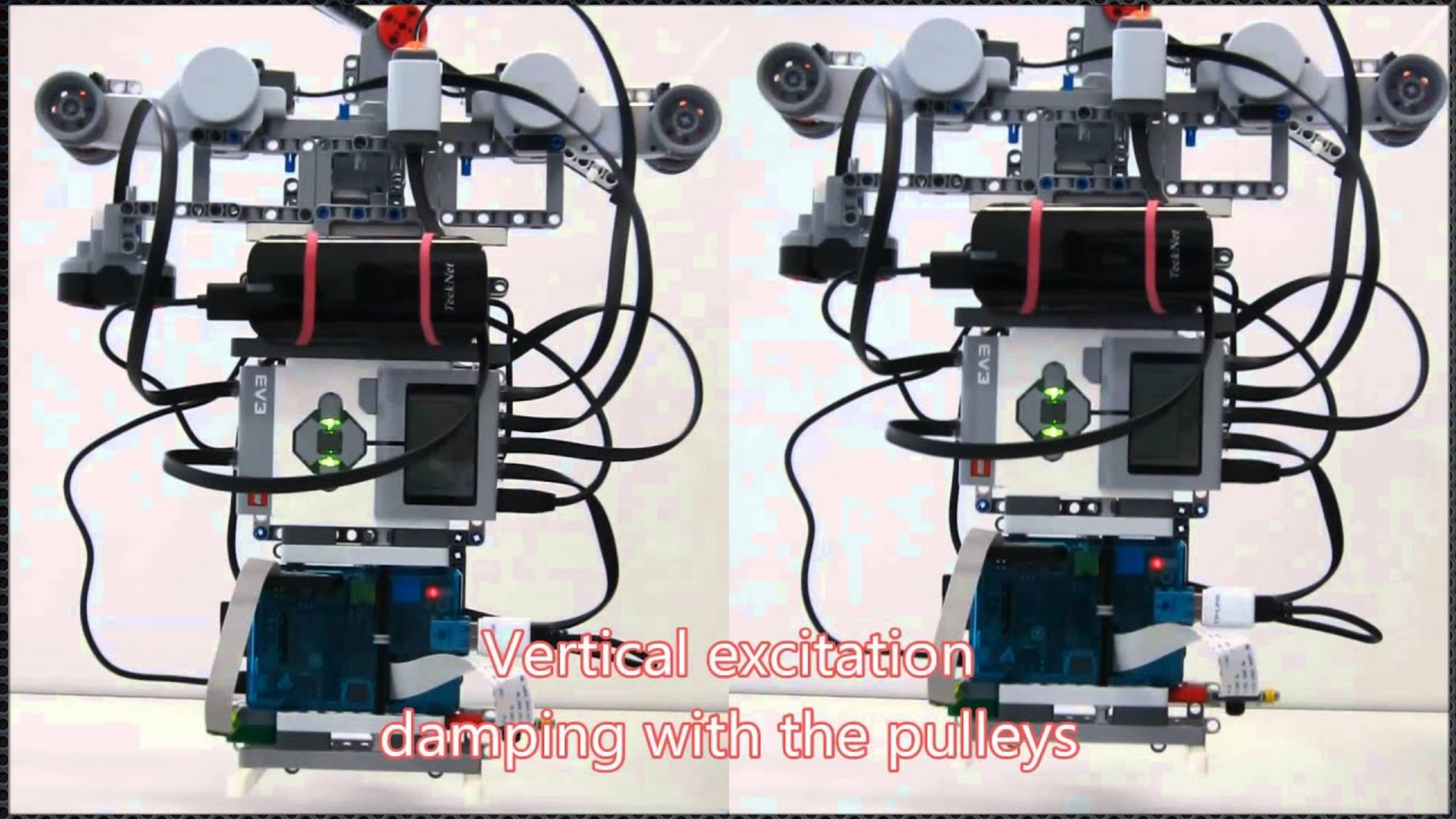
Jacques Gangloff, ICube lab, Strasbourg, GT UAV, July 6th 2021

