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Innovative deployable telescope enabling drastic remote-sensing enhancement capabilities of cubesats with a minimal platform impact

Elena Kostaropoulou, Tarik Errabih, Gilles Bailet, Christophe O. Laux

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Abstract

The student space center of CentraleSupélec has developed a deployable telescope named ASTERICS (deployable Space Telescope to Remotely Image lunar Craters on board Sirona). This payload is able to enhance significantly the remote-sensing capabilities of CubeSats. Since a telescope is essentially an empty tube, being able to pack it when not used and deploy it afterward out of the spacecraft is highly beneficial for the constraining CubeSat standard where available volume is usually a limiting factor.

We propose to pack a 2.5 U (26x10x10 cm³) into a 0.3 U (3x10x10 cm³) format thus allowing top notch performances for a CubeSat standard without having the full platform constrained and designed around it; more volume available for other payloads and/or better performing avionics. ASTERICS will first fly with the CubeSat SIRONA (Selenocentric platform hosting International payloads) to image the Moon in the visible spectrum with a very high resolution (2 meters/pixel at a 200 km altitude). It will contribute to date the lunar maria (or lunar seas) through the crater counting technique. They are the Moon's oldest surfaces currently dated with a 500 My uncertainty.

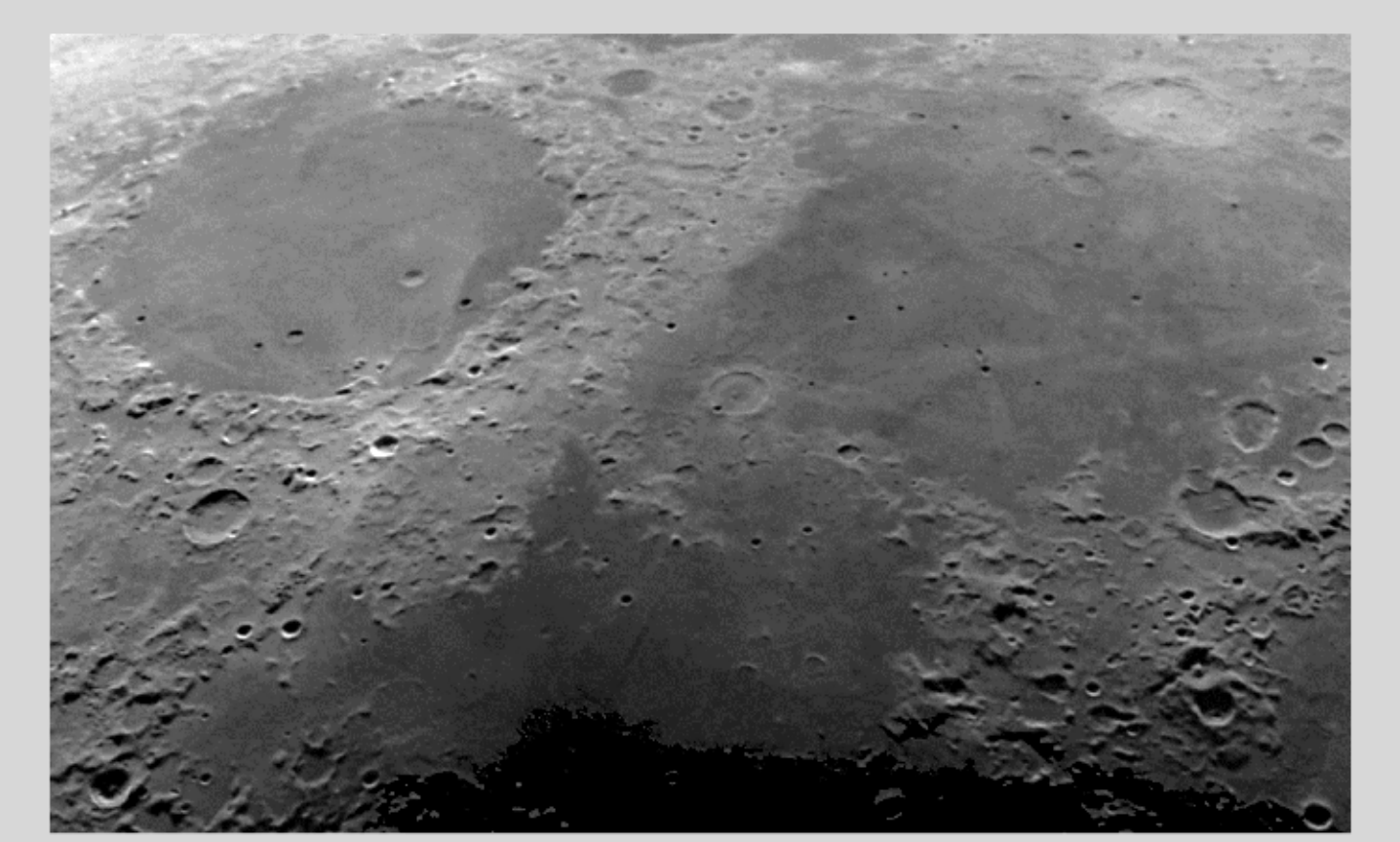


Figure 1: Three well known lunar maria

Optical specifications and performances

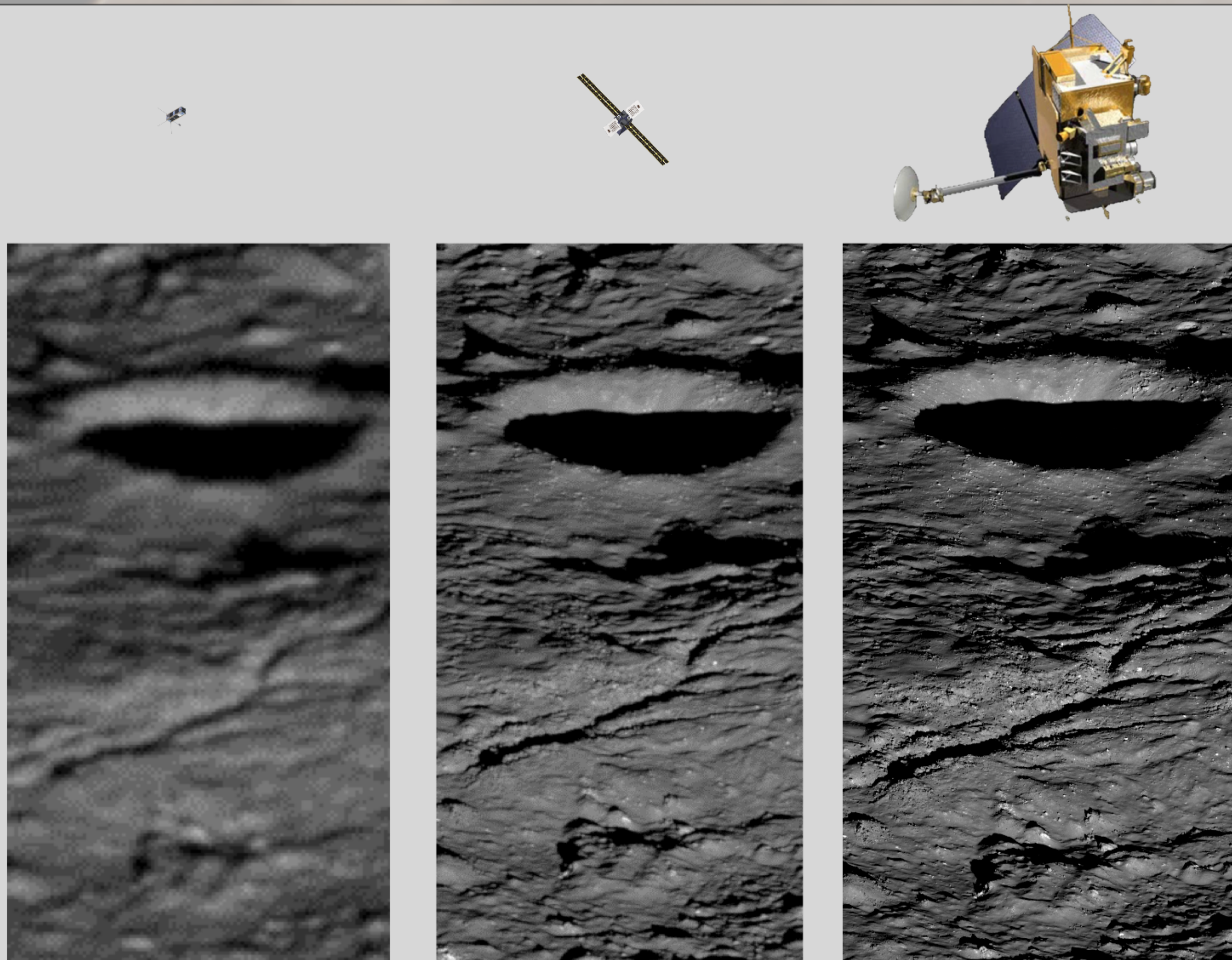


Figure 2: From left to right: Small Cubesats (simulated), SIRONA (simulated), Lunar Reconnaissance Orbiter (best available images of the Moon, four times closer to the Moon than SIRONA).

