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Innovative compact solar and antenna array drive assembly enabling deep space cubesat missions

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Abstract

CubeSats have demonstrated their utility as a standardised low-cost, low mass-volume platform, with the current largest format (12U) not exceeding 22x22x34cm³ and 25 kg. In line with the increasing interest in the human colonisation of the Moon or Mars, CubeSats find themselves on the verge of being deployed for scientific purposes outside their traditional terrestrial orbit. With increasing distance from the earth and sun, requirements for both the pointing accuracy of antennas and solar panels increase. To address these challenges, the conceptual design of a Panel Array Drive Assembly (PADA) for CubeSats is presented in this poster. The PADA enables precise antenna and solar array orientation to optimise link and power budgets. Development of the PADA is being conducted within the lunar SIRONA mission, which is a 12U CubeSat lead by the space centre (CS³) of CentraleSupélec, France. SIRONA will autonomously travel to lunar orbit and thus requires some form of propulsion. Large-scale satellites conventionally rely on chemical propulsion; however, with the more stringent mass-volume constraints of a nanosatellite, electrical propulsion emerges as the primary choice for a long-range missions to maximize payload volume and mass. One consequence of this choice is a step up in on-board power consumption; [during propulsion mode] the electrical propulsion system will account for the clear majority of energy usage aboard. To satisfy the mission objectives, SIRONA must be equipped with an appropriate PADA mechanism to optimise the power budget by maximizing the time for which the solar panels are pointing the Sun.

System Requirements

OVERALL

- Peak power consumption < 1.0W
- Mass < 60g
- Volume: Must occupy space that is unused (by the 12U)
- Maximum dimensions 220 x 20 x 40 mm

RANGE & ACCURACY

- 270° angular range of motion
- +/- 2° standalone pointing accuracy
- End-end continuous rotation

OTHER

- Minimise adverse rotation effects on SIRONA
- PADA unit must be self-contained inside SIRONA
- Compatibility with deployable mechanisms
- Promote integration of Commercial Off The Shelf (COTS) equipment
- Compatible with ISIS 12U structural specification

Mechanical Design

The PADA will be located a distance of approximately 12cm from the top of SIRONA - see figure 1a - in the vicinity of SIRONA'S centre of gravity/rotation: this reduces the magnitude of any moments, generated directly by the PADA, or due to solar radiation pressure. The unit itself is designed to be compatible with the ISIS 12U structural specification [1] and fits in between the individual units of a CubeSat; this distinguishes it from existing externally mounted designs for lower volume missions [2]. The PADA presents modularity in its design, offering the possibility of mounting a second, identical unit perpendicular to the first, to orient a second pair of arrays. This is made possible, by mounting a second identical PADA unit, upside down to the first. With the main shaft now located above the motor, there is now sufficient height clearance where the [perpendicular] main shafts of each PADA unit cross-over.

The mechanical configuration of a single main PADA unit - shown in blue in figure 1b - consists of one motor-gearbox, driving a main shaft that is common to both hollow output shafts. Note the second output shaft (not shown), that supports the second panel array, enters the main structure on the opposite face of the CubeSat coaxially with the output shaft shown in figure 1b. This configuration is selected over other candidates since it minimises the volume of the PADA unit, whilst maintaining sufficient clearance for cables to exit internally. All required cabling will pass through the hollow output shafts such that cables remain protected from the radiation present in lunar orbit.

The motor selected is the EC10 manufactured by MaxonMotor AG. It's desirable parameters include its compact size (10mm Diam. x 50mm Length), integrated 1024:1 gearbox as well as the proven flight heritage of the manufacturer. Furthermore, this motor features an inbuilt hall-effect sensor which will return accurate information on the motor shaft angular speed: this is essential in order to fulfil the pointing and continuous rotation requirements (see electrical design for discussion). The PADA cannot be made to rotate with unbounded angular range of motion. This is due to the excessive torsional strain that would be placed on the cables passing inside the output shafts (leading to their premature fatigue failure). A 270° angular range of motion is a compromise that maintains sufficient range of motion.

A second location where cable-related issues are prone to occur is at the interface with the deployable mechanism located outside the structure (see figure 2). Cable clearance through the output shaft is achieved by moving the deployable axis below the output shaft axis. Nevertheless, great care must be taken in implementing cables with sufficiently small bend radius for when the arrays are folded down.