Genesis



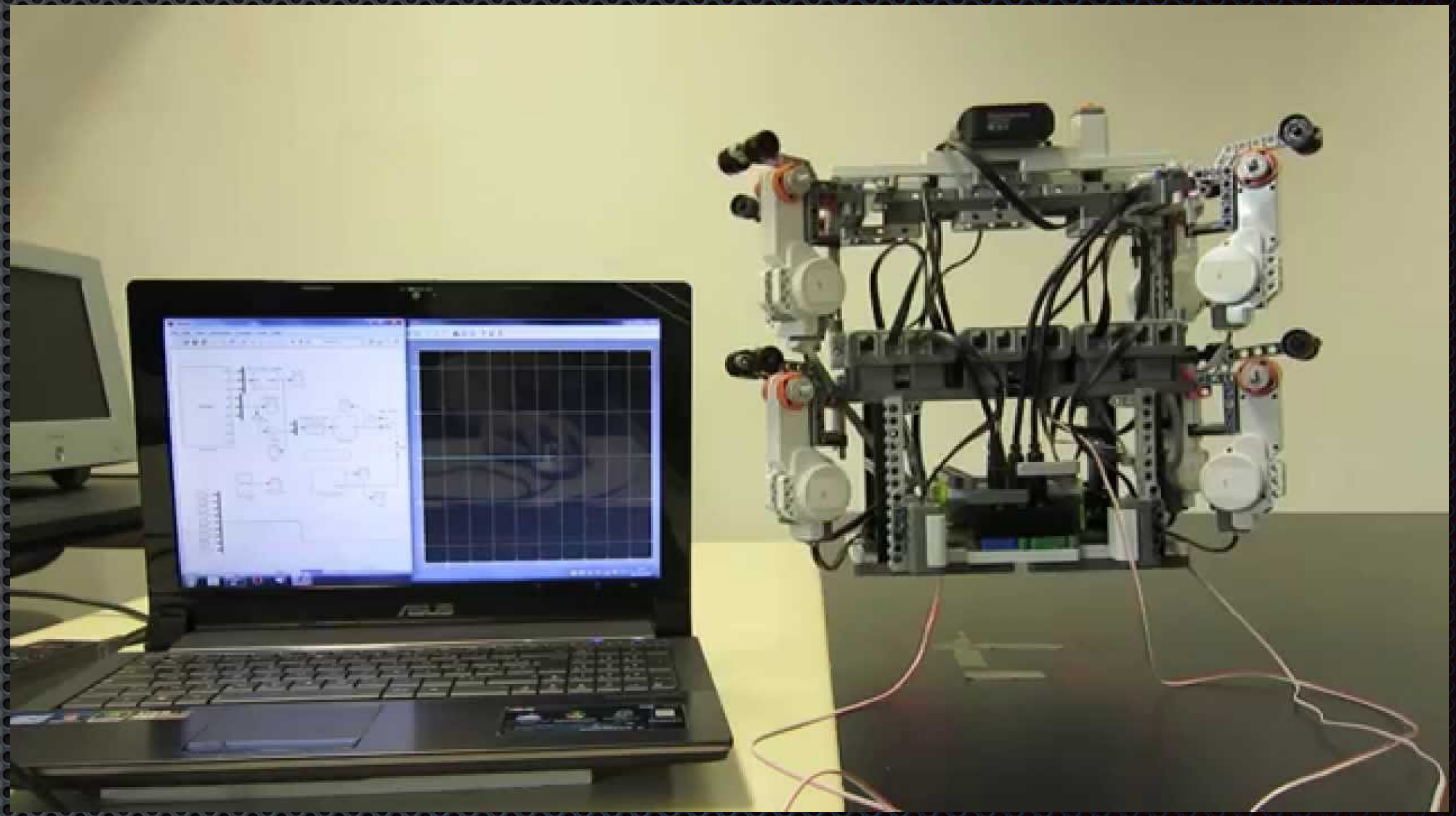
GyroLock

Active stabilization using CMG



NXT cable

Active stabilization using reaction wheels



CoMiRo

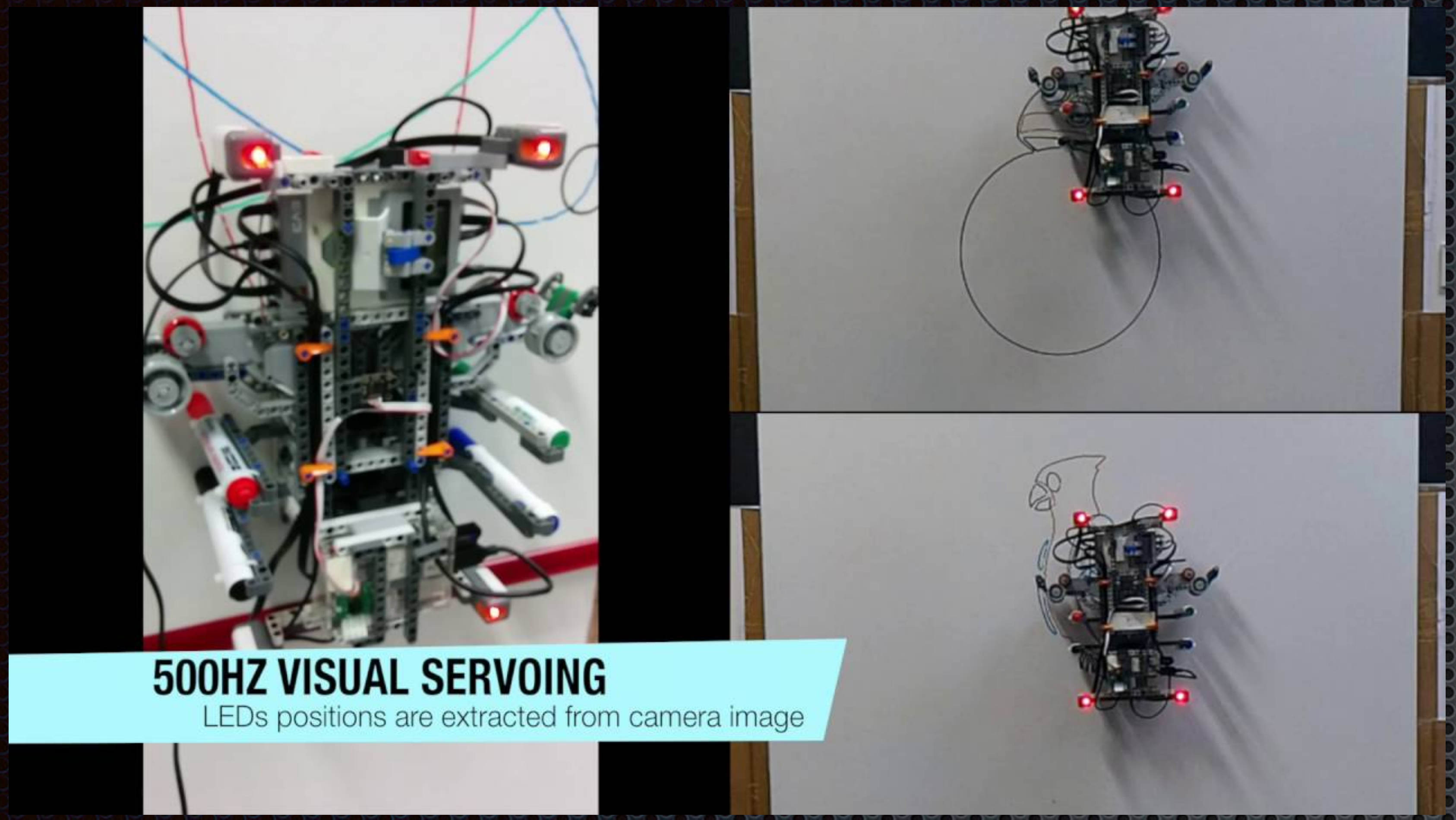
Active stabilization using modal control

J. Gagne , O. Piccin, E. Laroche, M. Diana, J. Gangloff, GyroLock: Stabilizing the heart with control moment gyroscope (CMG) - From concept to first in vivo assessments, IEEE Transactions on Robotics, pages 942--954, Volume 28, n° 4, 2012, doi:10.1109/TRO.2012.2188162

X. Weber, L. Cuvillon, J. Gangloff, Active vibration canceling of a cable-driven parallel robot using reaction wheels, IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), Chicago, United States, septembre 2014

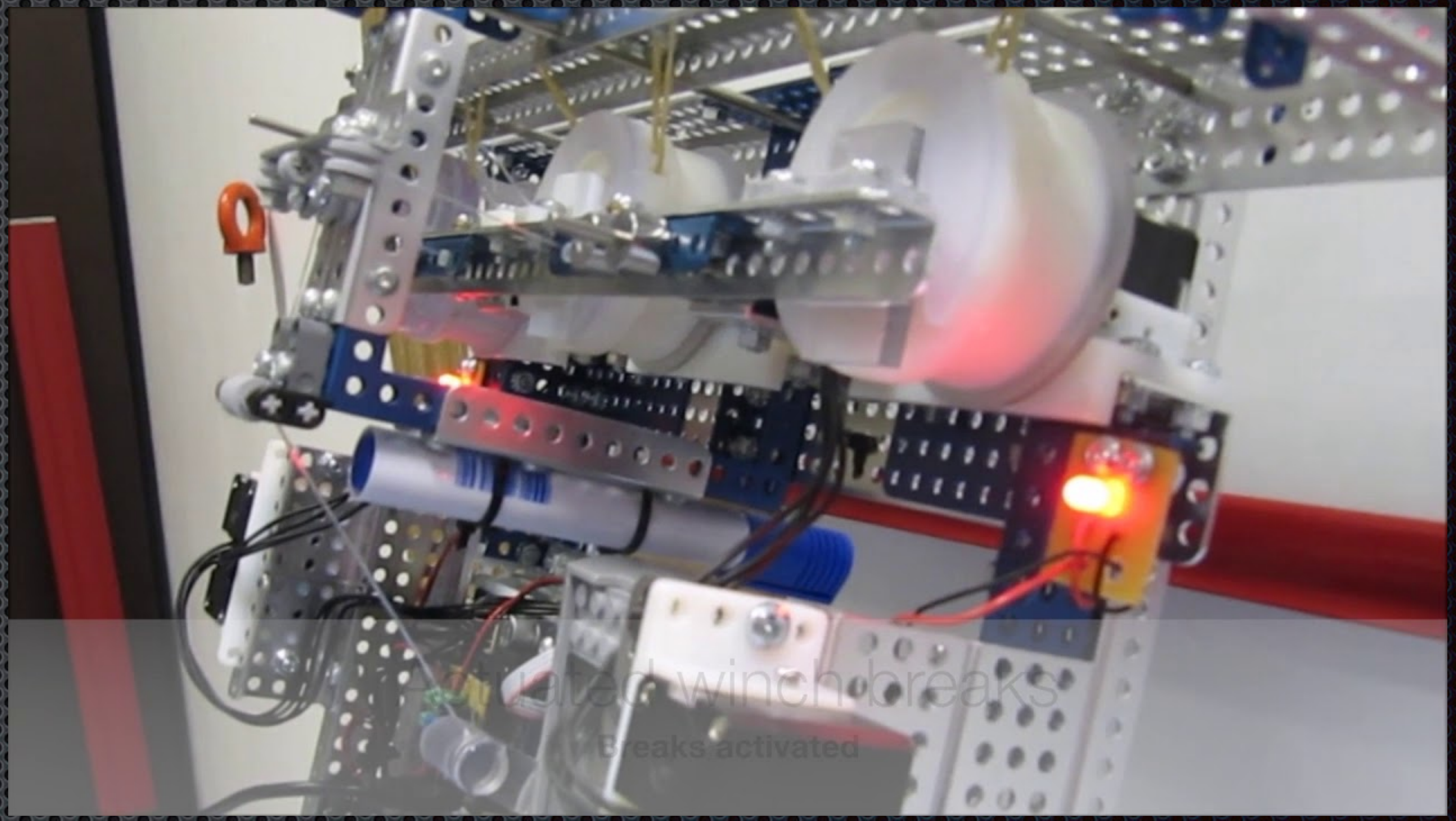
L. Cuvillon, X. Weber, J. Gangloff, Modal Control for Active Vibration Damping of Cable-Driven Parallel Robots, Journal of Mechanisms and Robotics, American Society of Mechanical Engineers, Volume 12, 2020

