ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

eSpace SPACE ENGINEERING CENTER

Active Model Rocket Stabilization via Cold Gas Thrusters

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Supervisors: Anton Ivanov and Nikolay Mullin

Padova, Italy
11 December 2015

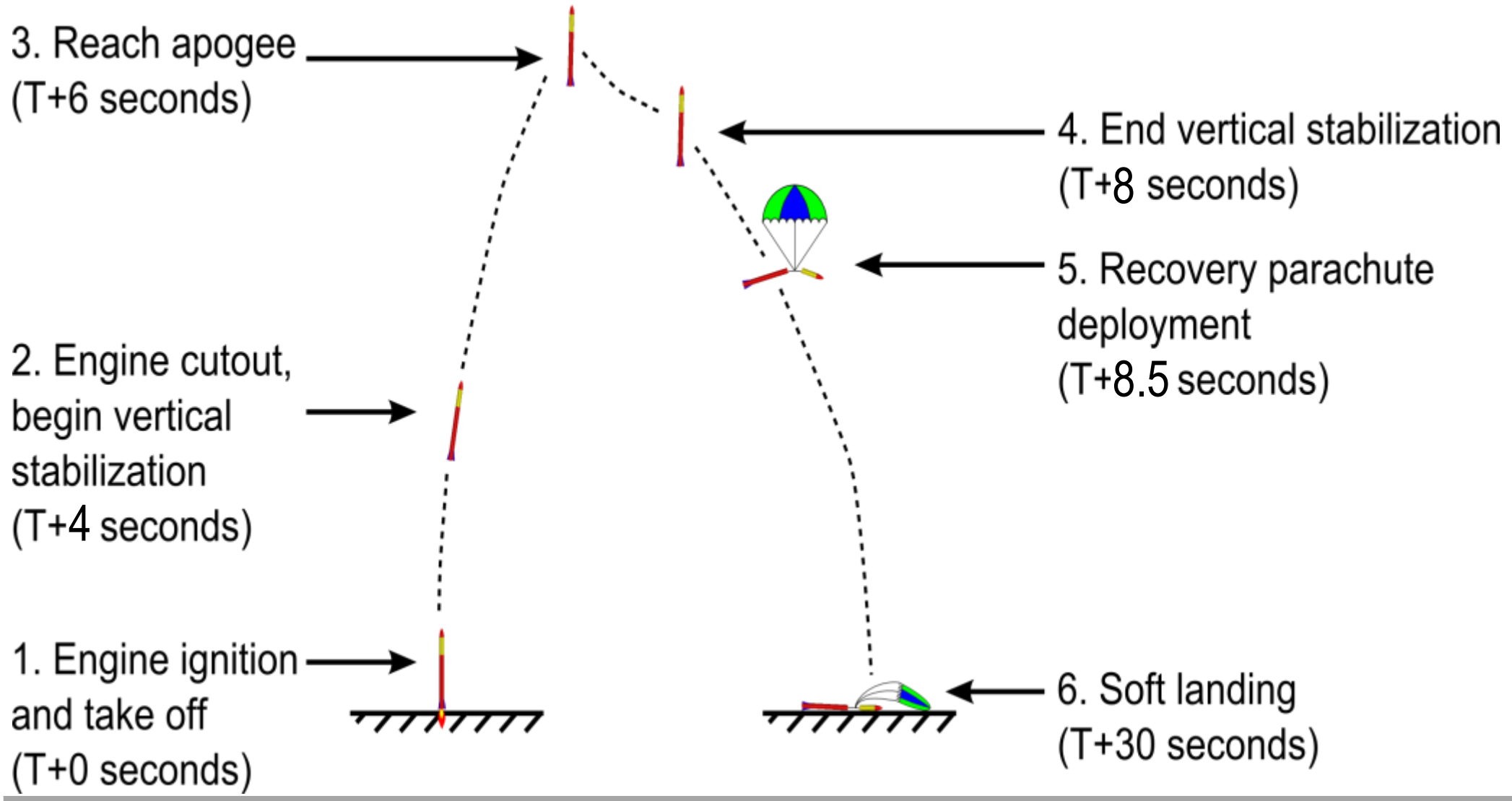
The team

Aim of the project

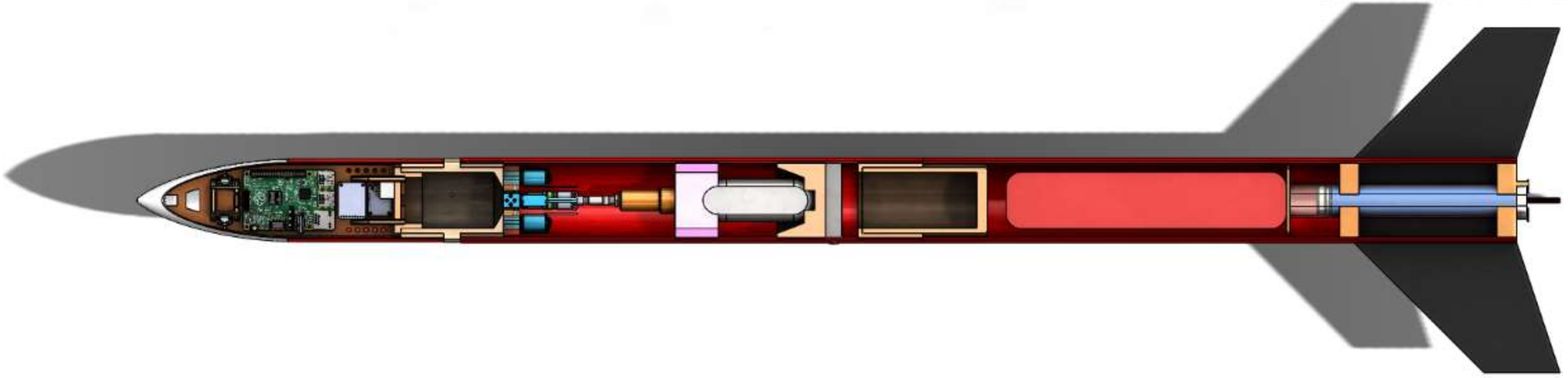
SPACEX

BLUE ORIGIN

Our goal


3. Reach apogee
(T+6 seconds)
4. End vertical stabilization
(T+8 seconds)
5. Recovery parachute
deployment
(T+8.5 seconds)
2. Engine cutout,
begin vertical
stabilization
(T+4 seconds)
1. Engine ignition
and take off
(T+0 seconds)
6. Soft landing
(T+30 seconds)

