Concept Design of a Low-Cost Hybrid AOCS for a Student CubeSat

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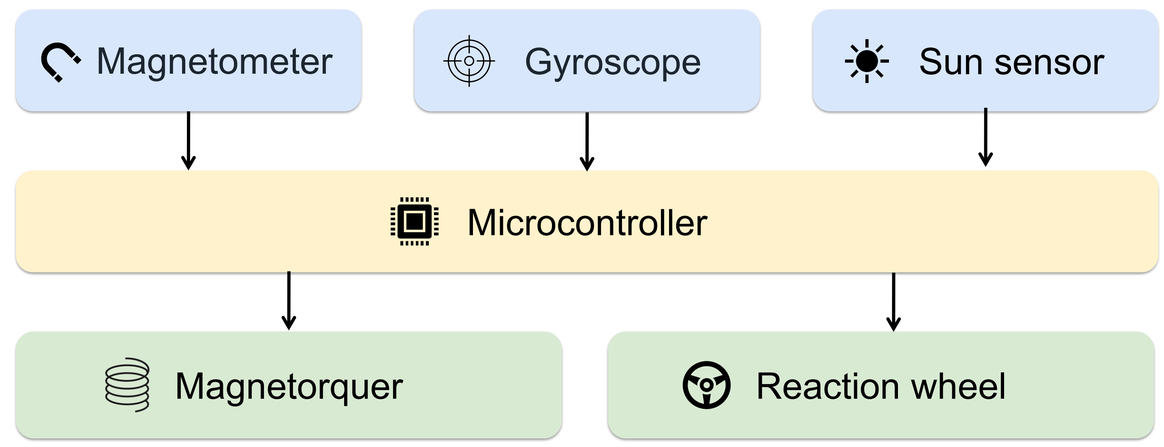
PROJECT BACKGROUND

Space-grade AOCS components typically cost €2,500–€8,000, placing them beyond the reach of most university teams. This work presents the concept design of a hybrid attitude control system for a 1U CubeSat, combining commercial off-the-shelf sensors with in-house developed actuators to achieve comparable functionality at a fraction of the cost.

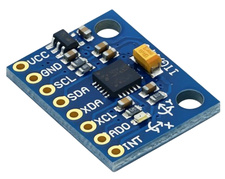
The CubeSat platform is built on the LibreCube open-source framework (a community-driven ecosystem for open space exploration) adopted and extended at the University of Debrecen. *(librecube.org)*

AOCS SYSTEM ARCHITECTURE



SENSOR SELECTION (COTS)

PNI RM3100
3-axis magnetometer: attitude determination, MTQ coil self-test
Manufacturer: PNI Sensors
€25.0
pnisensor.com



MPU-6050
3-axis gyroscope and accelerometer: bridges sensor blackout periods
Manufacturer: TDK InvenSense
€4.5
hestore.hu

BPW34
Sun sensor: one per face, cosine response
Manufacturer: Vishay
€2.8
hestore.hu

