UNIVERSITY OF TRENTO

Università di Pisa

# Design, Realization and Testing of an Azimuth-Stabilized Modular Stratospheric Platform

PhD SST
Space Science and Technology

Irene Marsili
University of Trento / Space Systems Laboratory, University of Pisa, Italy

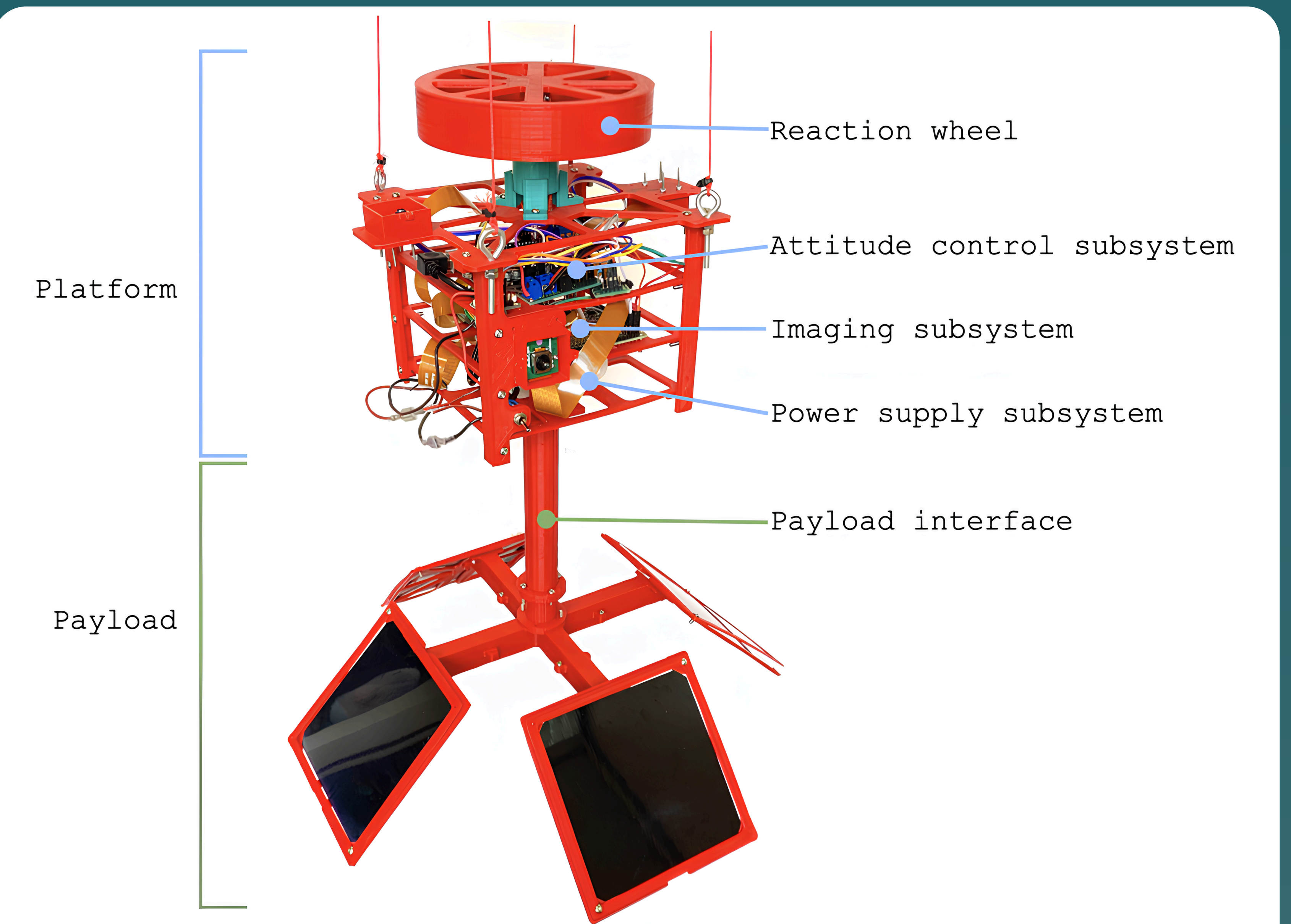
Space Systems Laboratory

This platform is a first-iteration prototype into the development of a new near-space facility to test space hardware and to carry scientific instrumentation for space and Earth exploration, with stratospheric sounding balloons.