Preliminary Studies: PiSaRo 1 & 2



PiSaRo 1

Planar suspended CDPR built with Lego NXT
Basic visual servoing

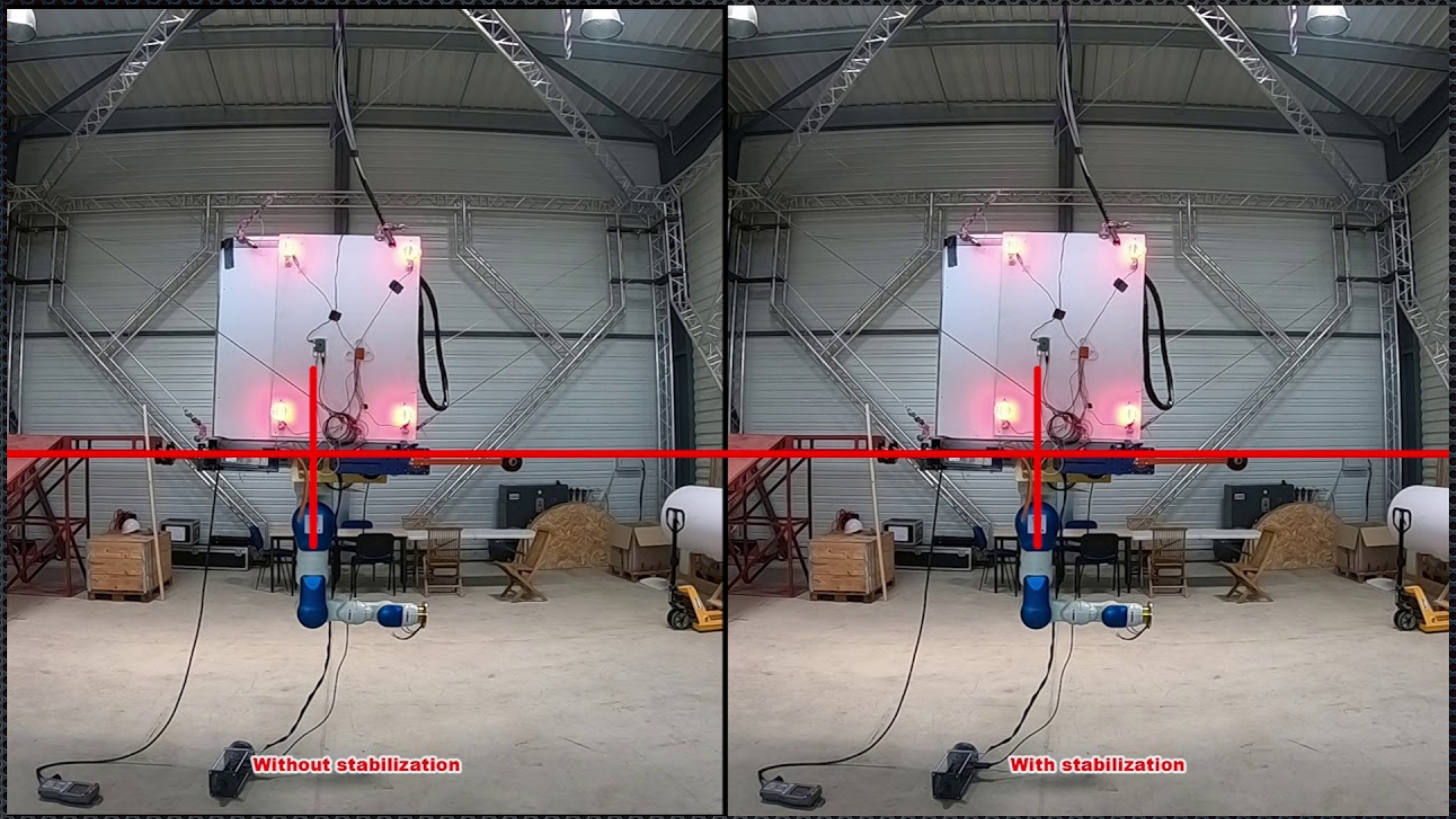


PiSaRo 2

Planar suspended CDPR built with Tetrix
Feedback linearization control

J. Begey, L. Cuvillon, M. Lesellier, M. Gouttefarde , J. Gangloff, Dynamic Control of Parallel Robots Driven by Flexible Cables and Actuated by Position-Controlled Winches, IEEE Transactions on Robotics, Volume 35, n° 1, 2019

ANR DexterWide

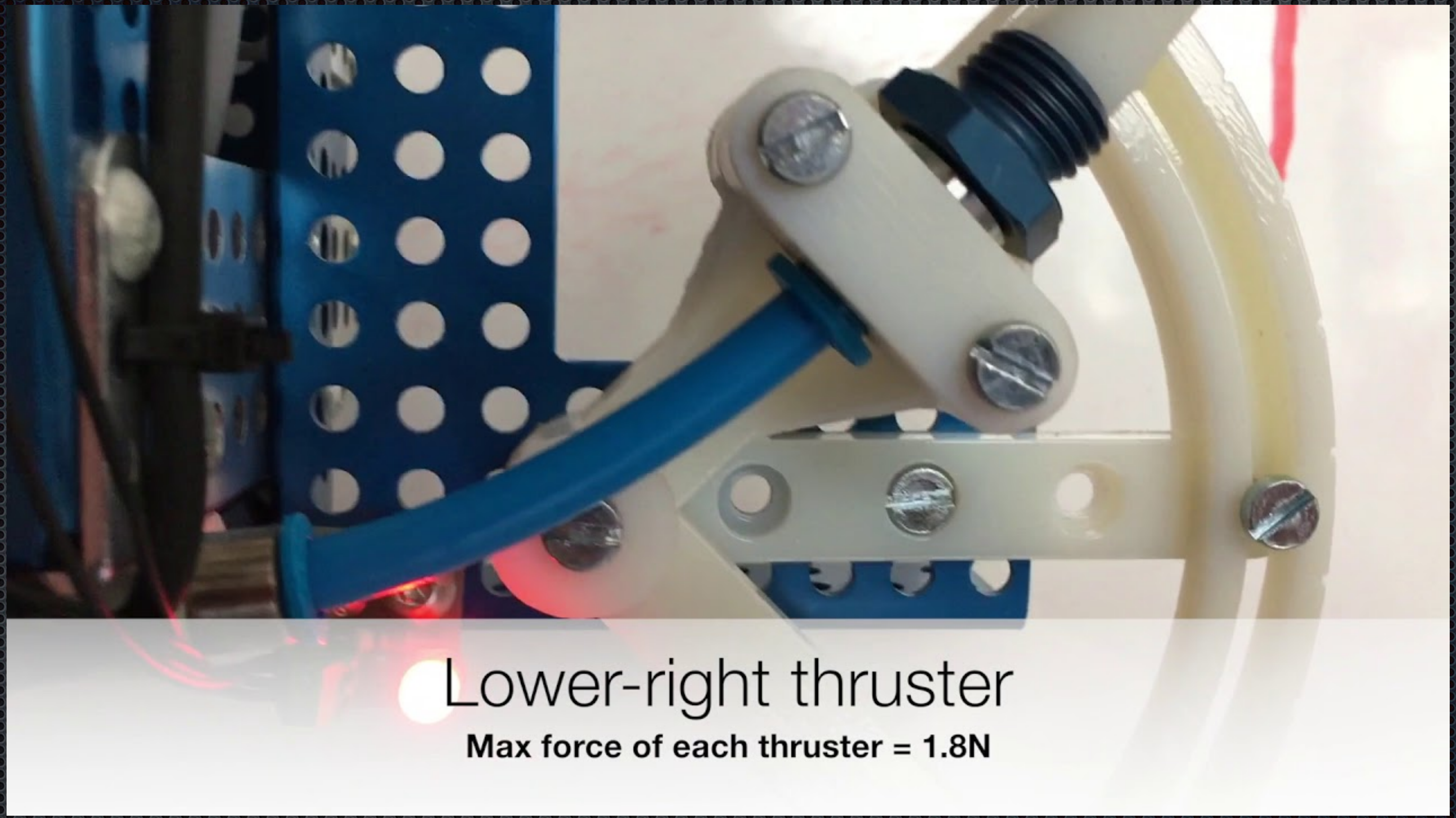


Active stabilization of the CoGiRo CDPR (LIRMM)

Using rotating arms

M. Lesellier, L. Cuvillon, J. Gangloff, M. Gouttefarde, An Active Stabilizer for Cable-Driven Parallel Robot Vibration Damping, IEEE/RSJ International Conference on Intelligent Robots and Systems, Madrid, France, janvier 2018

CDPR with Cold-Gas Thrusters



PiSaRo 3

CDPR with on-board cold-gas thrusters

H. Sellet , I. Khayour, L. Cuvillon, S. Durand, J. Gangloff
Active Damping of Parallel Robots Driven by Flexible Cables Using Cold-Gas Thrusters, International Conference on Robotics and Automation, Montréal, Canada, janvier 2019

