LUMIO CubeSat: Toward a Lunar Situational Awareness

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Abstract

The Lunar Meteoroid Impact Observer (LUMIO) is a CubeSat mission to observe, quantify, and characterise the meteoroid impacts by detecting their flashes on the lunar far-side. This complements the knowledge gathered by Earth-based observations of the lunar near-side, thus synthesising a global information on the lunar meteoroid environment. LUMIO envisages a 12U CubeSat form-factor placed in a halo orbit at Earth-Moon L2 to characterise the lunar meteoroid flux by detecting the impact flashes produced on the far-side of the Moon. The mission employs the LUMIO-Cam, an optical instrument capable of detecting light flashes in the visible spectrum. LUMIO is one of the two winner of ESA's LUCE (Lunar CubeSat for Exploration) SysNova competition, and as such it is being considered by ESA for implementation in the near future. An independent assessment of the mission has been performed by ESA's CDF team. In this work, the latest results on the assessment of the scientific output of LUMIO will be shown, with a focus on how they will impact the currently existing knowledge of meteoroid models. An overview of the present-day LUMIO CubeSat design will be also given, with a focus on the latest developments.

1. Introduction

After the conclusion of the LUMIO mission preliminary design and the issuing of Concurrent Design Facility Study Report performed by ESA, some updates were introduced in the LUMIO-Cam design. The need of a more detailed and robust procedure to estimate detections number taking into account a more sophisticated model of the payload (P/L) pushed the LUMIO consortium to develop an improved methodology. As a consequence, a novel methodology to estimate effectively the number of detections with a statistical approach, called LUMIO-POE, is herewith presented.

2. LUMIO-POE Overview

POE is the acronym for *Payload, Orbit, and Environment simulation*. LUMIO-POE is actually a byproduct of the LUMIO mission that relies on a statiscal approach to estimate the number of meteoroid impact detections. LUMIO-POE is composed by several modules among which there are: the POE Engine, the Meteoroid Gun (MeGun), the LUMIO-Cam model, and SPICE [1].

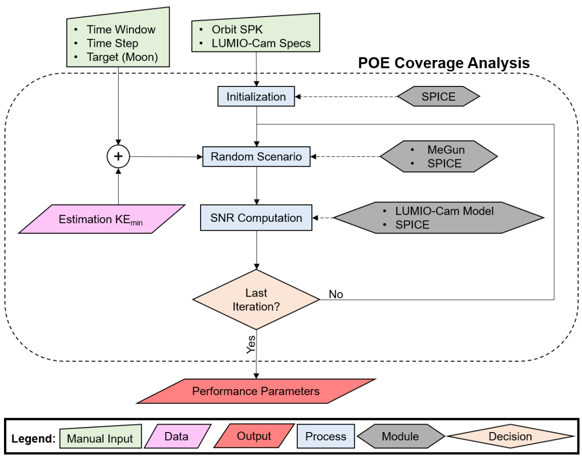

Figure 1: Schematic representation of the LUMIO-POE methodology.

The methodology consists in the following steps: *i)* the Mission Analysis team provides the orbital path by means of a SPICE SPK kernel, while the P/L team furnishes the LUMIO-Cam specifics; *ii)* it follows the generation of all SPICE kernels related to CubeSat attitude and optical instrument geometry; *iii)* MeGun breeds the random environment scenario, the required minimum impact kinetic energy is estimated, while the time window and the time step are provided by the user; *iv)* the LUMIO-Cam model is used to compute the Signal-to-Noise Ratio (SNR) of a subset of impacts; *v)* the number of effective detections is retrieved counting the number of SNR values that exceed the minimum threshold. A schematic representation of the methodology is shown in Fig. 1. Steps *iii*, *iv*, and *v* can be repeated N times to get good statistical results.

3. Parametric Analysis

In order to enhance the scientific output of the mission, a parametric analysis about three specifics of the LUMIO-Cam has been performed. The investigated parameters were: the aperture diameter of the optics, the wavelength of the dichroic lens, and the exposure time. The investigation about the dichroic wavelength was requested by ESA. The estimation of the number of meteoroid impacts detected by LUMIO during its 1 year lifetime as a function of the dichroic wavelength is shown in Fig. 2.