Final design FALCO-4



Structure

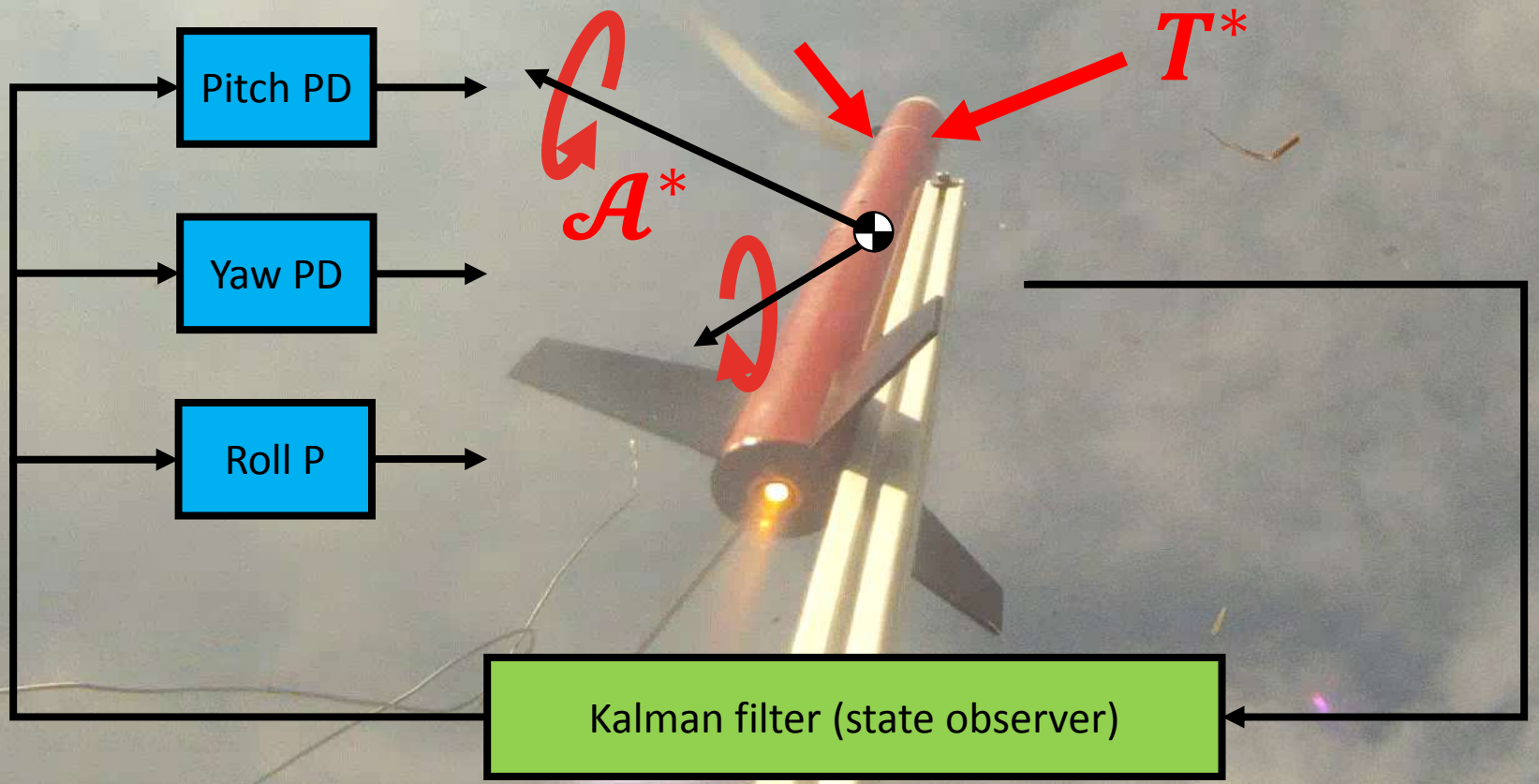
- Weight 2560 [g]
- Long 1360 [mm]
- Diameter 76 [mm]
- Fiber Glass, Wood, 3D printed parts

Motor

AeroTech RMS 29/180 Reusable

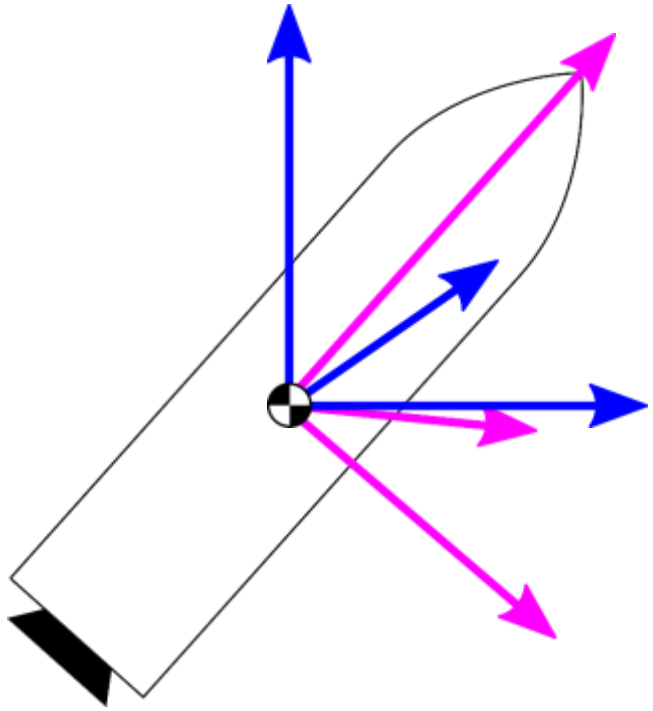
- Specific impulsion 178.8 [Ns]
- Combustion time 0.9 [s]
- Average force 193.3 [N]