Electrical Design

The main purpose of the electrical design is implementing a method to control the motor so that it fulfils the requirements of continuous rotation at desired speed. A microcontroller and MaxonMotor compatible motor controller or driver are necessary. Additionally, a PCB must be designed to connect the motor controller to the motor and microcontroller. The choices of the components were principally done according to performances, weight and size. The motor driver is the 1-Q-EC Amplifier DEC Module 24/2 from MaxonMotor. It is chosen for its compatibility with the MaxonMotor EC10 and is the most compact solution MaxonMotor offers. A simple Arduino Nano acts as the Microcontroller for our breadboard testing; it is an easily programmable device that can output 5.0V and hence power both the controller and motor. The motor is supplied with a voltage below it's nominal value of 6.0V in accordance with the EC10 datasheet. The electronic circuit was created in the circuit development software EAGLE. Again, focus was put on the compactness of the design. For that reason, the microcontroller and the MaxonMotor controller were implemented as shields over the passive electrical components.

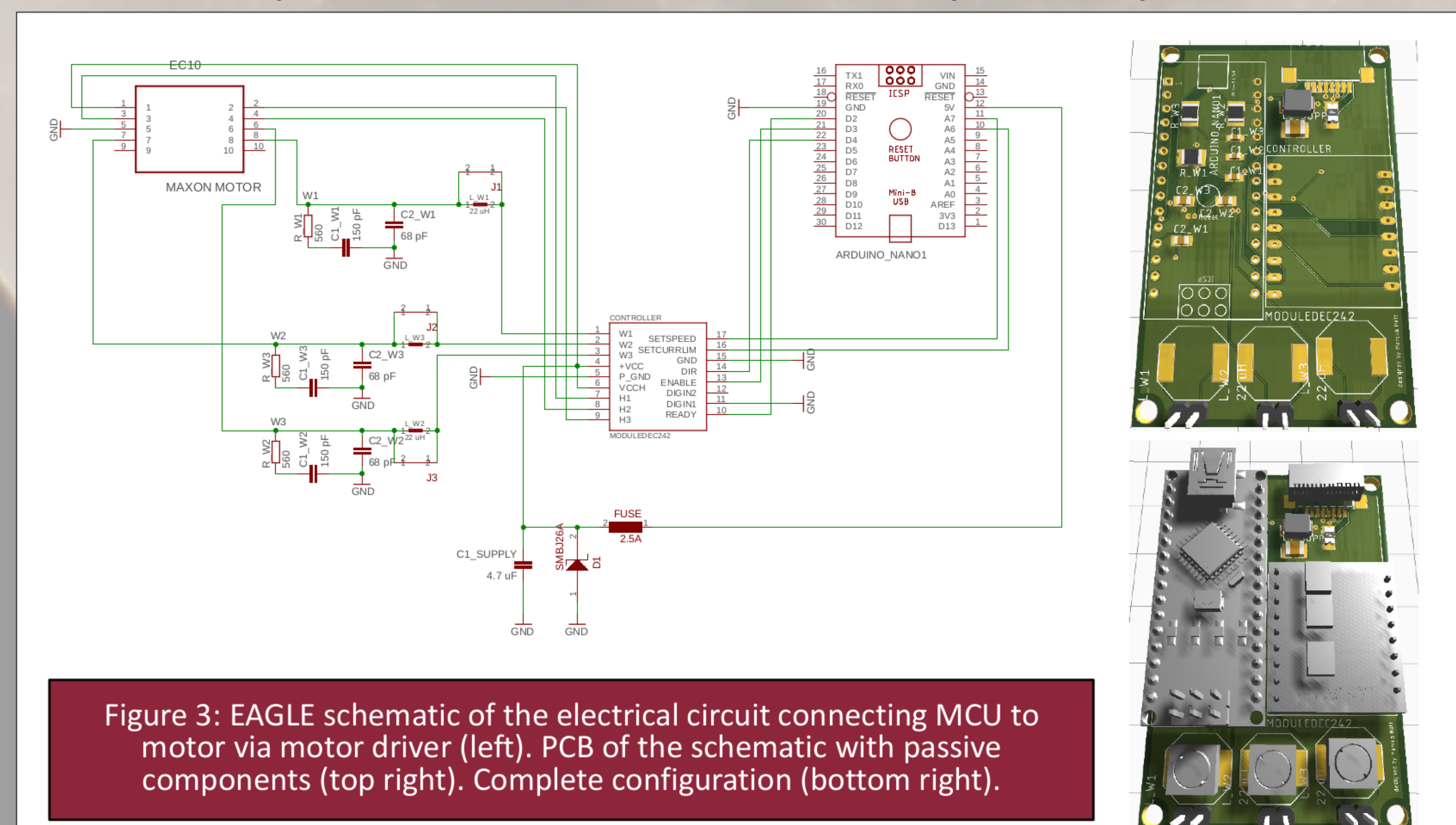


Figure 3: EAGLE schematic of the electrical circuit connecting MCU to motor via motor driver (left). PCB of the schematic with passive components (top right). Complete configuration (bottom right).