This platform includes a reaction wheel to offer an azimuth-stabilized frame, which is not a feature currently offered by state-of-the-art small-scale gondolas. The reaction wheel is controlled by a PI software with respect to angular speed.

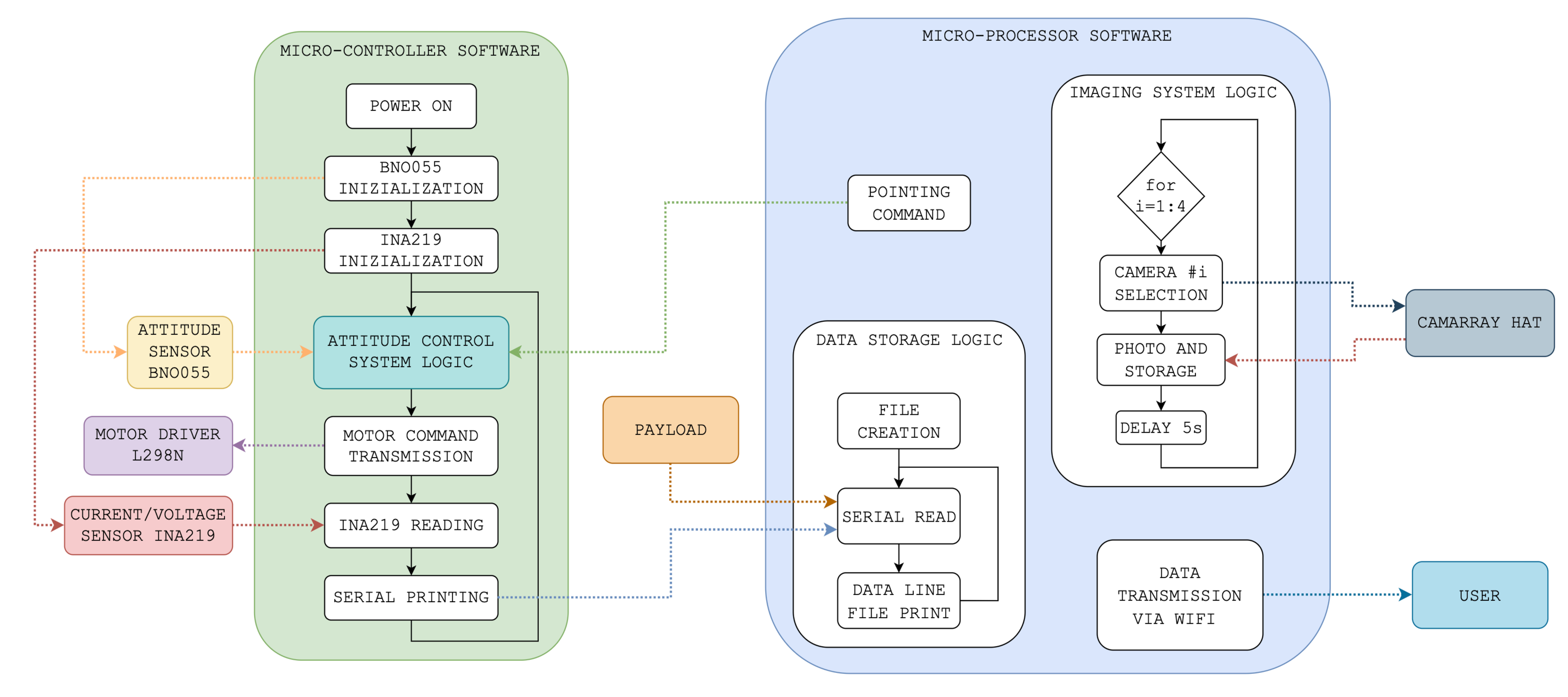
During the platform development, passive attitude stabilization techniques were employed and a axial bearing swivel was introduced to decouple ballon's and platform's rotation.