CDPR with Drone Thrusters

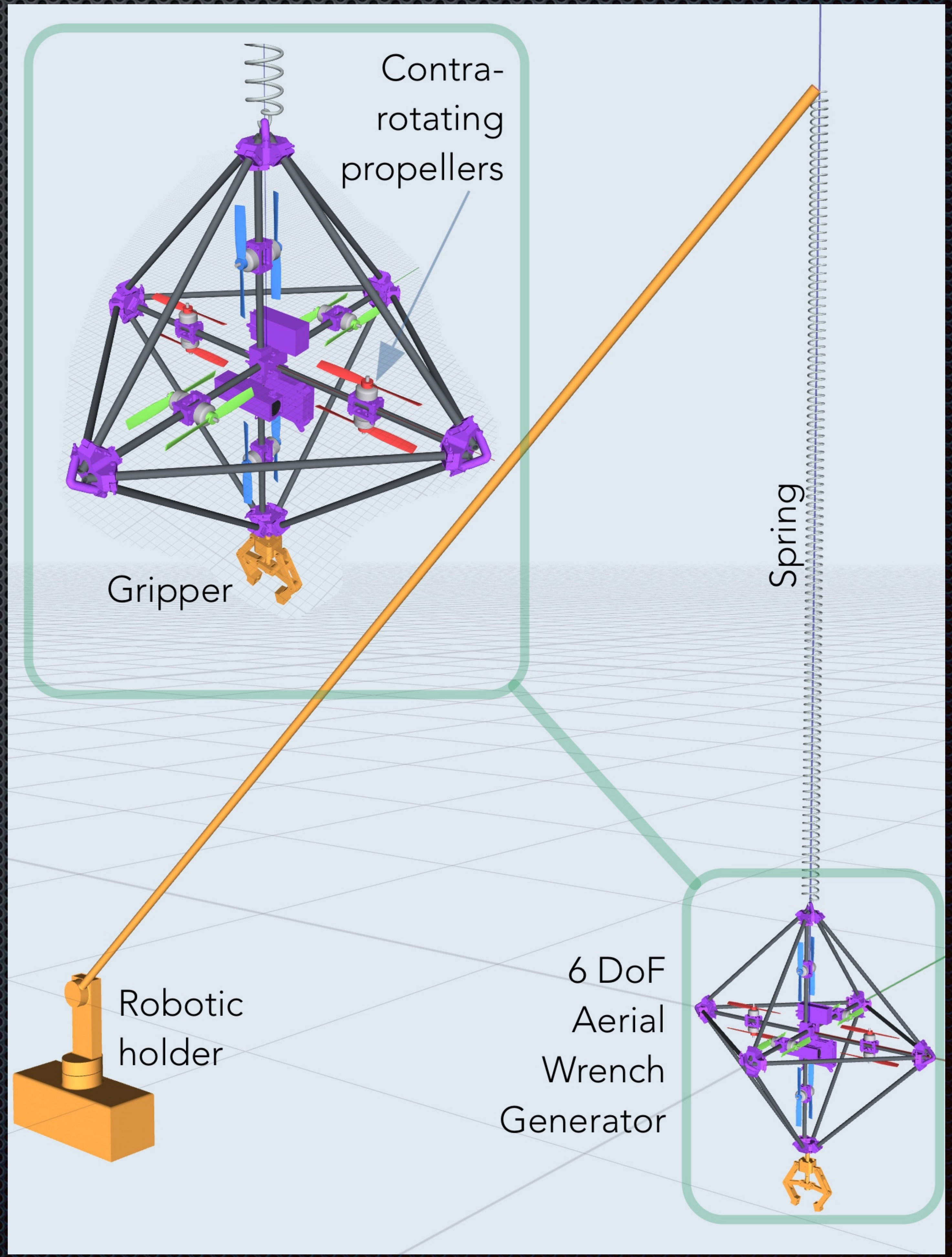
PiSaRo 4

CDPR with on-board drone thrusters

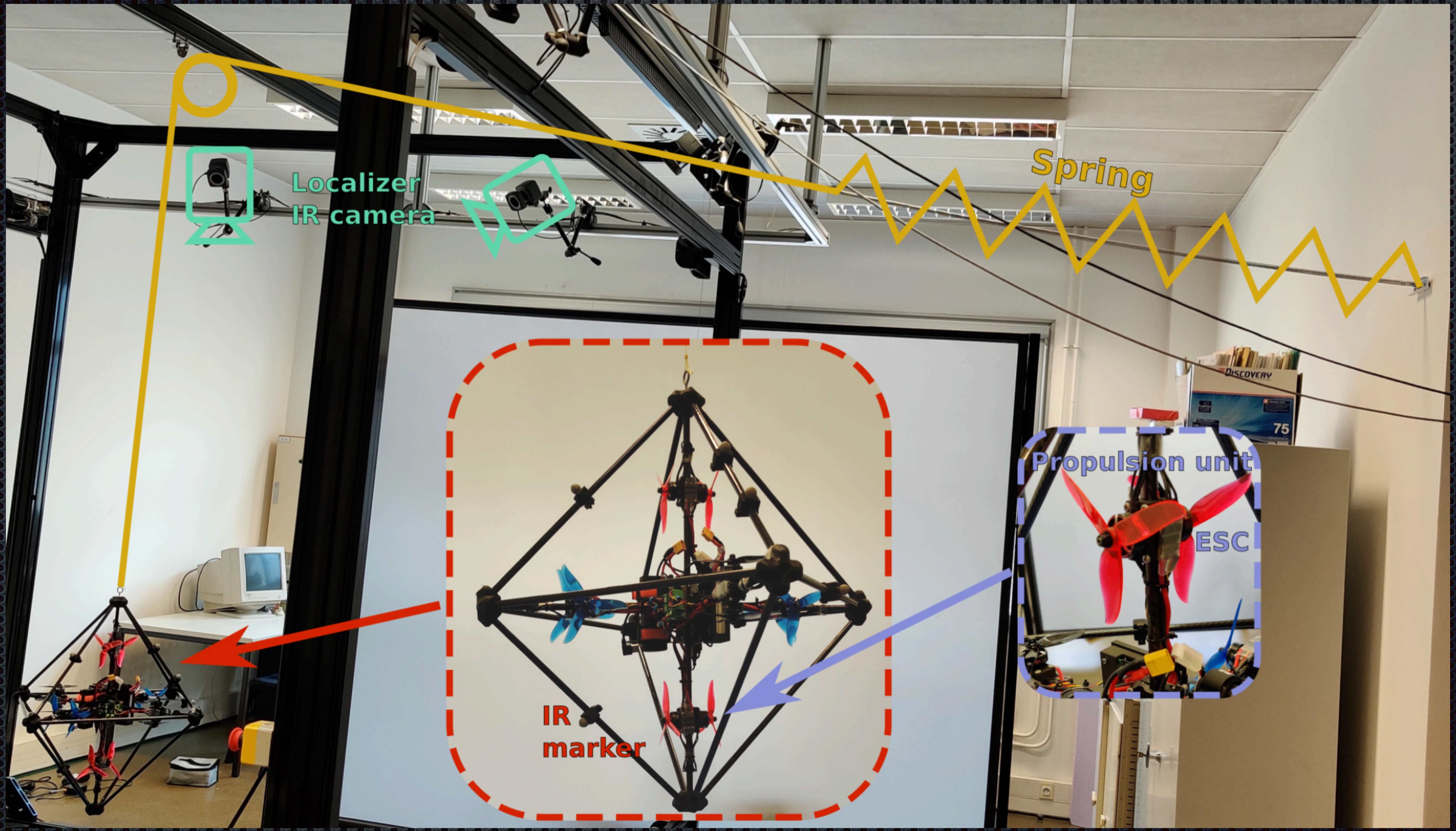
I. Khayour, L. Cuvillon, C. Butin , A. Yigit, S. Durand, J. Gangloff, Improving Disturbance Rejection and Dynamics of Cable Driven Parallel Robots with On-board Propellers, IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), Las Vegas, United States, octobre 2020

dextAIR: concept

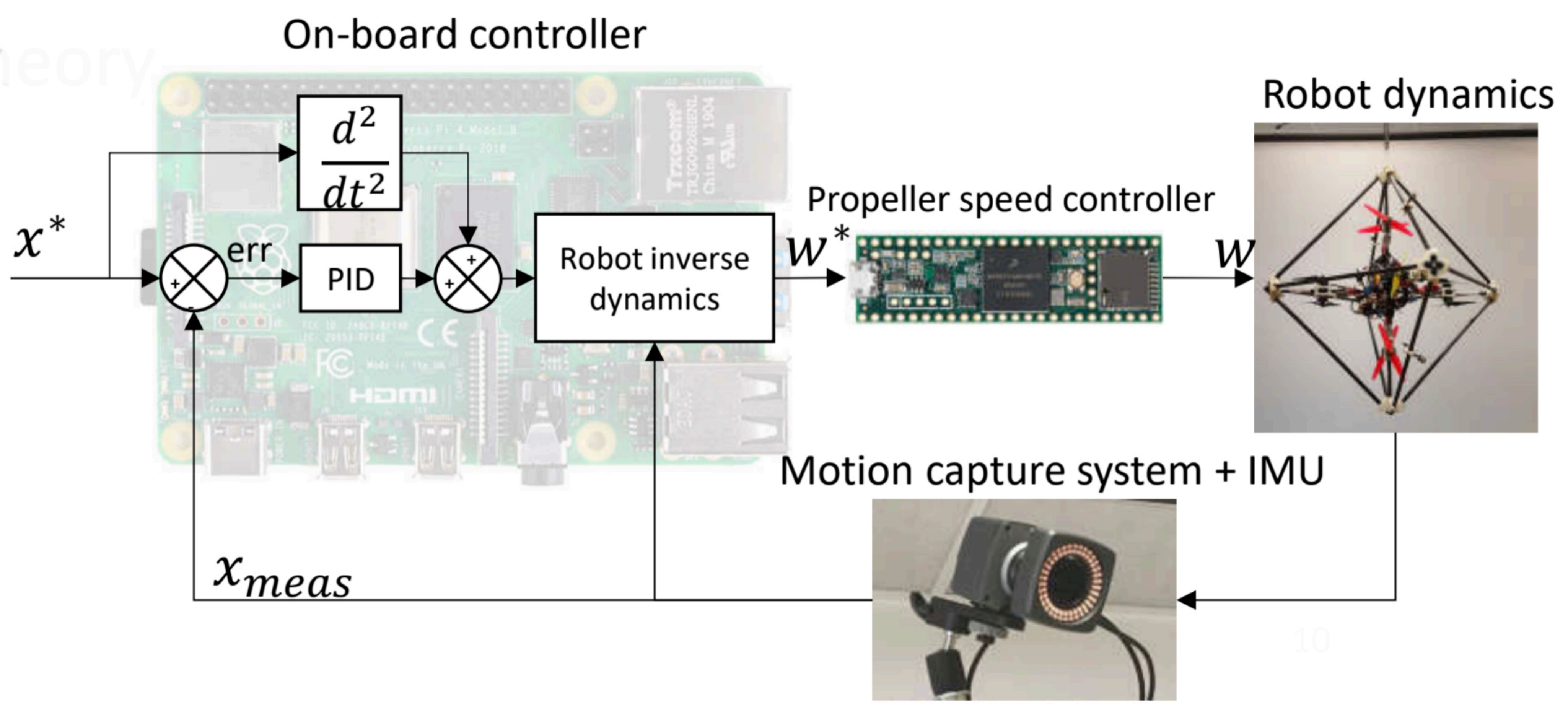
- Simplified cable-driven robot
- Gravity compensation
- Dynamic decoupling between carrier and aerial manipulator