Control system design

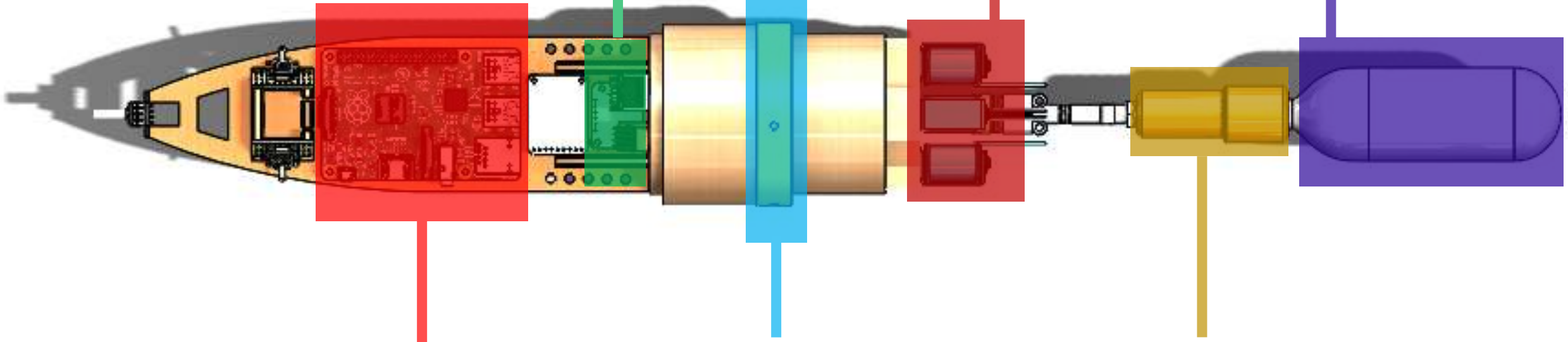


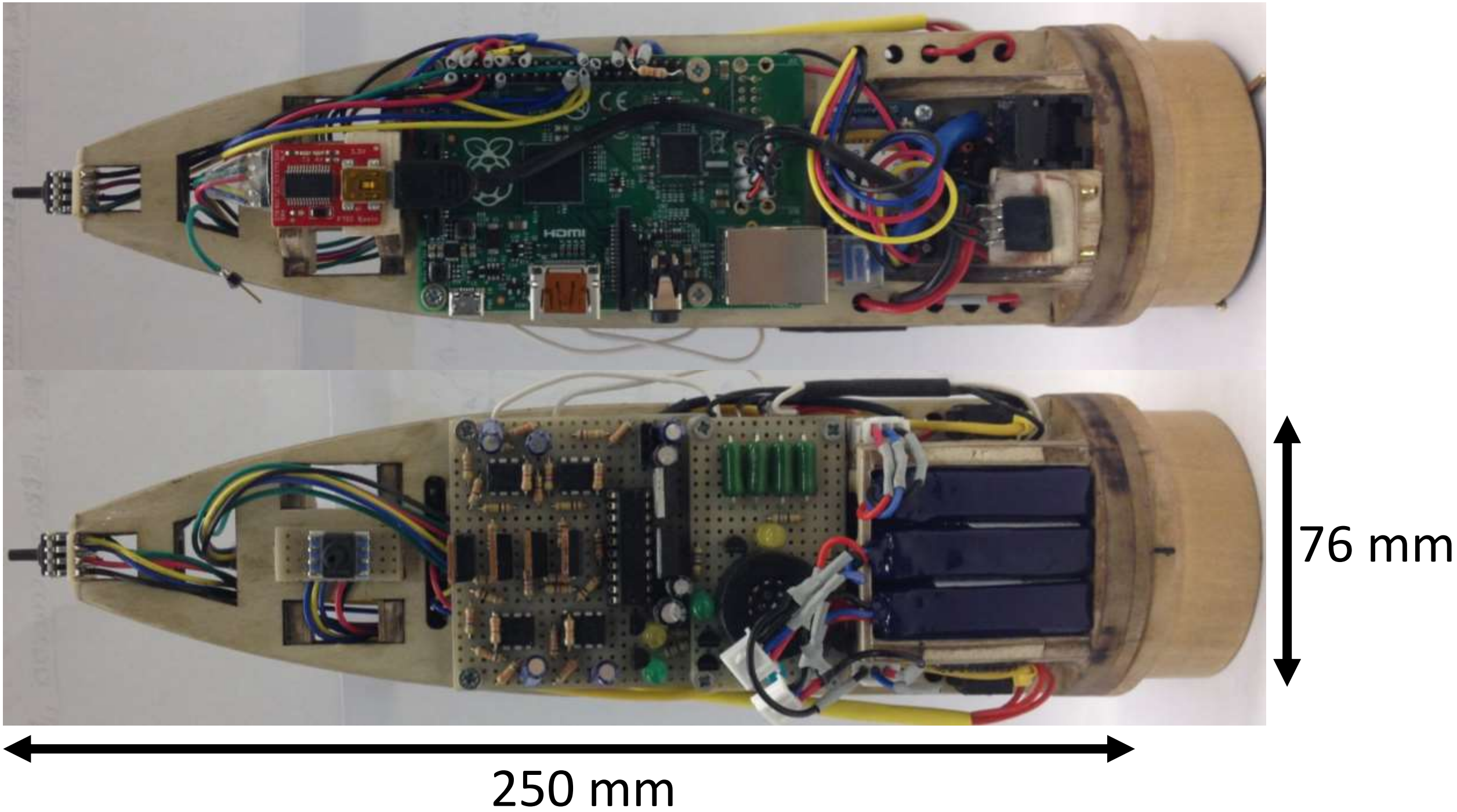
Control system design

Goal: regulate the rocket attitude back to the inertial vertical.