As a first application of the platform, a payload of four solar cells is hosted, but modular design was implemented, so that the integration of a different payload would require the re-design of just the interface and/or the resizing of the flywheel



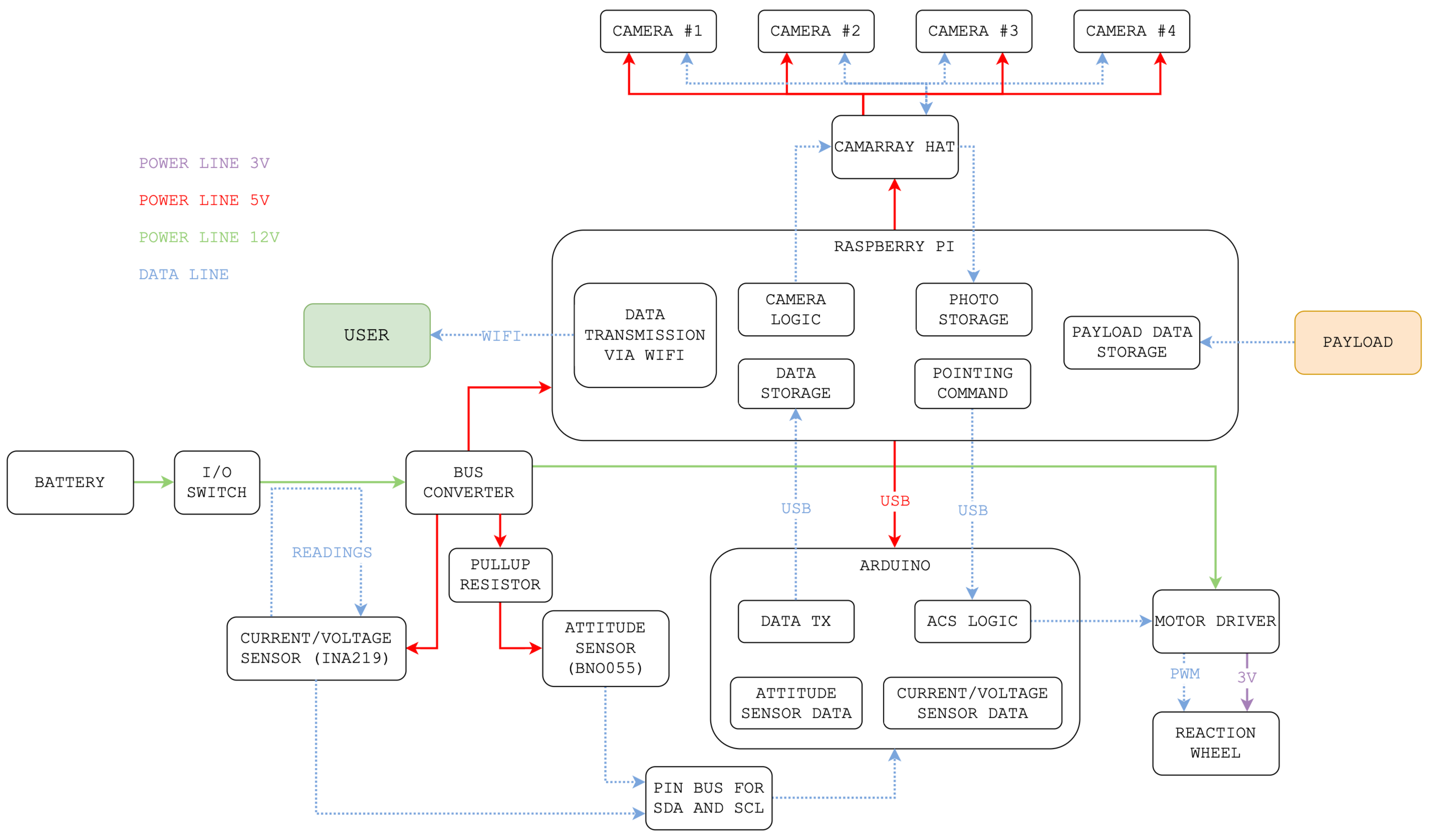

**Assembled platform, attached to suspension ropes**

This is the setup used to perform testing. A fan was used to mimic the disturbances induced by the wind action in the operating environment.




**Function block diagram of the platform's software**

The green block contains the micro-controller software logic, which main task is the ACS control. Either pre-determined or inputted by the user during operations, pointing commands are received form the micro-processor. The micro-processor software is also responsible for on-board data storage, telemetry transmission to the user and imaging subsystem control.