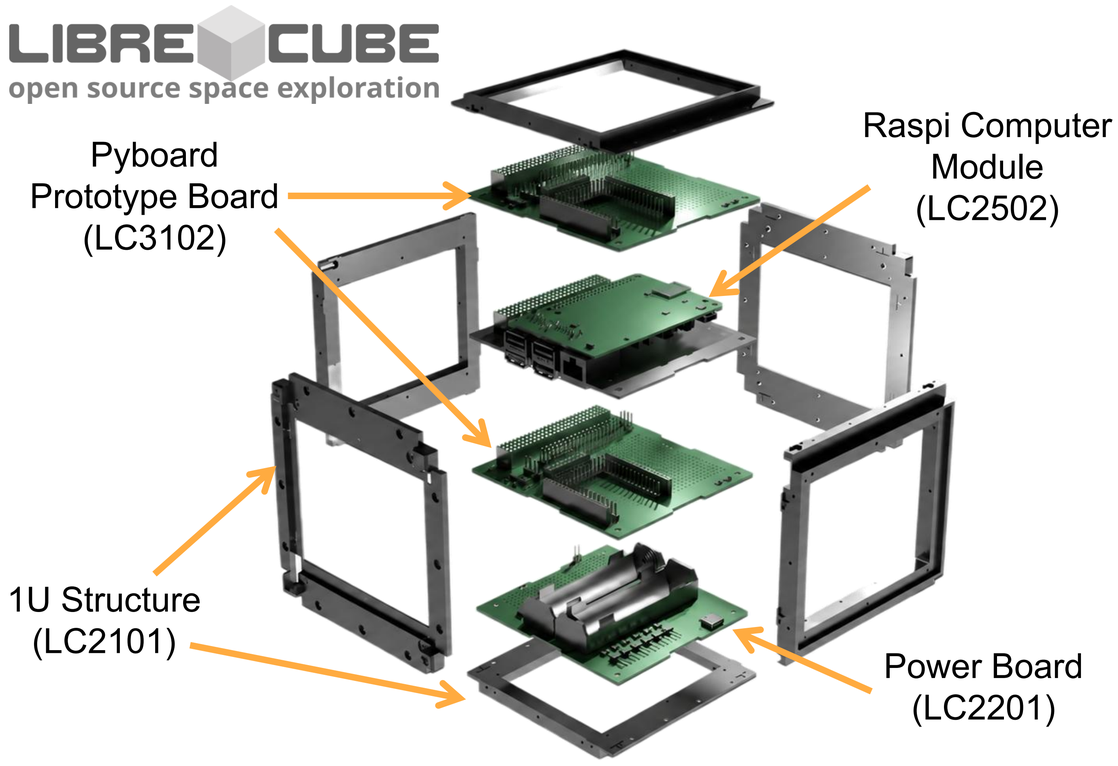
Bill-of-Materials

Microcontrollers ARM Cortex-M4 (MTQ), ESP32 (reaction wheel)	€15.5
H-bridge motor driver Dual H-bridge, bidirectional coil drive	€7.7
Power regulator, passives, actives 3.3 V buck-boost, capacitors, resistors, crystal, headers, OpAmps	€22.0
Coil winding wire 30 AWG enamelled Cu, 100 m reel	€10.3
Brushless DC motor Nidec 24H, one per axis	€32.2
Reaction wheel frame 3D-printed PLA/PETG, M2-M4 fasteners	€15.5
4-layer PCB 100×100 mm, inner layers = spiral coils	€25.0
LiPo battery 3s1p 500 mAh, 11.1 V	€15.5
TOTAL ESTIMATED COST	**€176.0**

Commercial AOSC: ~ € 5,000+

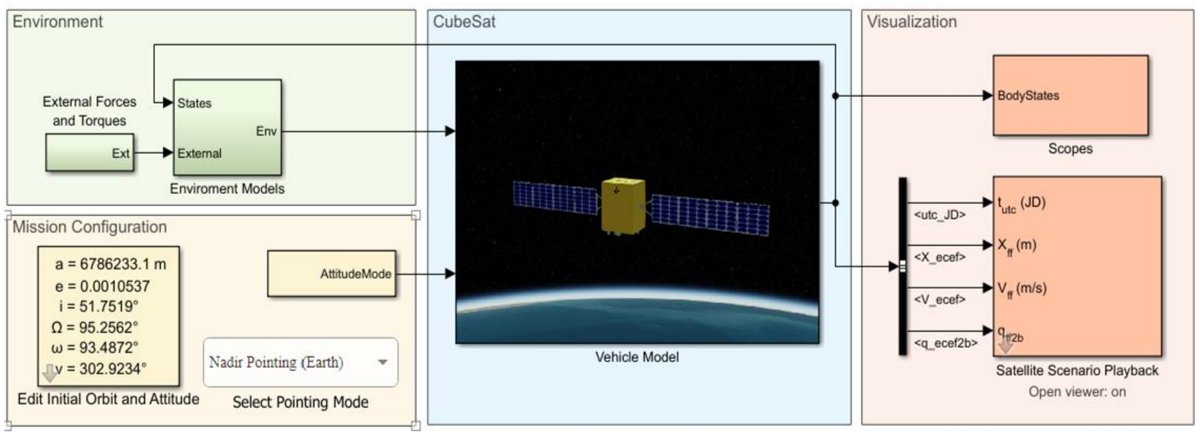
Custom AOSC: ~ € 176

Acknowledgement: The authors would like to thank Artur Scholz and the LibreCube open-source community for providing access to the LibreCube platform and for sharing their expertise in open-source space system development. This work is carried out within the University of Debrecen CubeSat team, including: Tului Bayasgalan, Adam Elachkar, Omar Ahmed, Muhammad Shehryar Khan.