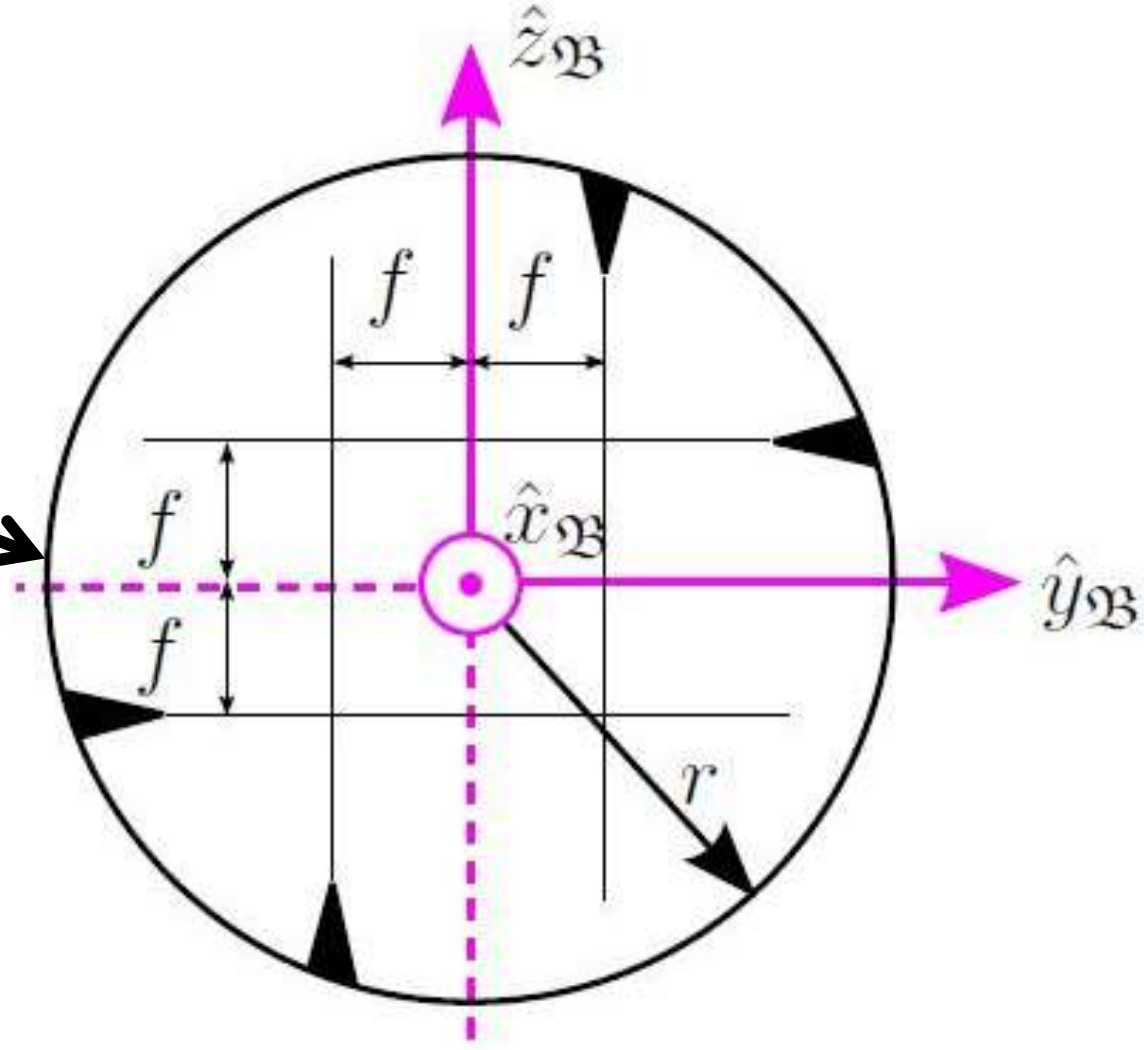


Active stabilization via cold gas thrusters

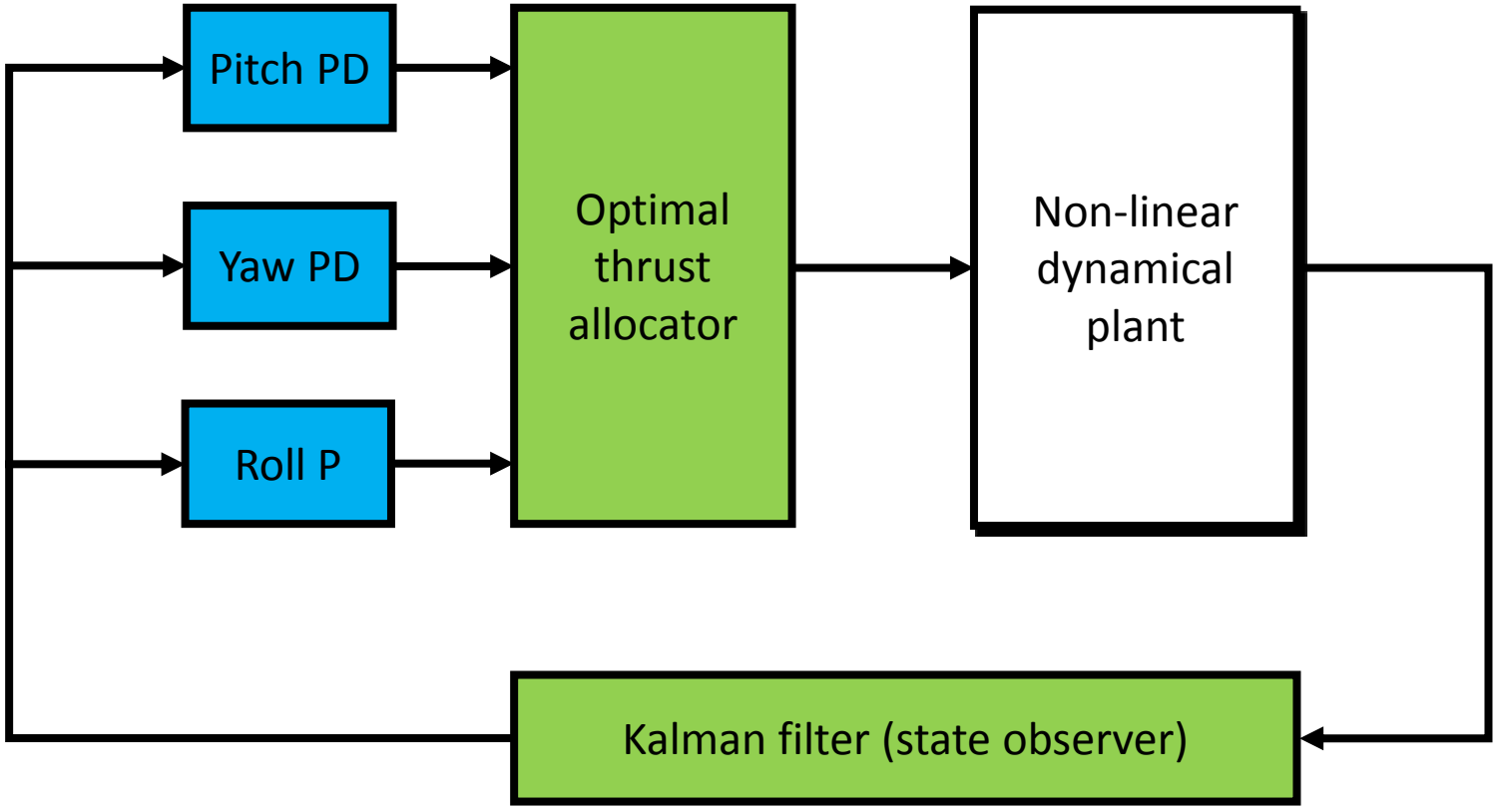


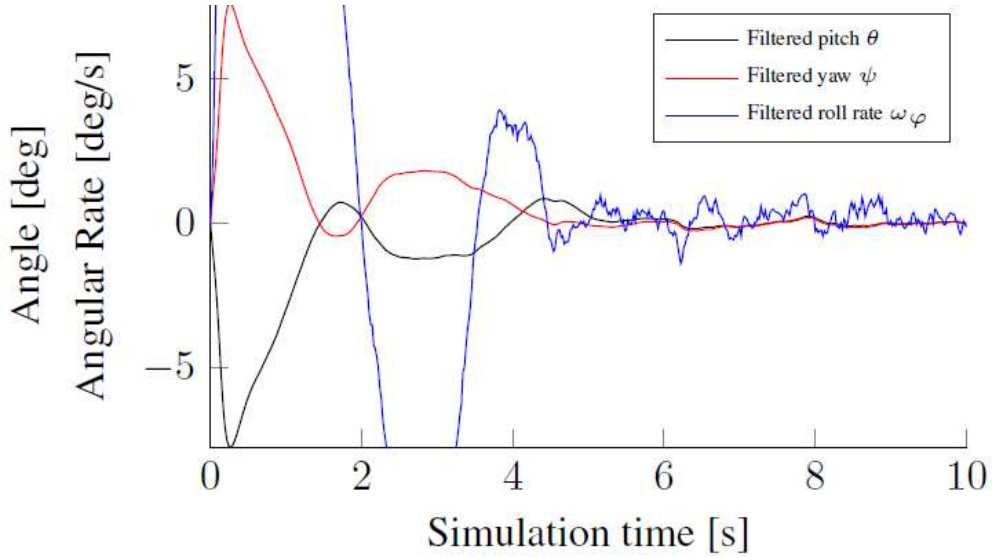

76 mm
250 mm

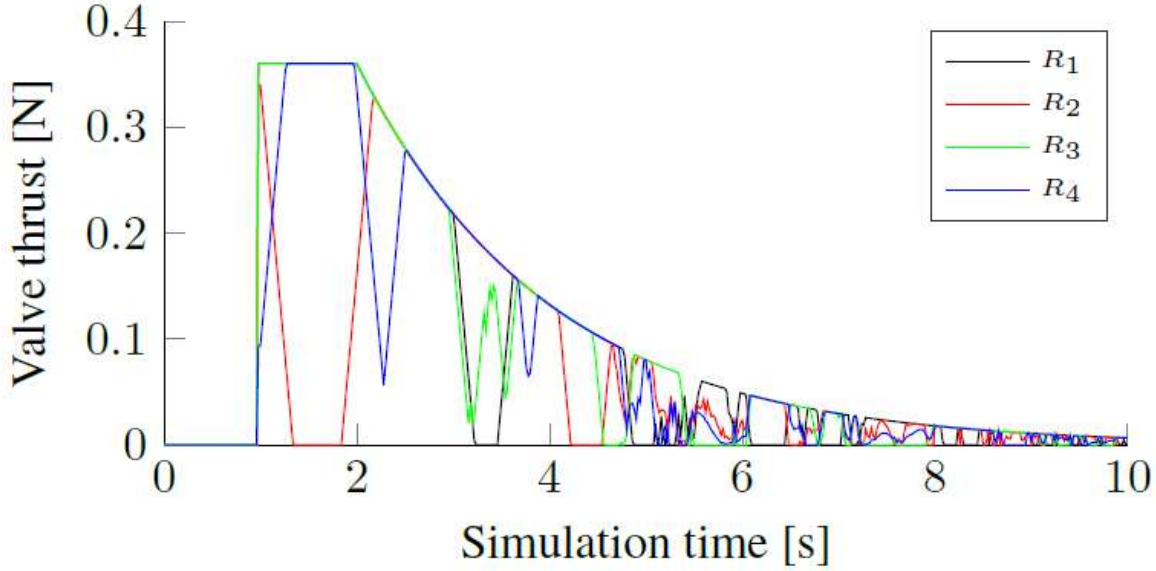
Jet valve thrusters