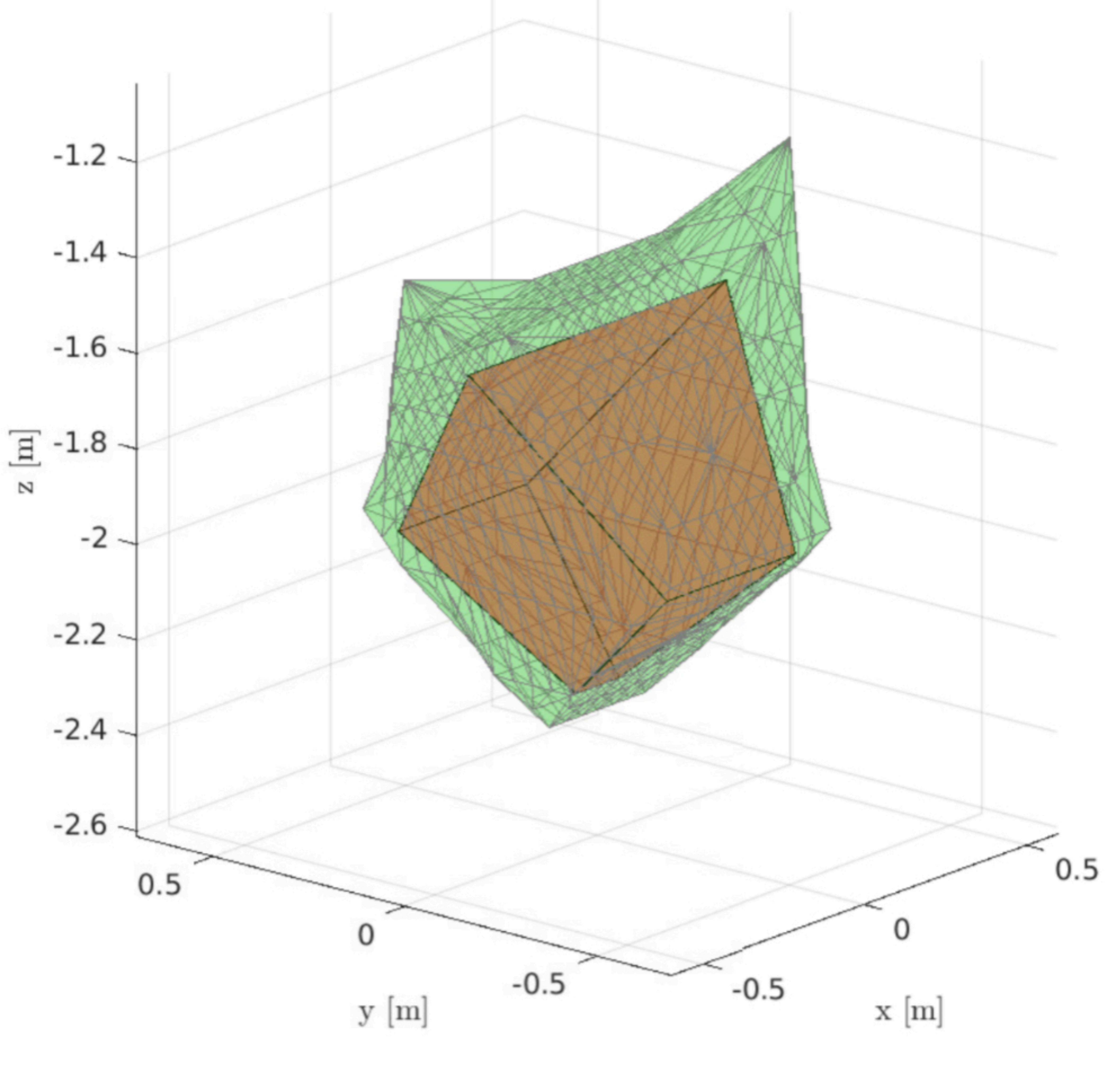


dextAIR: Experimental Setup



dextAIR: Computed Torque Control



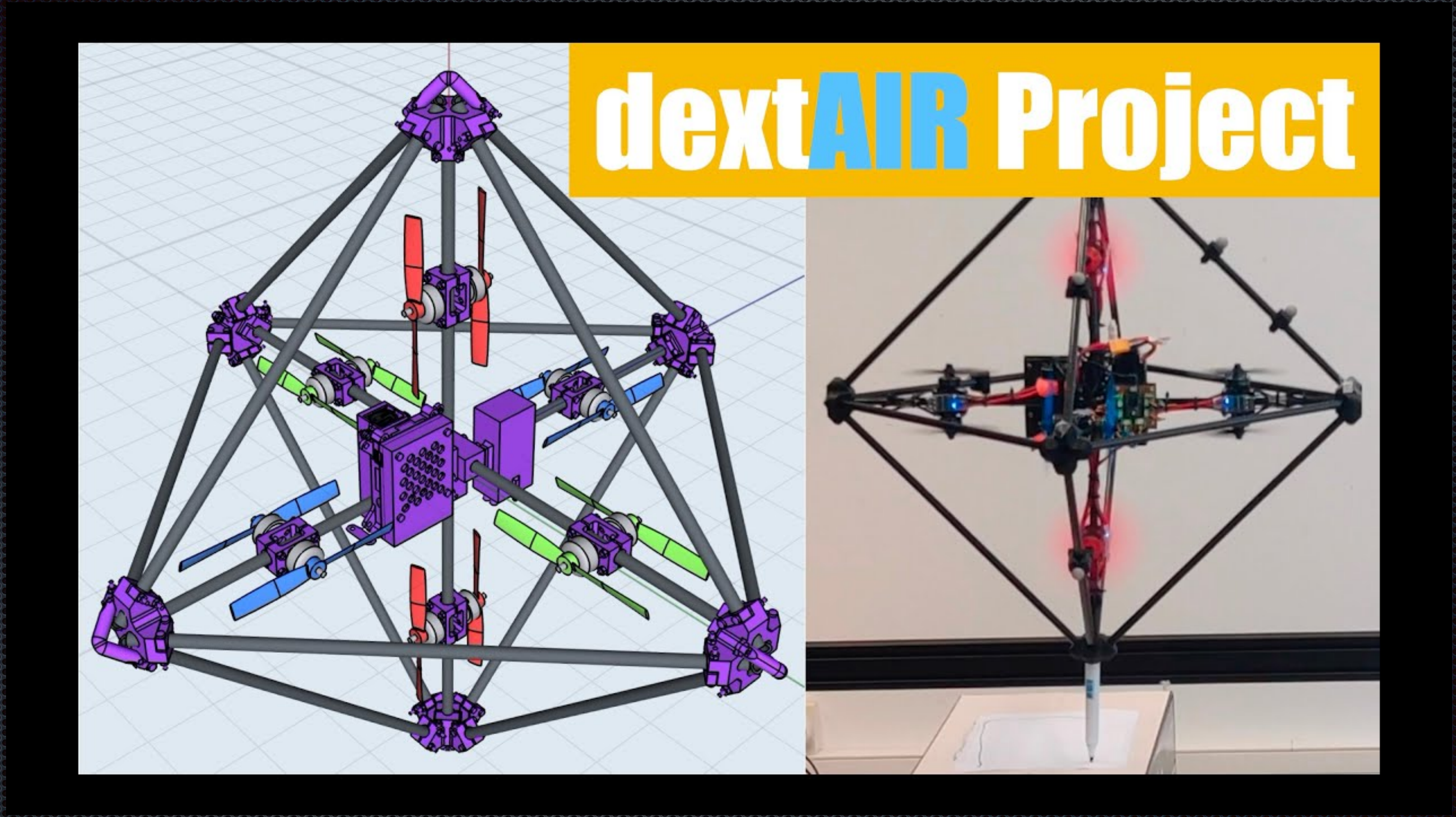


ACCURACY AND REPEATABILITY

Positions	P_1	P_2	P_3	P_4	P_5
AP_P [mm]	0.14	0.08	0.11	0.10	0.19
RP_l [mm]	0.48	1.49	0.57	1.05	1.73
AP_ψ [°]	0.00	-0.04	-0.01	-0.02	0.01
RP_ψ [°]	0.16	0.61	0.30	0.42	0.39
AP_θ [°]	-0.00	-0.01	0.01	-0.01	0.03
RP_θ [°]	0.13	0.43	0.16	0.29	0.42
AP_ϕ [°]	0.00	-0.02	-0.02	-0.01	-0.01
RP_ϕ [°]	0.27	0.56	0.30	0.31	0.57