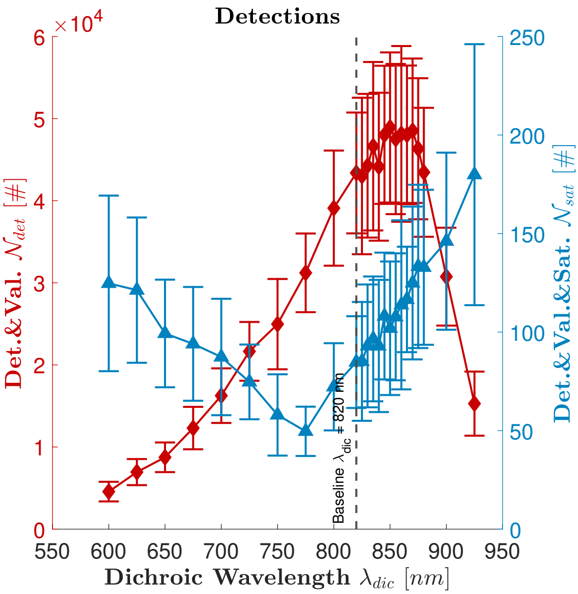

Figure 2: Results of the parametric analysis performed on dichroic wavelength. On the left y-axis, the number of detected and validated lunar impacts (the red diamonds joint with the red solid line). On the right y-axis, the number of impacts detected, validated, and that saturate the CCD (the upwards blue triangles joint with the blue solid line). The vertical dashed black line marks the LUMIO baseline dichroic wavelength. Results obtained from 100 runs.

4. Conclusions

The LUMIO-POE methodology grants to estimate the scientific output of the LUMIO mission and to compare the results with that of past programmes, as shown in Fig. 3. Furthermore, the methodology can be used to enhance the LUMIO CubeSat design. Moreover, it can be successfully applied to other mission designs, particularly if they can benefit from a statistical simulation of the meteoric environment.

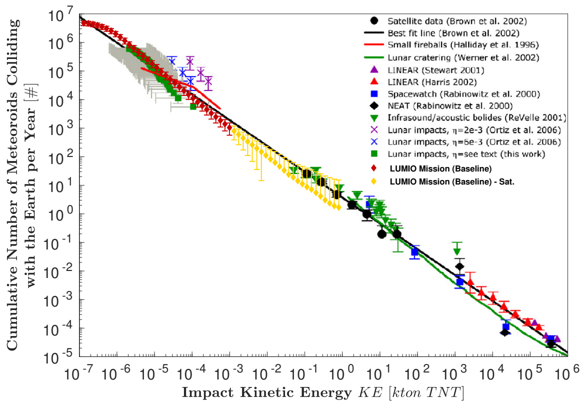

Figure 3: Scientific output of the LUMIO mission compared to previous programmes. Chart taken from [6], the LUMIO mission detections are overlapped. The yellow diamonds represent the detections that saturate the CCD.

References

[1] Acton, C., et al.: A look towards the future in the handling of space science mission geometry, Planetary and Space Science, Vol. 150, pp. 9-12, 2018.

[2] Bonanos, A.Z., et al.: NELIOTA: First temperature measurement of lunar impact flashes, Astronomy & Astrophysics, Vol. 612, p. A76, 2018.

[3] Bouley, S., et al.: Power and duration of impact flashes on the Moon: Implication for the cause of radiation, Icarus, Vol. 218, pp. 115-124, 2012.

[4] Cipriano, A.M., et al.: Orbit design for LUMIO: The lunar meteoroid impacts observer, Frontiers in Astronomy and Space Sciences, Vol. 5, p. 29, 2018.

[5] Madiedo, J.M., et al.: Analysis of Moon impact flashes detected during the 2012 and 2013 Perseids, Astronomy & Astrophysics, Vol. 577, p. A118, 2015.

[6] Suggs, R.M., et al.: The flux of kilogram-sized meteoroids from lunar impact monitoring, Icarus, Vol. 238, pp. 23-36, 2014.