**Function block diagram of the entire platform**

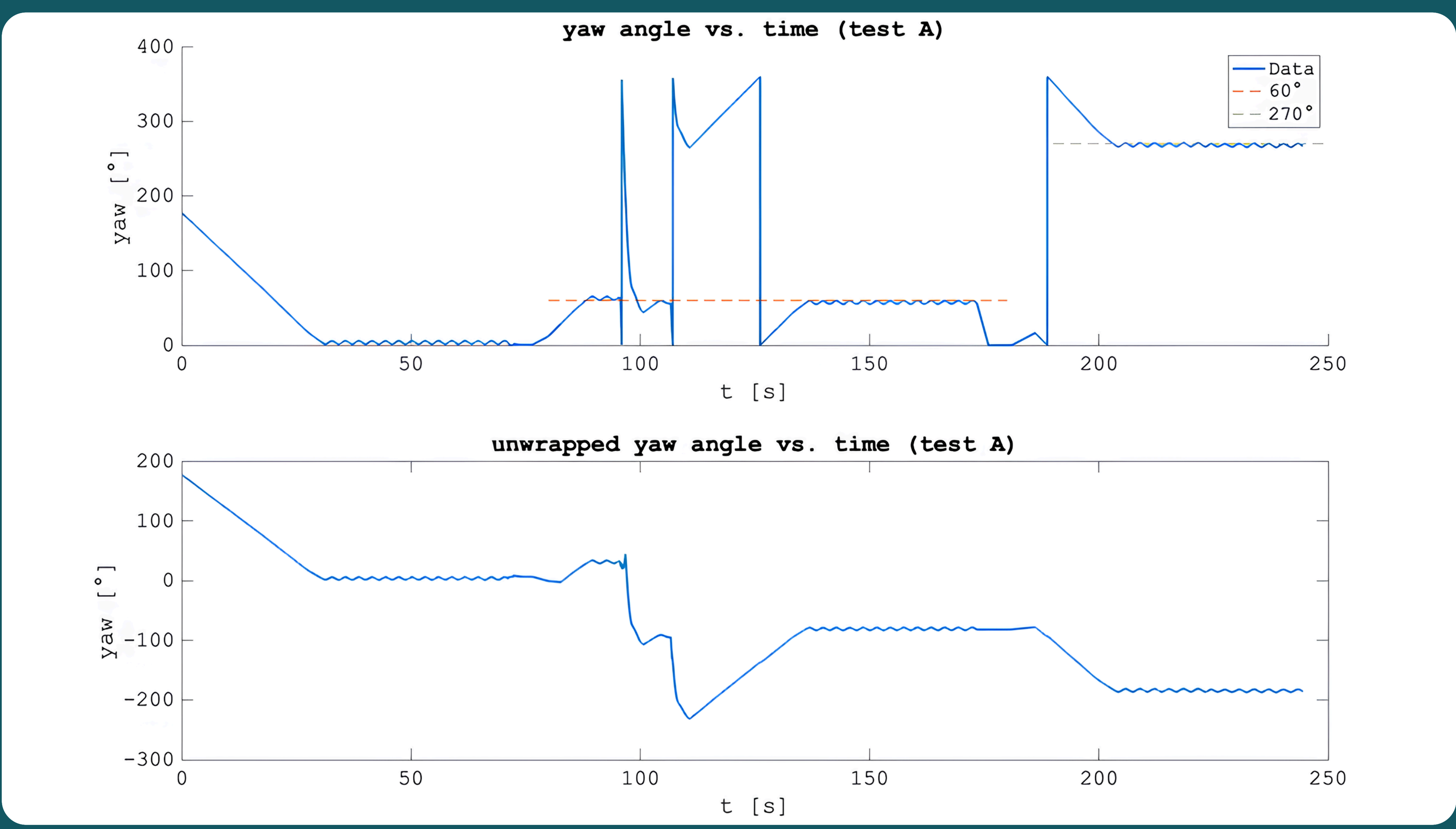
This block diagram depicts the components of the platform and their relations, both form the electrical and the functional point of view.