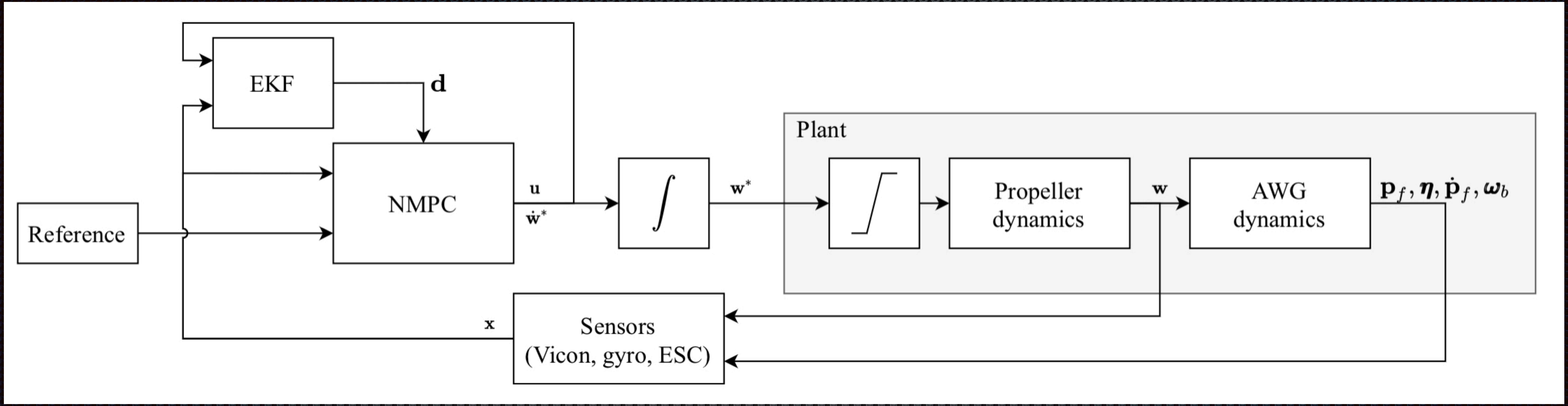
ISO 9283

dextAIR: Computed Torque Control



A. Yigit, M. Arpa Perozo , L. Cuvillon, S. Durand, J. Gangloff, Novel Omnidirectional Aerial Manipulator with Elastic Suspension: Dynamic Control and Experimental Performance Assessment, IEEE Robotics and Automation Letters, Institute of Electrical and Electronics Engineers (IEEE) (IF : 3.608), Volume 6, n° 2, 2021, doi:10.1109/LRA.2020.3048880

dextAIR: NMPC



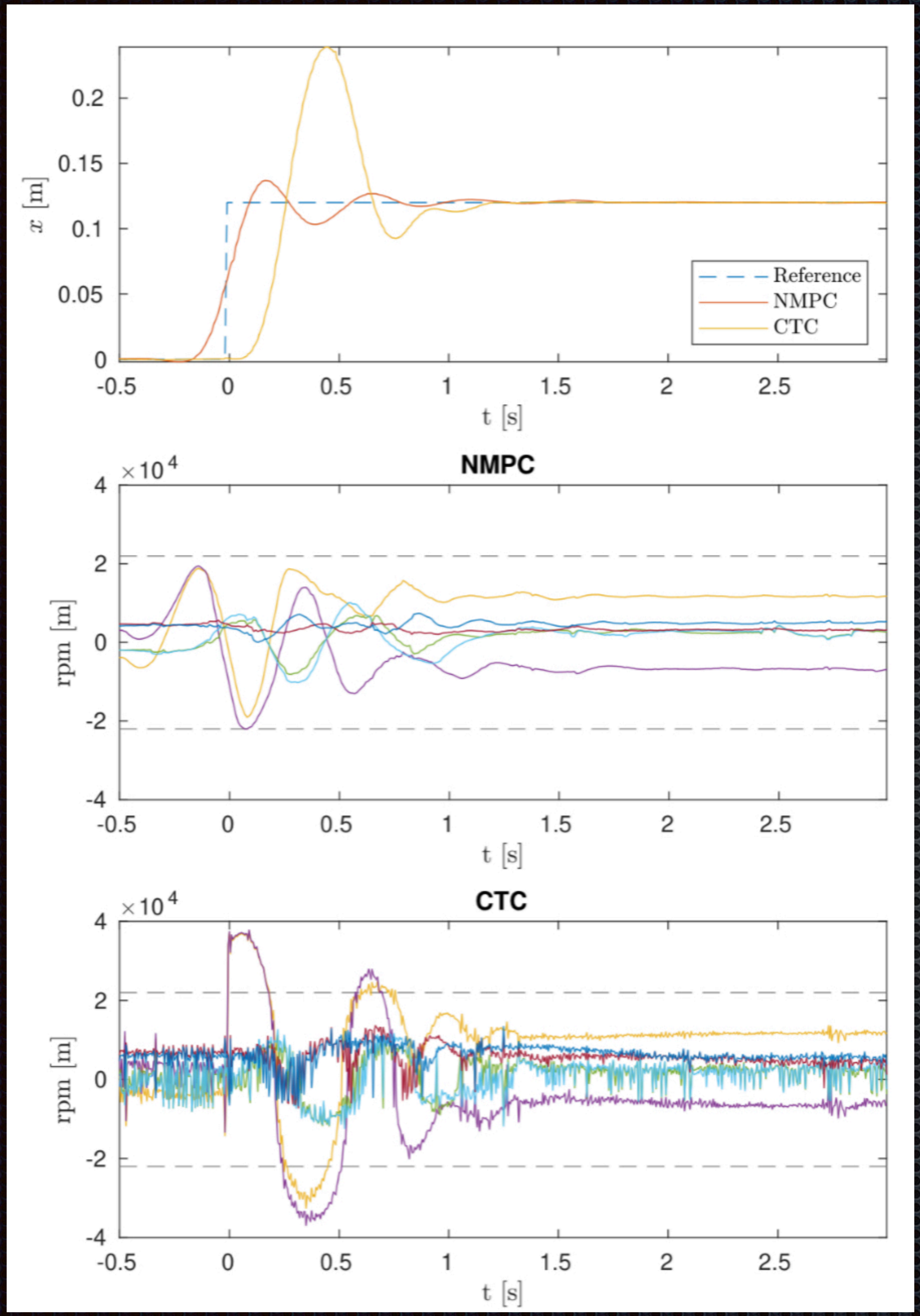
$$\min_{\mathbf{u},\mathbf{x}} \left[\int_0^T \left(\|\mathbf{y}(t) - \mathbf{y}^{\mathbf{r}}(t)\|_{\mathbf{Q}}^2 + \|\mathbf{u}(t)\|_{\mathbf{R}}^2 \right) dt \right]$$