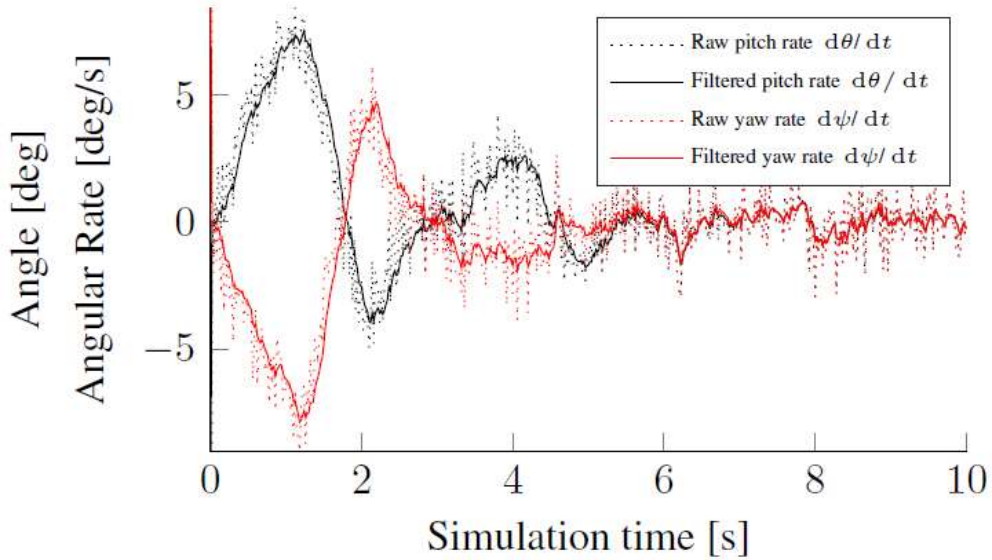


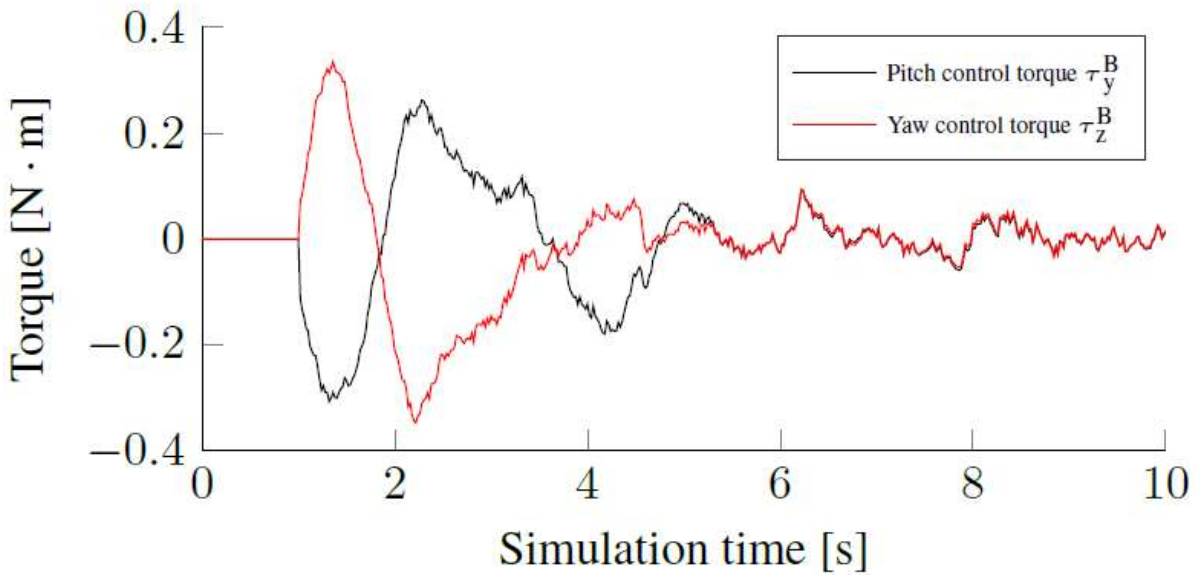
Control system design




Filtered pitch θ
Filtered yaw ψ
Filtered roll rate ω_φ
Angle [deg]
Angular Rate [deg/s]
Simulation time [s]


R_1
R_2
R_3
R_4
Valve thrust [N]
Simulation time [s]