ASTERICS is a f/10 Ritchey-Chrétien telescope of 900 mm focal length. It has two hyperbolic mirrors, primary (90 mm) and secondary (31 mm). Its field of view is 0,5° wide.

ASTERICS' performance is comparable to the American LRO probe (which is almost 100 times heavier than SIRONA, and four times closer to the Moon), as shown on figure 2. If it does not reach the same level of quality, it displays exceptional performance/cost, performance/volume or performance/mass ratios, which makes it a real breakthrough in the remote-sensing capabilities of CubeSats.

The optics were designed with the idea to minimize the aberrations on the whole field of view (which is 0,5° wide, corresponding to the full Moon as seen from Earth). The result is displayed in figure 3, which represents the spot diagrams of ASTERICS. The aberrations are always constrained inside Airy's disk (resolution limit).

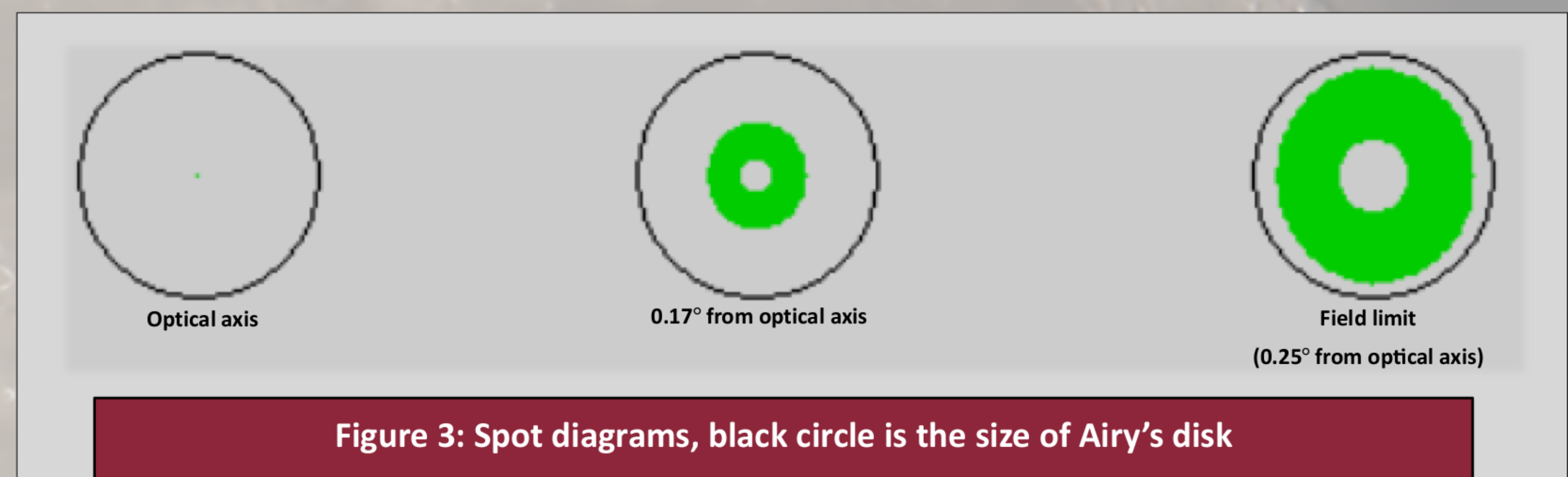


Figure 3: Spot diagrams, black circle is the size of Airy's disk

The telescope is designed for SIRONA's mission, but it can be adapted for many other purposes. For instance, the mirrors' coating can be upgraded from aluminum to UV-enhanced aluminum for missions that needs to observe in shorter wavelengths, or to gold for infrared observations. Moreover, the design is scalable, therefore, any mission that would need greater or lower resolution can exploit the compactness, lightness and power of ASTERICS for its purpose. The sensor behind the telescope can also be modified, as the one selected for SIRONA's mission may not match with other missions' requirements.