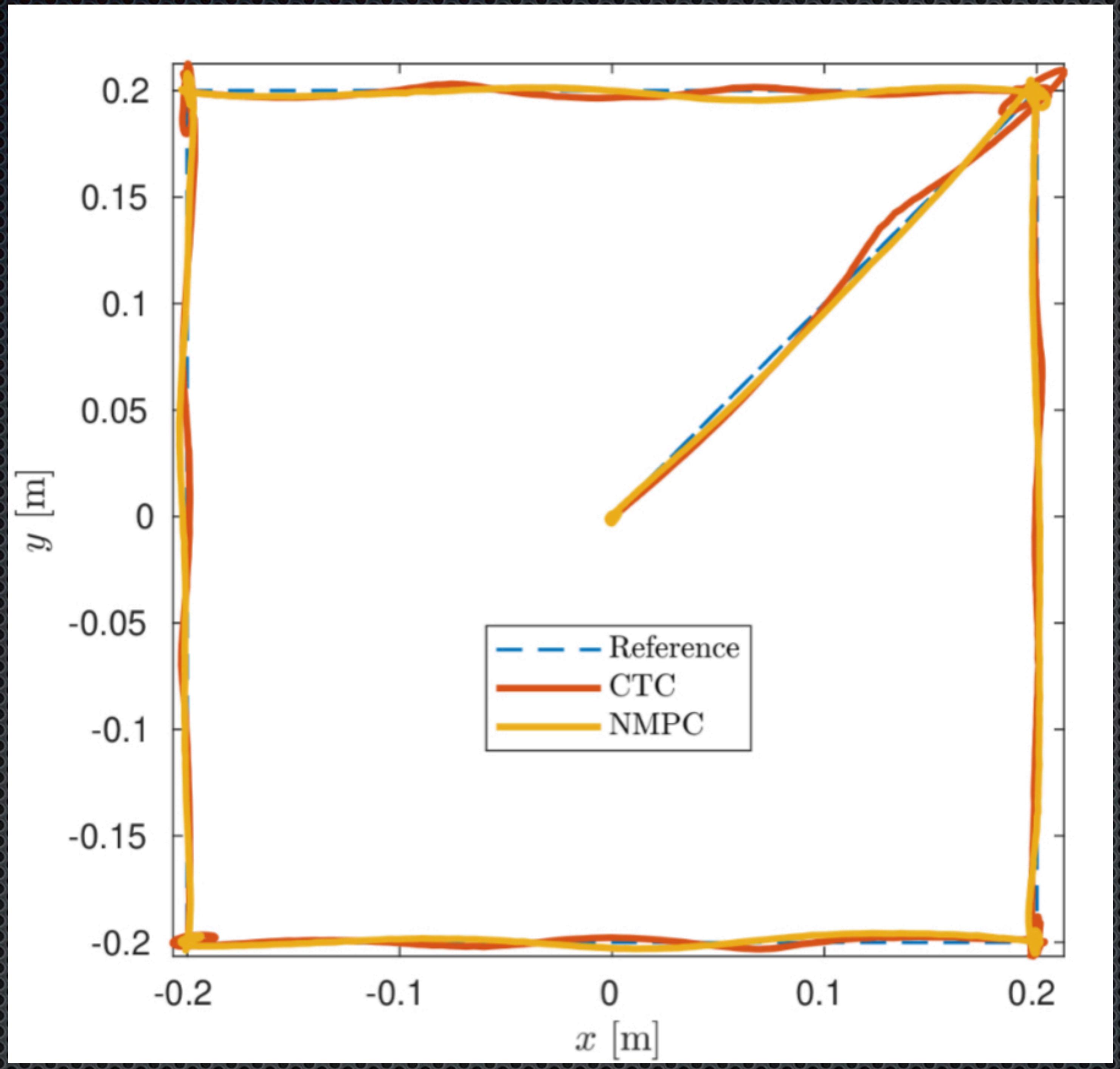
$$\text{subject to } \dot{\mathbf{x}} = \mathbf{f}(\mathbf{x}, \mathbf{u})$$

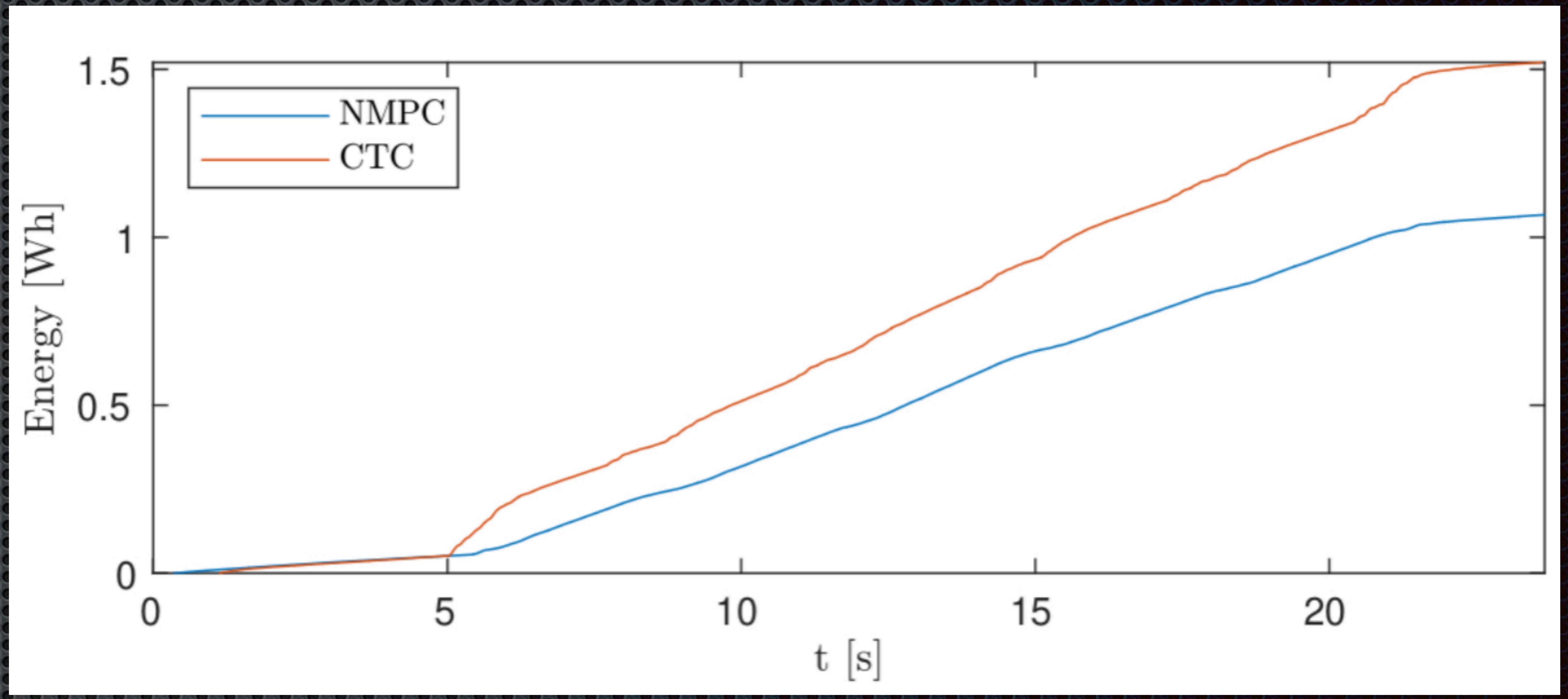
$$\mathbf{x}(0) = \mathbf{x_0}$$

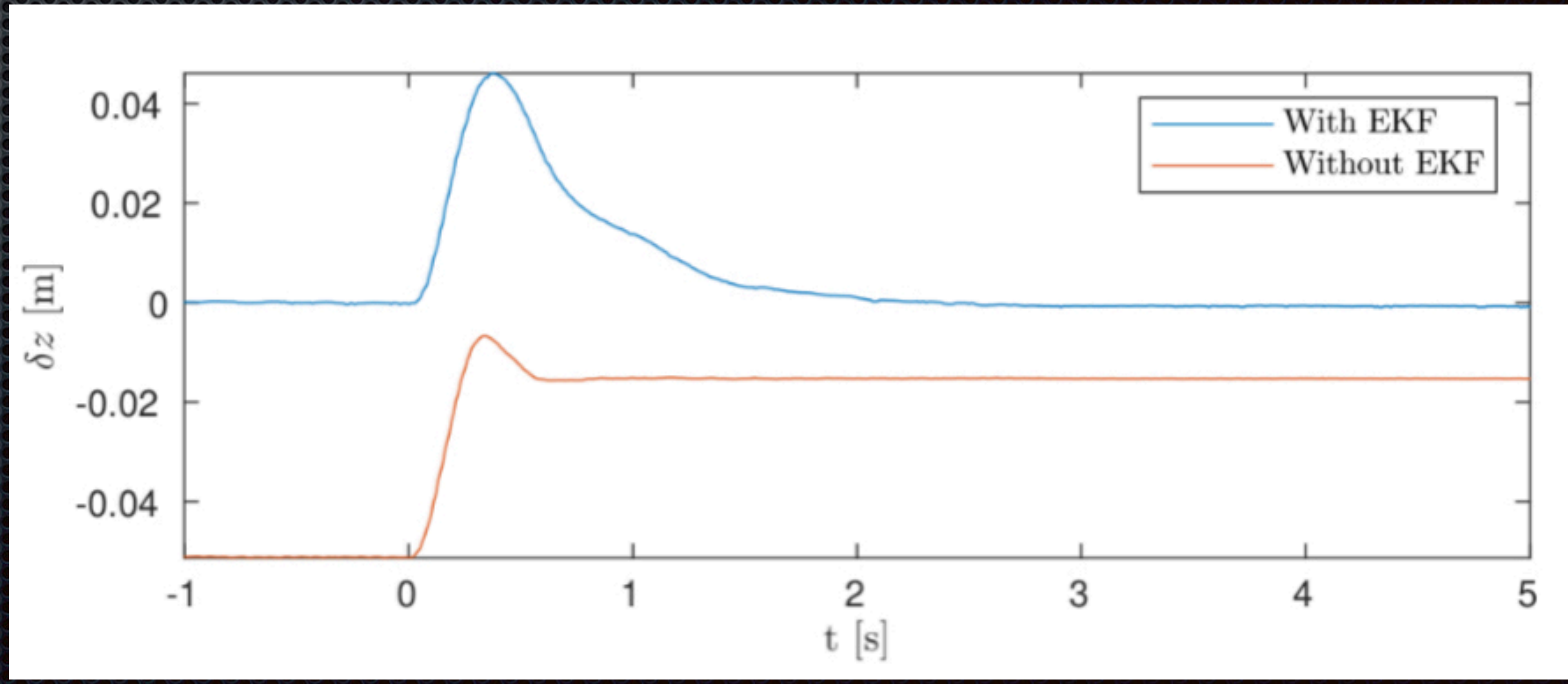
$$\mathbf{h}(\mathbf{x}, \mathbf{u}) \geq \mathbf{0}$$