Raw pitch rate $\mathrm{d}\theta/\mathrm{d}t$
Filtered pitch rate $\mathrm{d}\theta/\mathrm{d}t$
Raw yaw rate $\mathrm{d}\psi/\mathrm{d}t$
Filtered yaw rate $\mathrm{d}\psi/\mathrm{d}t$
Angle [deg]
Angular Rate [deg/s]
Simulation time [s]


Pitch control torque τ_y^B
Yaw control torque τ_z^B
Torque [N · m]
Simulation time [s]

Flight test results

Burn

Coast

Control

Parachute

Uncontrolled

Uncontrolled

Controlled

#3

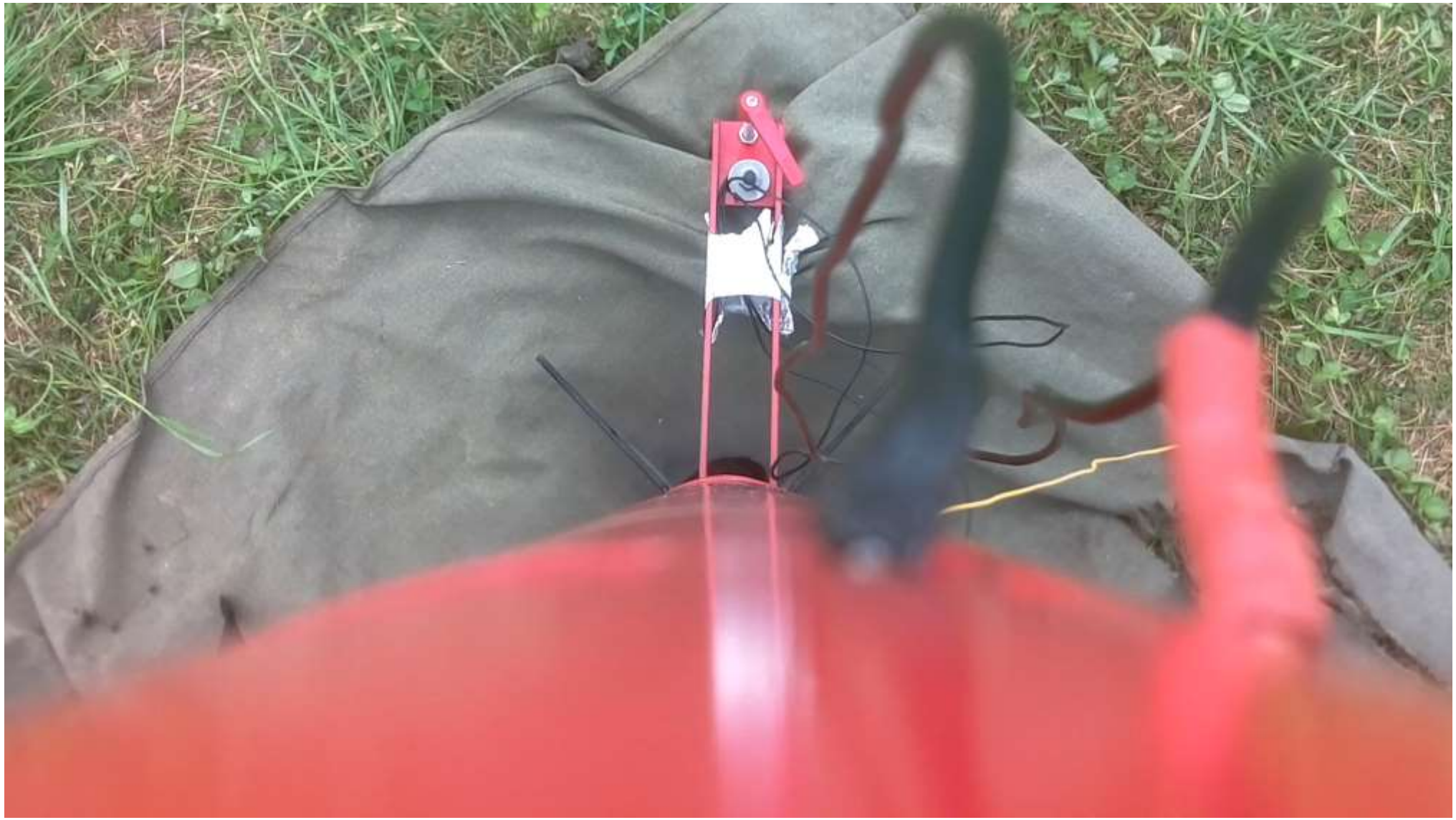