Figure 1a: SIRONA's structure showcasing the deployment of one pair of arrays.

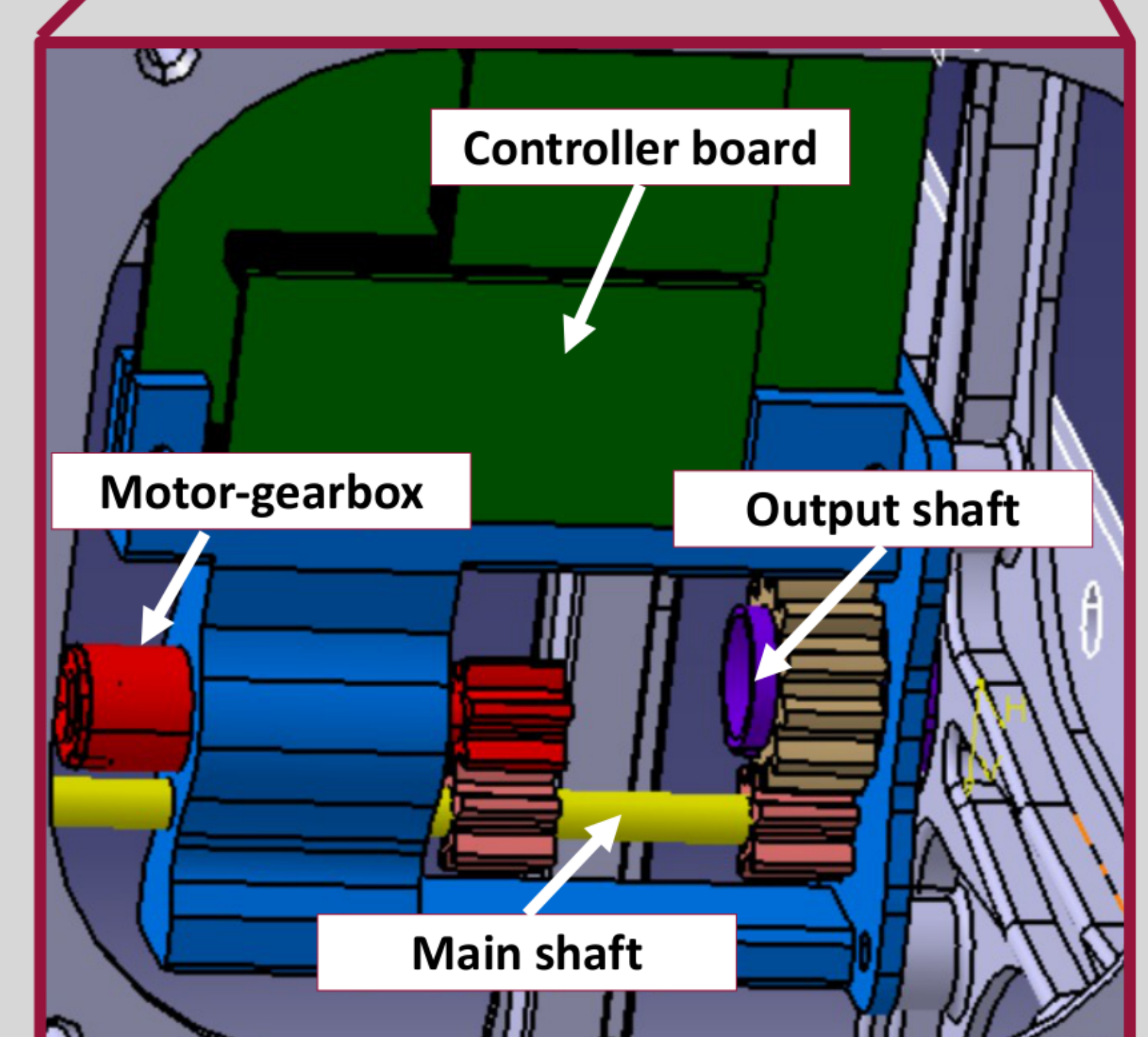