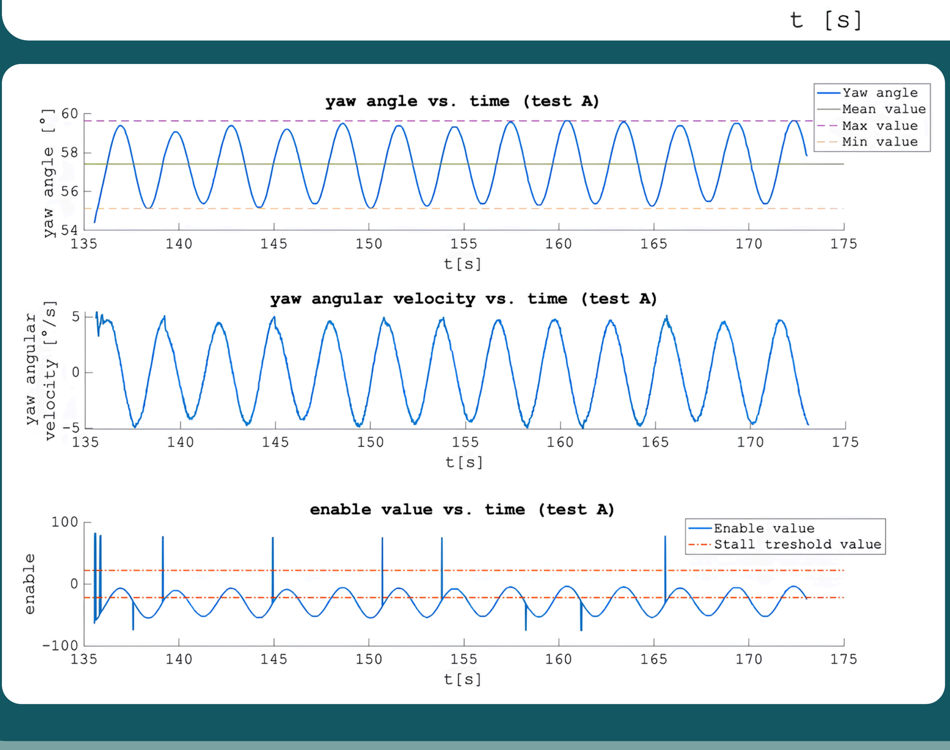
## *Performance Assessments.*

Performances were assessed measuring the platforms efficiency in matching the assigned azimuthal direction and maintaining the position, with minor oscillations around the equilibrium point.

After the power on and the attitude sensor calibration, starting form rest, the platform oriented towards the magnetic North and kept itself around said position. Then, two different target azimuth commands were sent in sequence.

The graphs below depict the azimuth and unwrapped azimuth as a function of time. From the upper graph, the presence of three distinct stabilization segments around 0°, 60° and 270° is evident. Rotations from a target azimuth to the subsequent one are managed performing the minimum angular displacement either in clockwise or counterclockwise direction.




A slight tilting of the actual azimuth stabilization angle with respect to the target one is noticeable, due to the non-linear stall of the brushed motor, as depicted in the graph on the left.

Nevertheless, the medium of tilting with respect to nominal heading is of 1.72° and the maximum deviation around the actual stabilization value is of 2.45°, in compliance with ±5° pointing capability requirement.