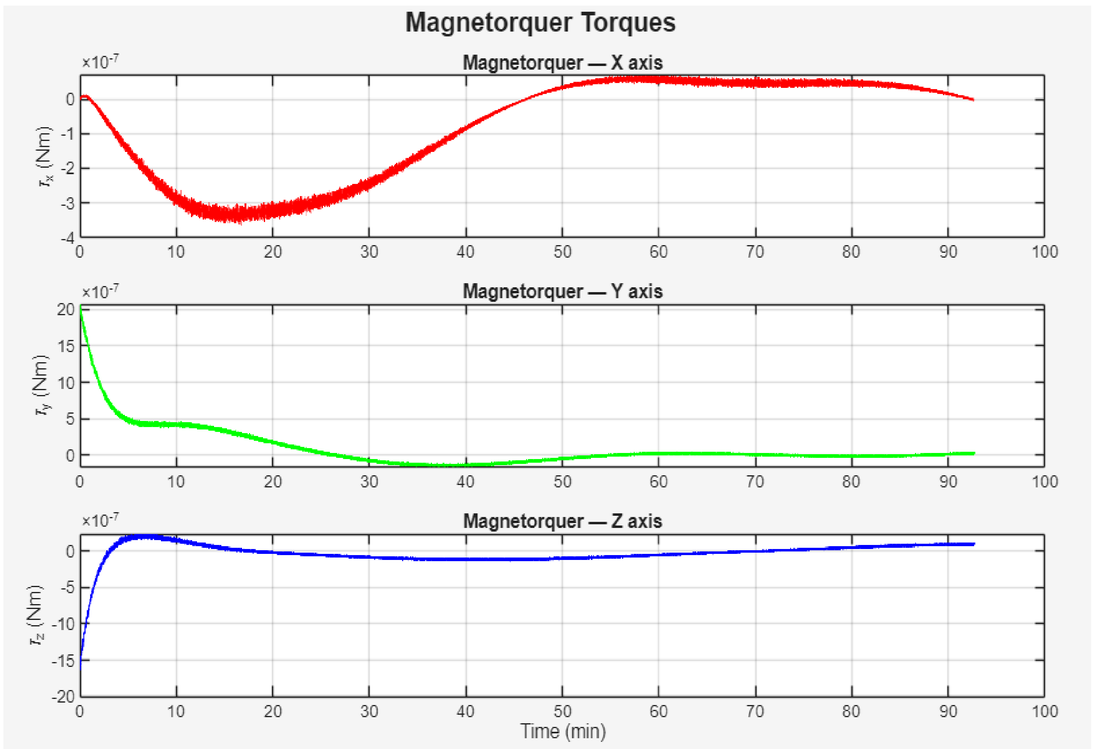


This figure presents an exploded view of the LibreCube CubeSat structural architecture, with its main modules.

SIMULATION



Attitude dynamics are simulated in MATLAB/Simulink using the LibreCube spacecraft model, incorporating LEO orbital parameters (406 km, 51.75° inclination) and environmental disturbance torques. The model evaluates B-dot detumbling via magnetorquers and Nadir-pointing via reaction wheels.



The plots show the simulated torques generated by the three-axis PCB magnetorquer along the CubeSat body axes during one LEO orbit. The X-axis torque exhibits a gradual settling behaviour, while the Y and Z axes converge rapidly toward zero. All three components remain in the sub-μNm to low-μNm range, consistent with the expected actuation level for B-dot detumbling in LEO.