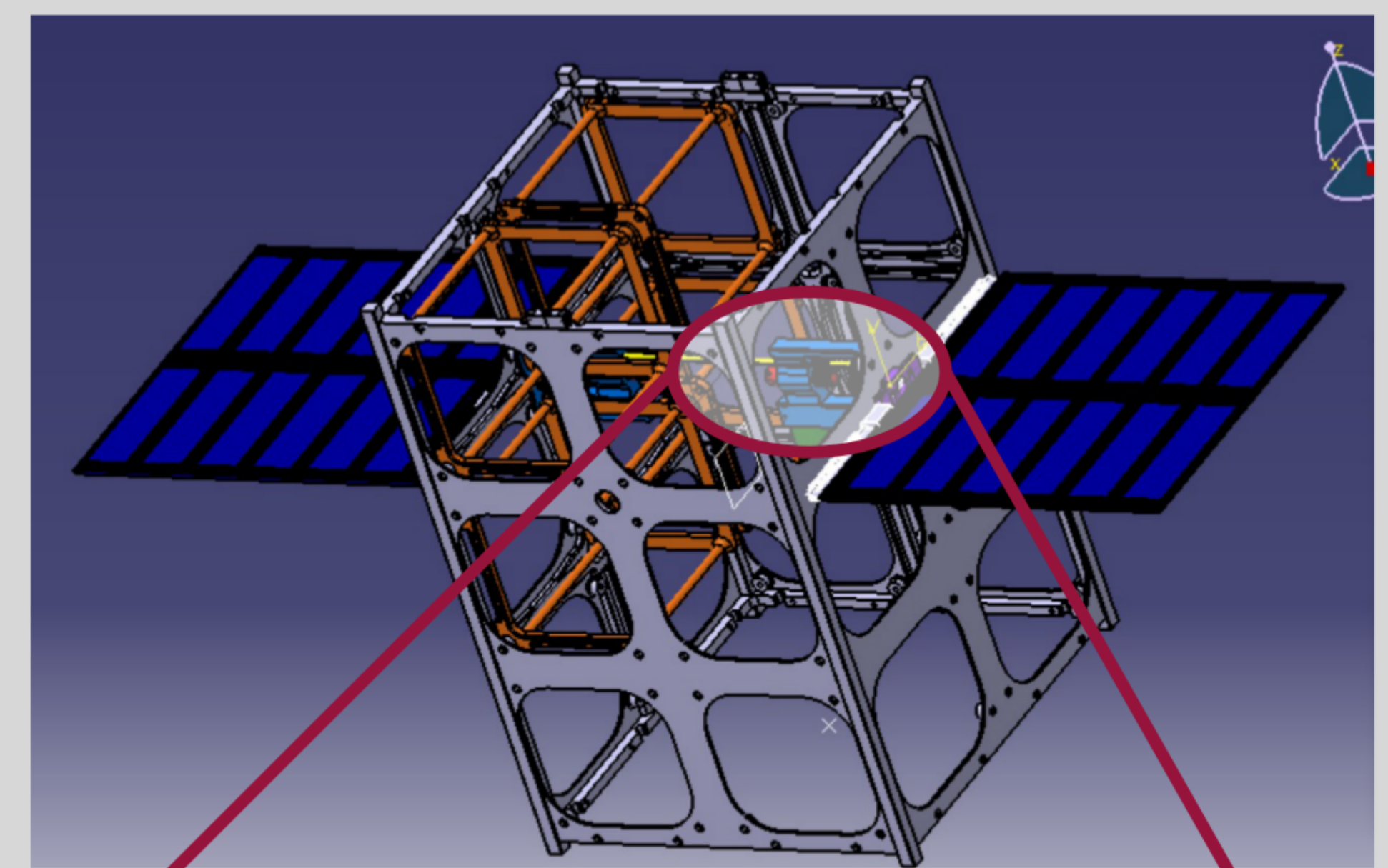


Figure 1b: Zoom on PADA mechanical assembly.