Structure design

ASTERICS is an innovative instrument that is able to fit within a 1 U CubeSat mission: it has a volume of 3x10x10 cm³ when folded (and 26x10x10 cm³ when deployed). The whole payload weighs less than 500 g. A rendering of ASTERICS' structure in the deployed configuration can be found on figure 5.

The structure is composed of the two mirrors used to take the images of the Moon (one at the base and one at the top of the structure, defining the limits of the deployment), 15 panels (which ensure the good placement of the mirrors) and a box where the whole structure is folded. The panels are connected to each other by an axis and spring hinges to assure a good deployment and rigidity (figure 4).

For stability and optical alignment, physical stops are located on the panels, in order to undertake the different forces applied on the telescope in space (figure 7). This way, the panels are well constrained between the spring hinges and the stops, while the structure reaches an optimal stability. With time and the loads imposed by the springs, the stops will be submitted to cold welding onto the panels ensuring a long lasting optical alignment. Finally, the whole structure will be covered by a light shielding (Mylar), in order to prevent any parasite ray of light from attaining the optics.

The telescope will be initially folded and held in that configuration by a nylon wire. The release mechanism consists in a hot knife: the nylon is in contact with a nichrome wire that heats up on command (once the satellite reaches the scientific orbit). When the nichrome is sufficiently hot, the nylon wire melts, allowing the structure to deploy due to the stored mechanical energy of the spring hinges. A micro-switch provides the deployment status feedback to the onboard computer. The release mechanism is shown on figure 6 and an animation of the deployment of the first level of panels is shown on figure 8.