#4

#2

#3

#4

#2



#3

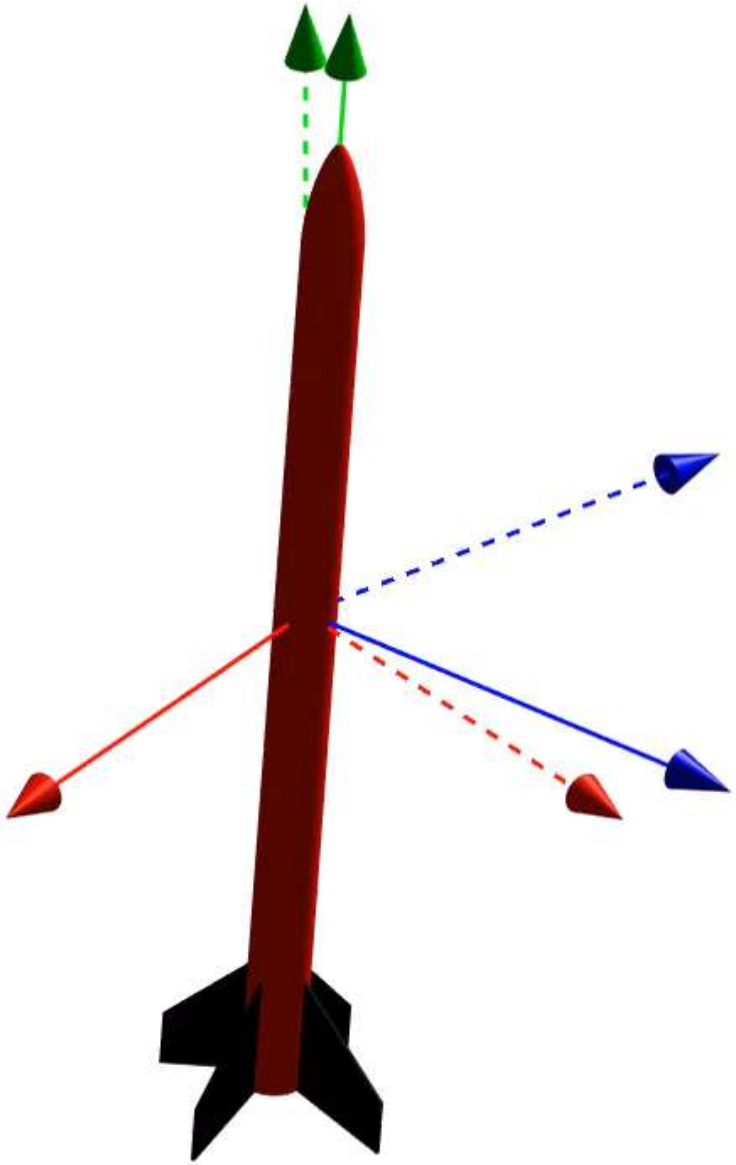
#4

#2

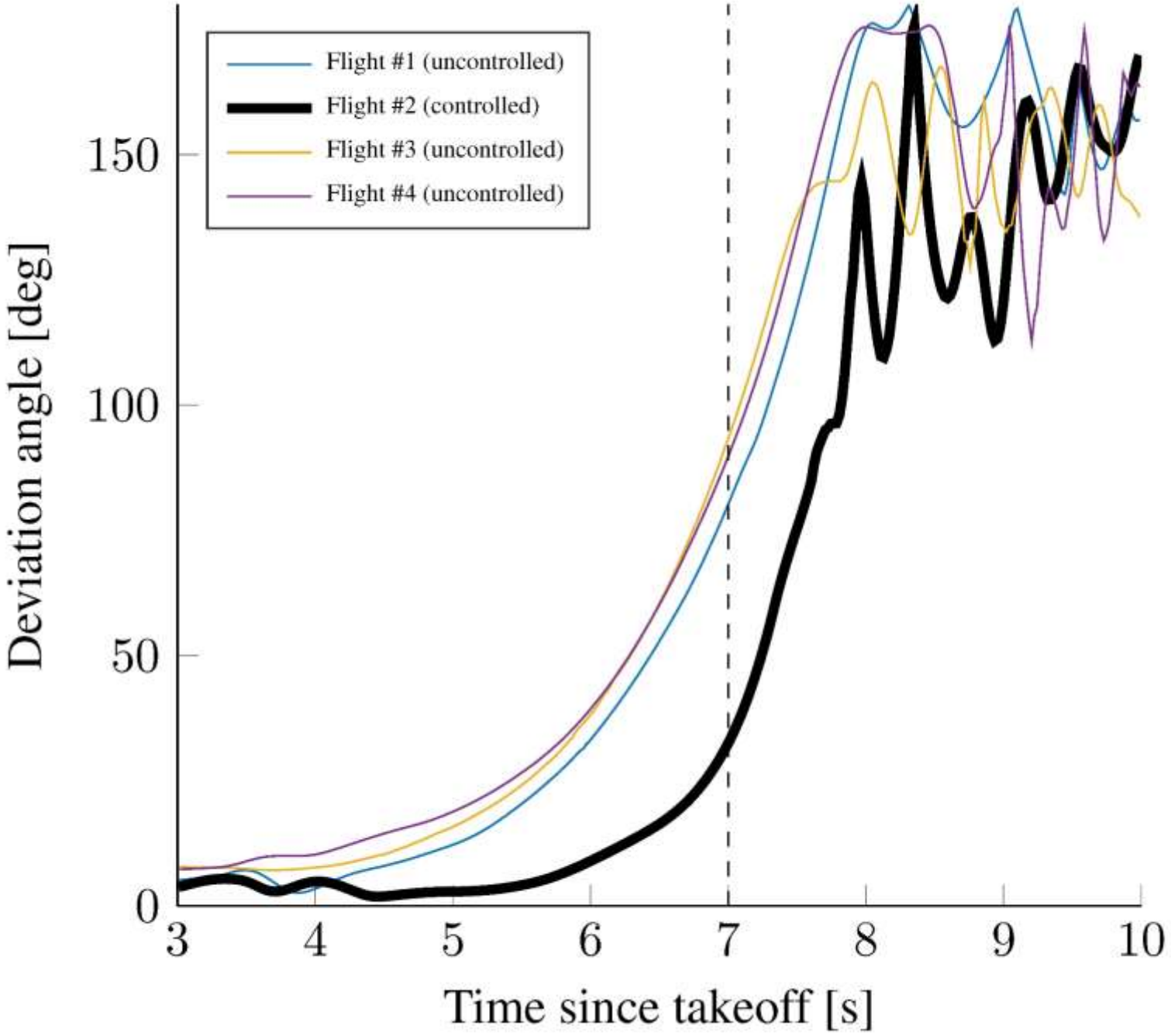
#3

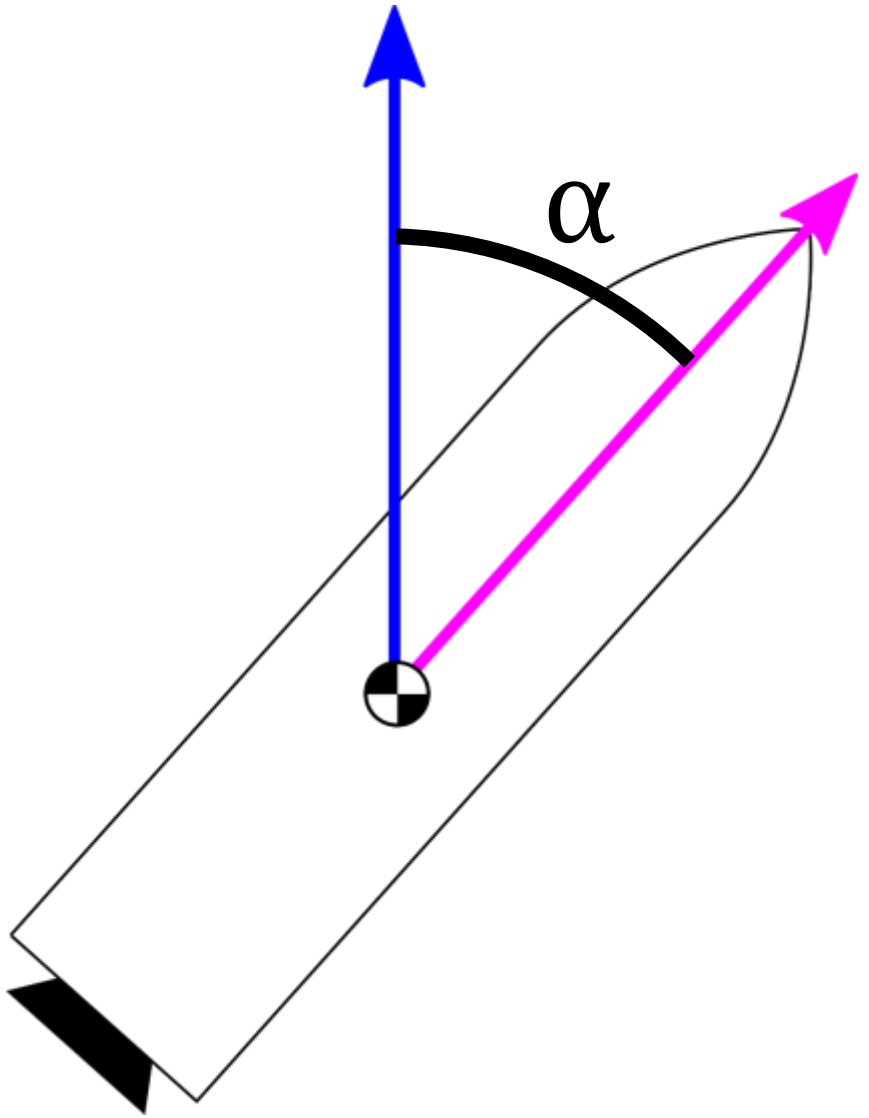
#4

#2



Flight time: 3.011


Flight #1 (uncontrolled)
Flight #2 (controlled)
Flight #3 (uncontrolled)
Flight #4 (uncontrolled)
Deviation angle [deg]
0
50
100
150
3
4
5
6
7
8
9
10
Time since takeoff [s]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Conclusion