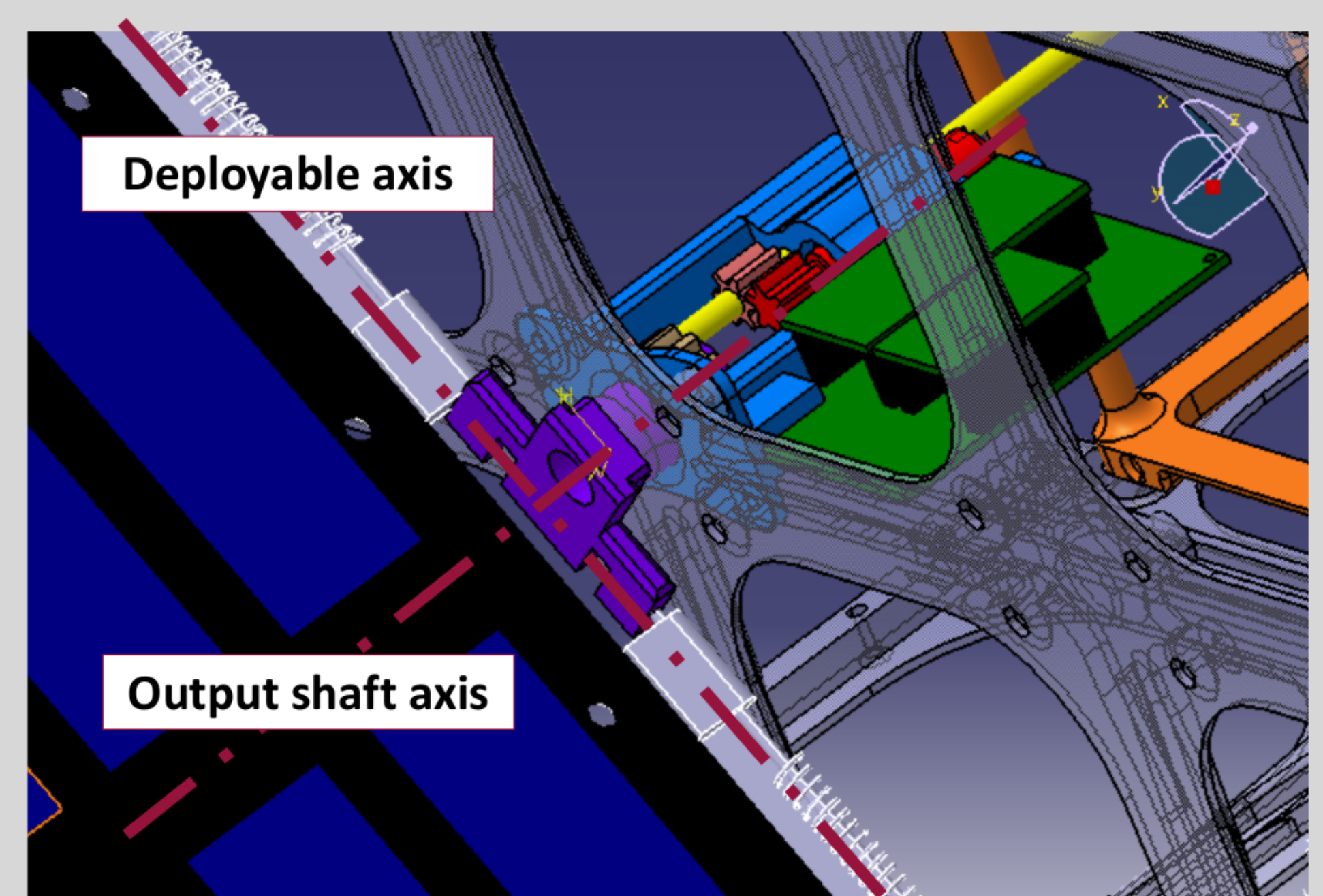


Figure 2: The interface between the PADA (blue) and an array deployable mechanism (purple & light grey)

Conclusion

A simple design for a PADA mechanism is presented. Its modularity, frugal volume requirements and compatibility with the ISIS 12U specification make the PADA a straightforward yet innovative implementation into today's CubeSat missions. The PADA system enables CubeSat space exploration in lower light intensities and at greater distances from earth. The use of more power demanding payloads is made equally possible. In summary, the PADA fulfils the wider function of power budget optimisation in multi-unit CubeSats, with minimal interference with existing subsystems.

Acknowledgments

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- [2] M. Passaretti, et Al. (2010), *Development of a Solar Array Drive Assembly for CubeSat*.