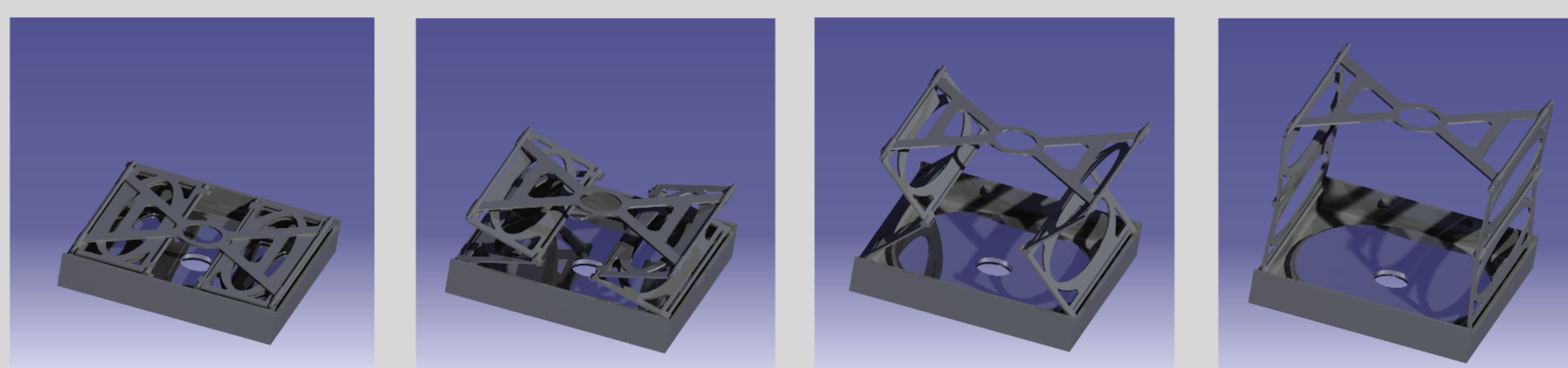


Figure 8: Different Phases of Deployment Process



Figure 4: Panels deployment by springs

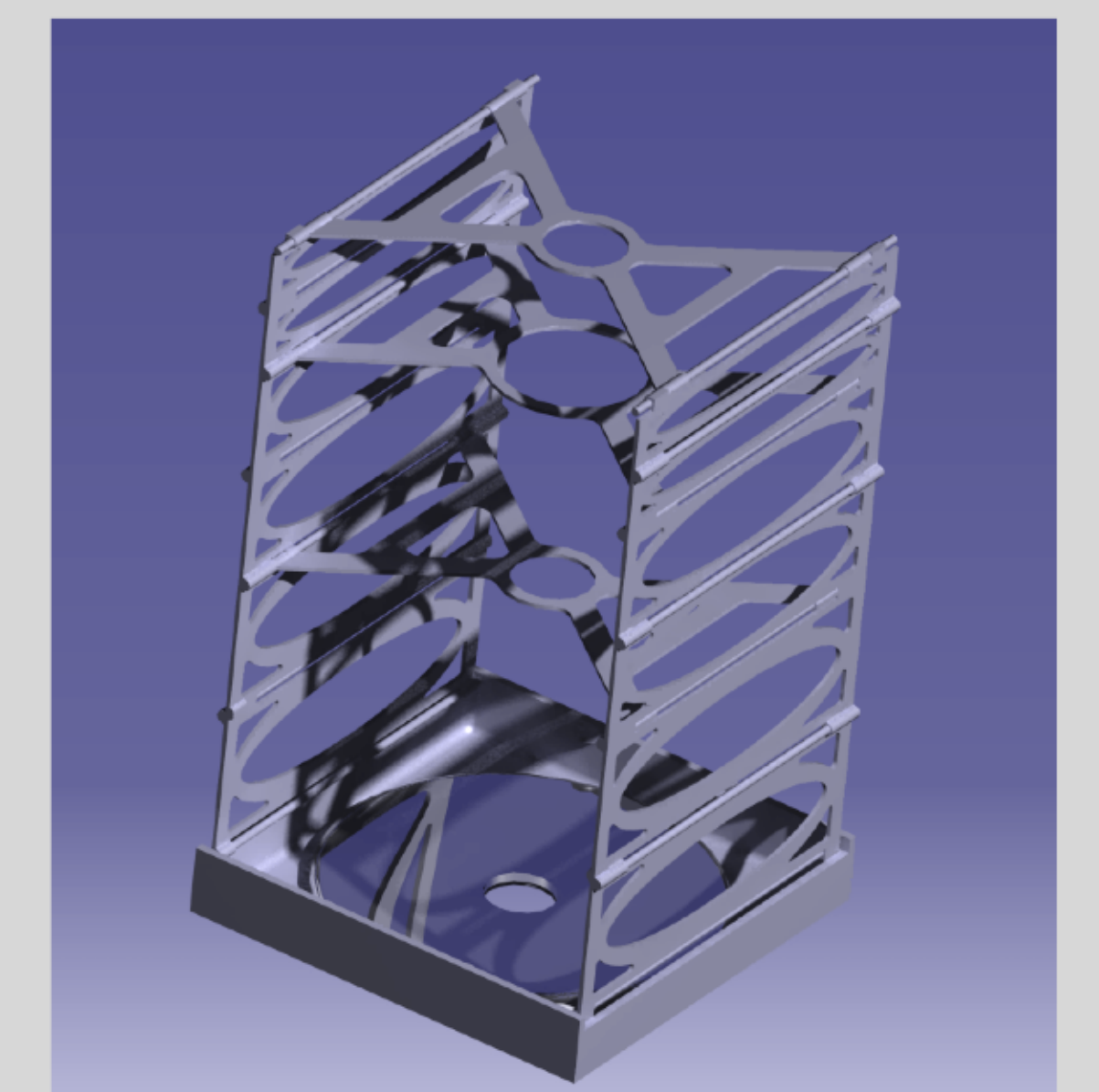


Figure 5: ASTERICS' structure

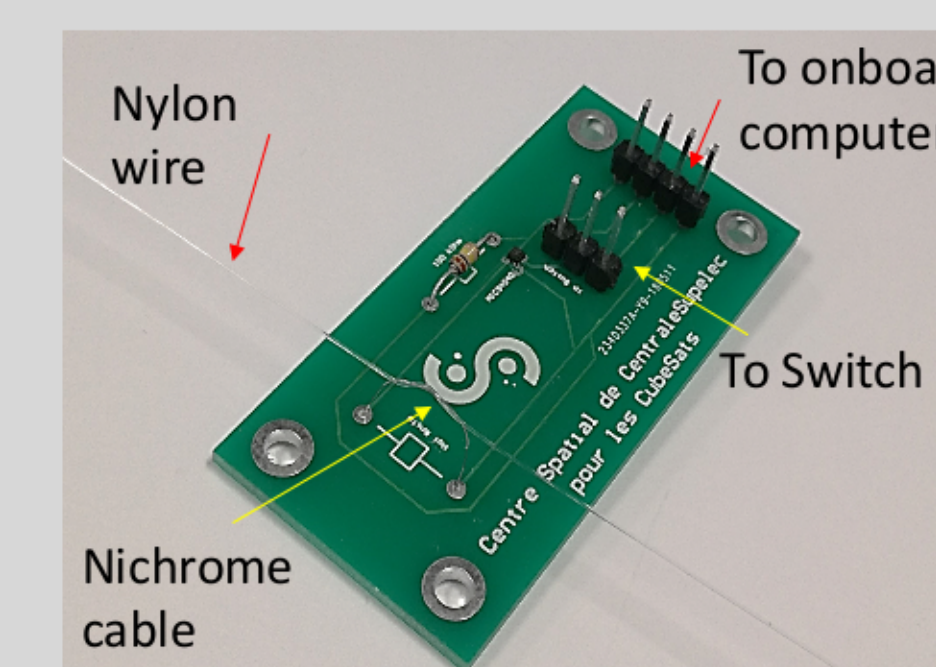


Figure 6: Release Mechanism

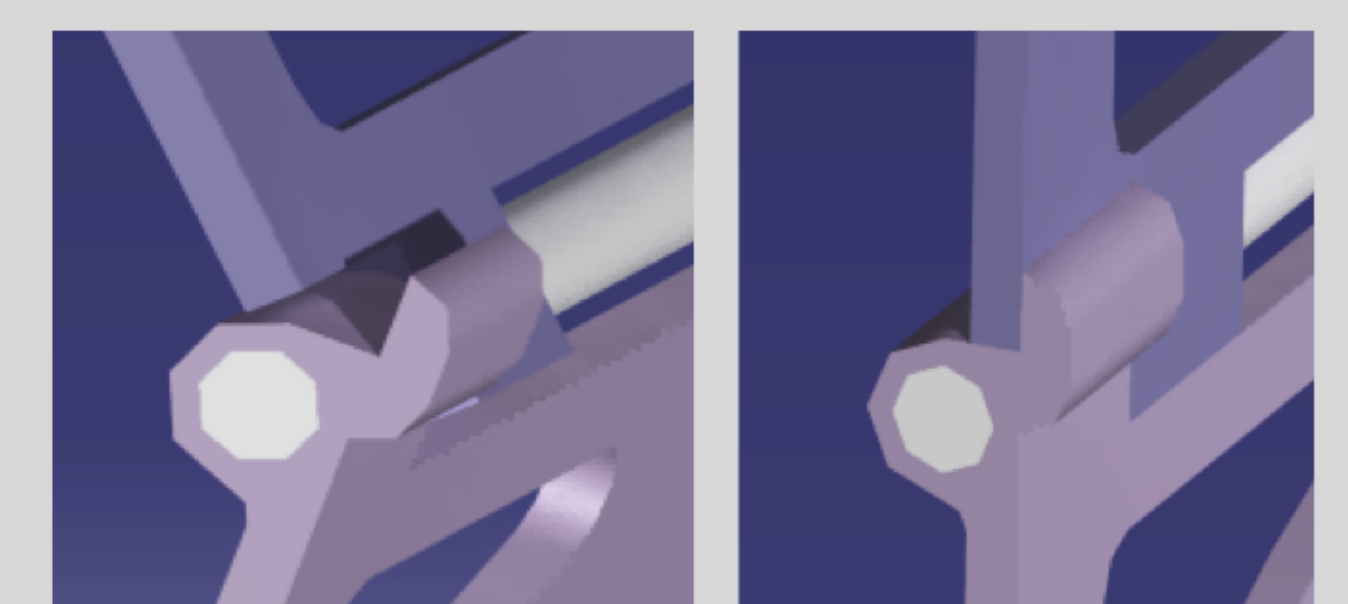


Figure 7: Lateral Stops Design

Conclusion

ASTERICS appears to be a significant improvement in the remote-sensing capabilities of CubeSats. Indeed, the deployable structure allows the telescope to be extremely compact for launch configuration, stable and lightweight while providing at the same time very high resolution images. As a result, ASTERICS is an innovative instrument which is able to deploy from 3 to 26 cm and that could be of great use for future missions in similar fields. In fact, and beyond SIRONA's mission, ASTERICS can be adapted for multiple purposes, such as low-cost Earth imaging, astrophysical observations or even as a piggyback payload for solar system exploration.

Acknowledgments

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