## *Operational Limits.*

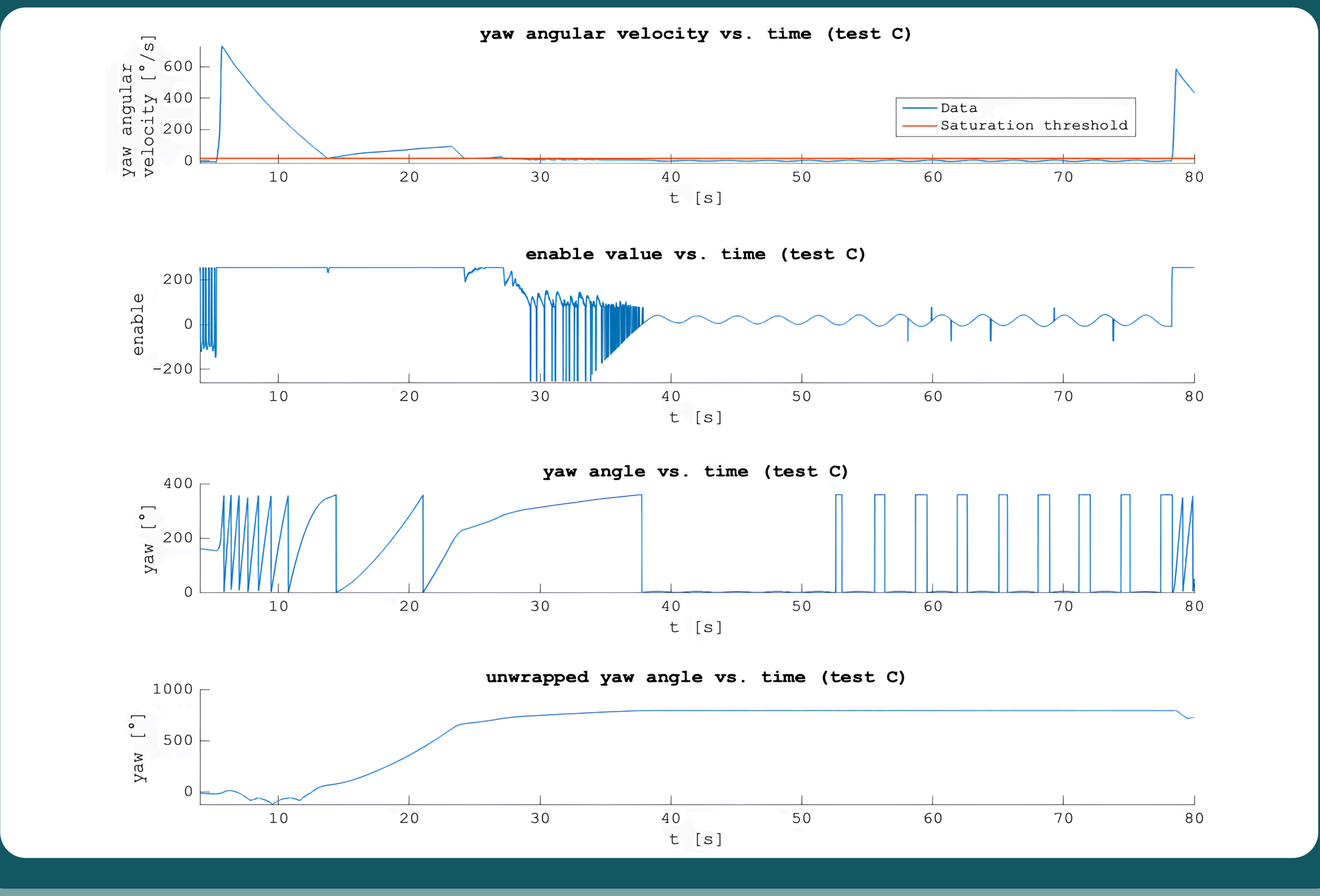
The reaction wheel saturates at known angular velocity thresholds, computable form controller gain. A test was conducted to assess the behaviour in case of saturation: after the power on of attitude control system and the attitude sensor calibration, the platform was kept at a stable position and quickly rotated in clockwise direction, so to induce saturation. A sufficient time was then awaited so that the platform could stop its spin and position itself around the target 0° azimuth.

The upper graph of the figure below depicts angular velocity and shows a peak in correspondence of the instance where the rotation is applied. The second graph from the top depicts the induced PWM value sent to the motor, which is in the interval [−255, 255]. A consistent pattern is evident:

- saturation segment - corresponds to the flat part of the graph;
- rotation segment - it corresponds to the highly dense part of the graph;
- stabilization segment - has an oscillatory pattern.

Comparing the PWM graph with the two bottom one, it is evident that during the saturation segment the platform is subjected to full rotations, that progressively become slower as the platform decelerates. In the final part of the saturation segment and throughout the rotation segment, the platform is rotated in a controlled approach towards the target azimuth, decelerating a gradually until the 0° azimuth is reached. When the stabilization segment is reached, PWM values are very far from saturation.

The reaction wheel desaturates spontaneously and efficiently, independently from its initial speed, due to the continuous exchange of momentum with the surrounding air. This effect can therefore vary with the altitude.




Finanziato dall'Unione europea
NextGenerationEU

Italiadomani
PIANO NAZIONALE DI RIPRESA E RESILIENZA

Ministero dell'Università e della Ricerca