- Deviation from vertical significantly lower with active control
- Vertical attitude can be maintained using this system, given sufficient thrust
- This knowledge will be used for the next rocket landing projects

Danylo Malyuta

Mikael Gaspar

Gautier Rouaze

Xavier Collaud

Raimondo Pictet

Nikolay Mullin

Anton Ivanov

Simon Dandavino

eSpace (EPFL Space Engineering Center)

Currently staff of 11 with ~20 project students

- Including 2 ex-JPL senior scientists (Muriel Richard-Noca and Anton Ivanov)
- Expertise in system engineering and mission analysis, microsystems, propulsion

Launched one satellite

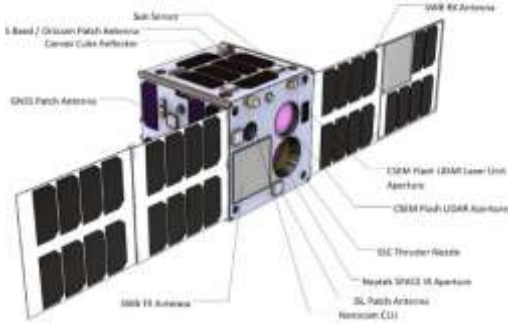
- SwissCube, now operating > 6 years

Focus on agile small satellites

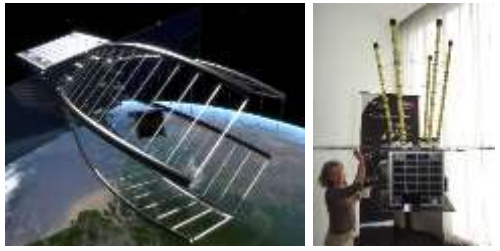
- In-orbit technology demonstrators including attitude and orbit control with on-board intelligence

SwissCube Launch 2009

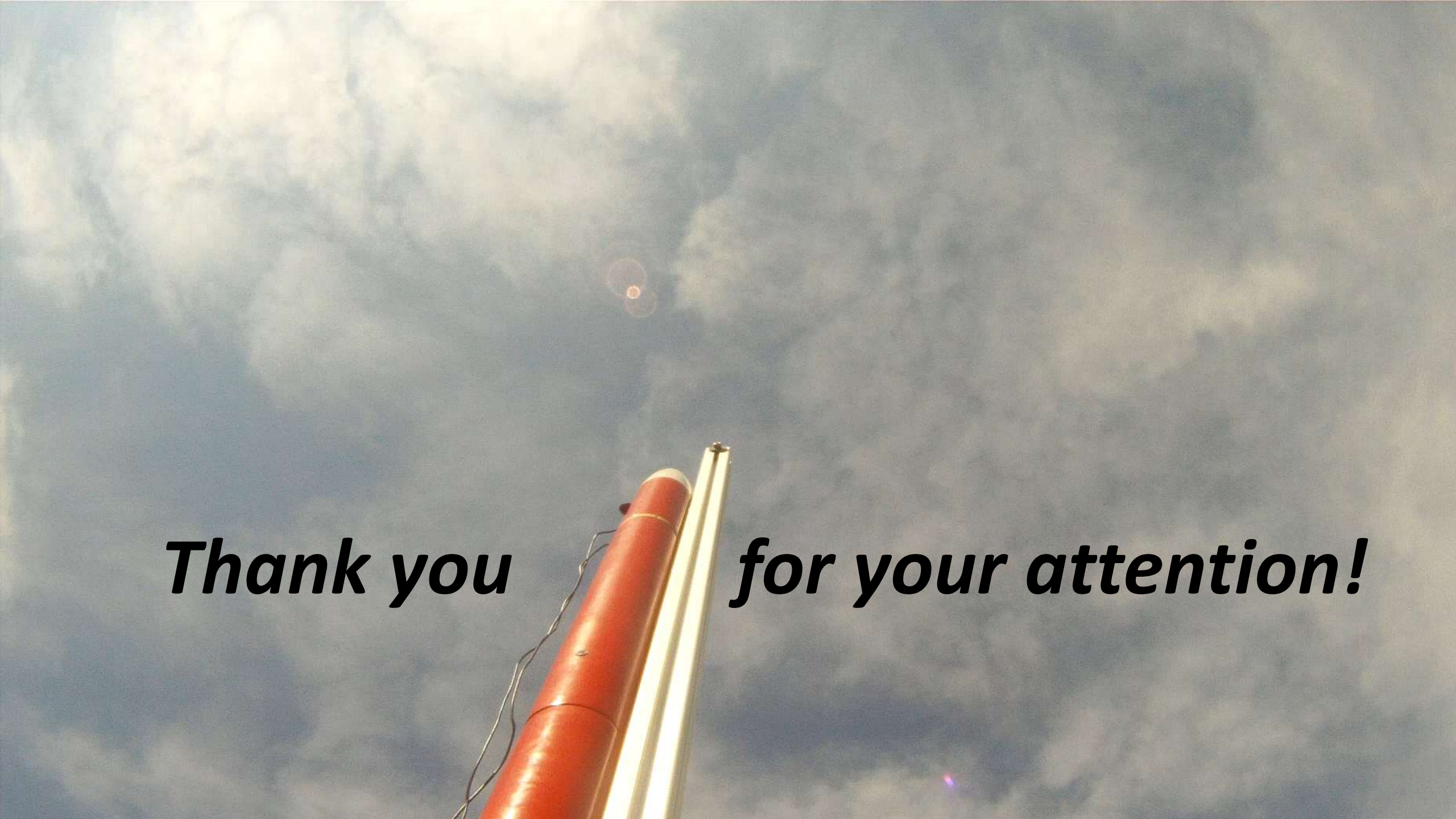
CubETH Launch 2017



CADRE-1 (ESA IoD). Launch 2018



CleanSpace One. Launch 2019


Thank you for your attention!

Questions?