dextAIR: CT vs NMPC

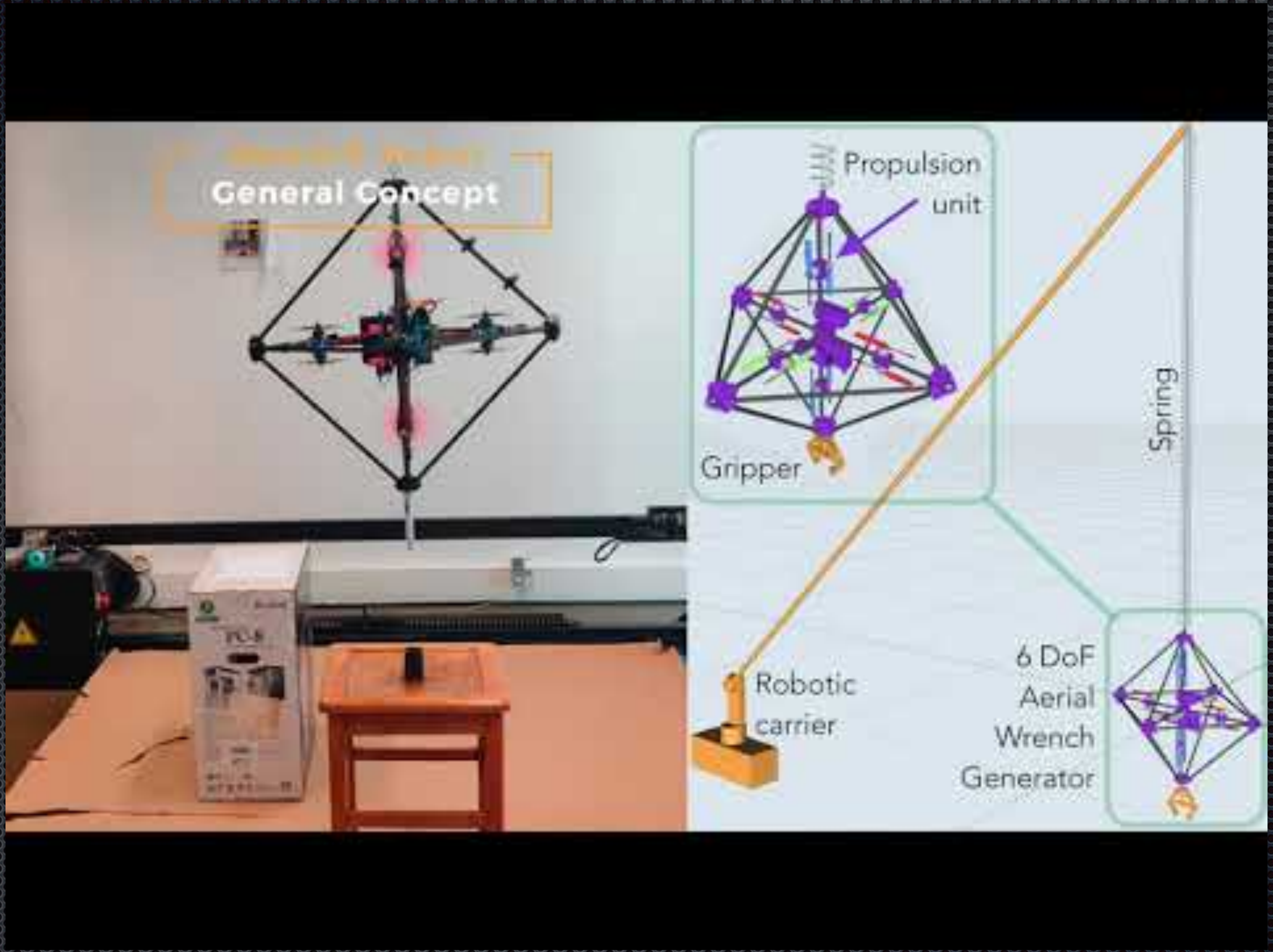








dextAIR: CT vs NMPC



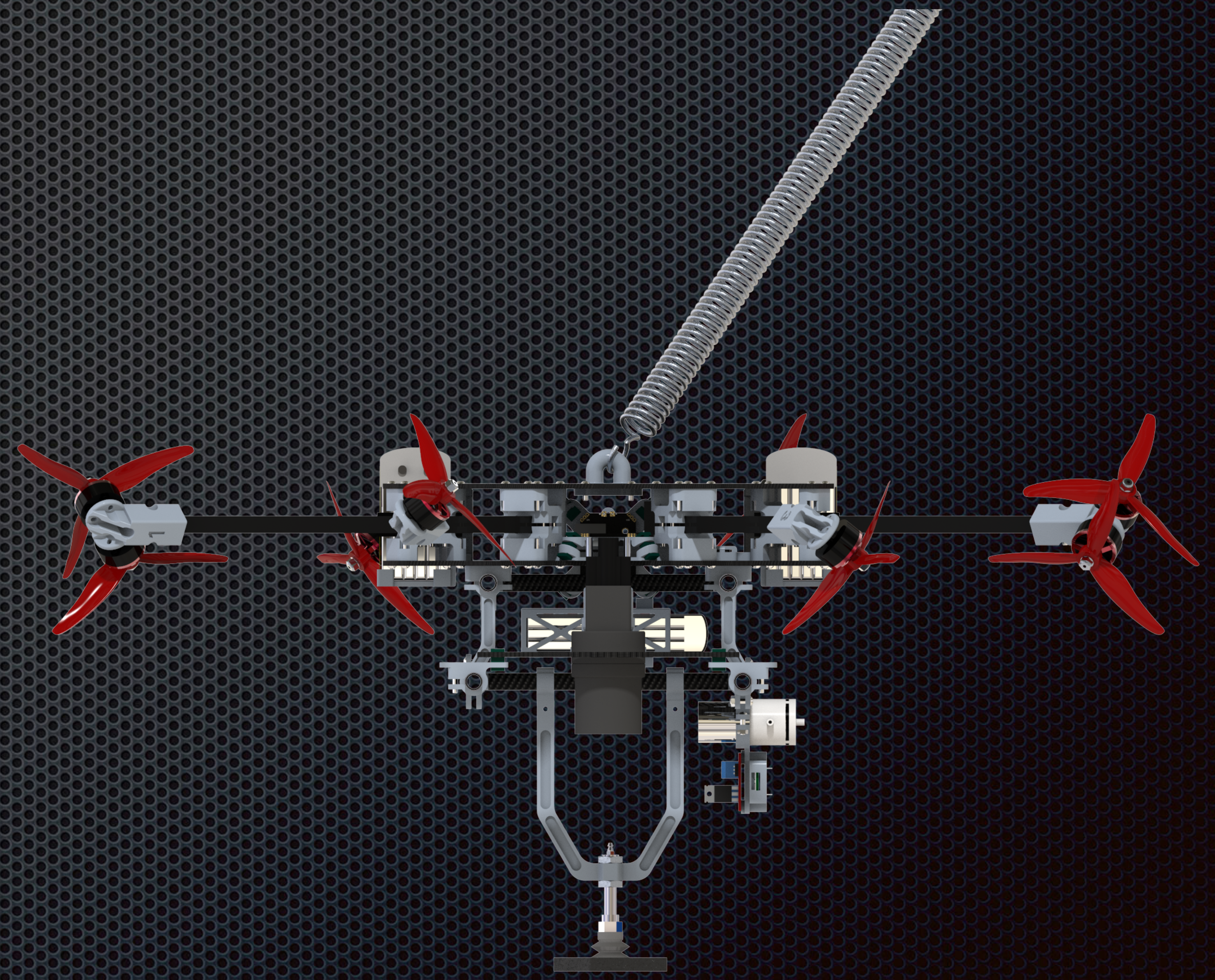
A. Yigit, M. Arpa Perozo , L. Cuvillon, S. Durand, J. Gangloff, Improving Dynamics of an Aerial Manipulator with Elastic Suspension Using Nonlinear Model Predictive Control, 2021 IEEE International Conference on Robotics and Automation (ICRA), Xi'an, China, janvier 2021

dextAIR with CDPR Carrier

A. Yigit, M. Arpa Perozo , M. Ouafo , L. Cuvillon, S. Durand, J. Gangloff, Aerial Manipulator Suspended from a Cable-Driven Parallel Robot: Preliminary Experimental Results, IEEE/RSJ International Conference on Intelligent Robots and Systems, Prague, Czech Republic, octobre 2021

dextAIR: Future Work

- dextAIR + carrier NMPC control
- Visual servoing with eye-in-hand high-speed visual feedback
- dextAIR v3 with extended workspace and dynamics
- Frugal / low-cost robotics
- New applications



Open Source Software

- TeensySHOT: ESC speed control for KISS ESCs
- RPIt: Simulink toolbox for HIL robotics experiments