

FLAMES: Radiation-Hard Flash-LiDAR CMOS Imager for Space Missions[‡]

Ayman Morsy¹, Arno Van Hoorbeek¹, Victor Schuddinck¹, Walter Verbruggen¹, Ajit Kumar¹, Jan Vermeiren¹, Mohamed El-Barkouky¹, Koen Liekens¹, Benjamin Van Camp¹, Gaozhan Cai¹, Amir Babaiefishani¹, Ahmed Mahmoud¹, Rishabh Nagarkar¹, Bart Dierickx¹, Anders Hansen², Håvard Tørring², Karl Haugholt², Matthew Soman³, Pol Ribes³

¹ Caeleste, Hendrik Consciencestraat 1 b, 2800, Mechelen, Belgium

² SINTEF, Strindvegen 4, 7465 Trondheim, Norway,

³ ESA, ESTEC, The Netherlands

Corresponding author Ayman.morsy@caeleste.be

Abstract:

FLAMES is a Flash-Lidar CMOS imager, designed for space landing missions, autonomous rendezvous operations, terrain mapping, and obstacle avoidance. The sensor has a 14 μm global shutter pixel architecture with backside illumination (BSI), optimized for synchronization with a high-power 532 nm pulsed laser source. By scanning each pixel's sample & hold (SH) signal versus the laser return pulse, the system achieves precise Time-of-Flight (ToF) imaging.

The FLAMES sensor is a 1280 x 1024 array operating up to 367 frames/s. It has a full well capacity of 23 ke^- . It can operate in three readout modes RM1, RM2, and RM3. Each has a different balance between time-gating sharpness and noise performance. The readout mode is buffered using a programmable gain amplifier (PGA) with gains 1,2,4, and 8, followed by on-chip 12-bit ADCs. RM1 provides the sharpest rising edge of 2.5 ns and shortest gating time of 8.5 ns by the direct action of the reset switch. However, RM1 is limited by reset noise beyond 30 e^-_{RMS} . RM2 mitigates this reset noise by in-pixel correlated double sampling (CDS), achieving a readout noise of 22.3 e^-_{RMS} . Although the noise level is approximately twice the expected value, the root cause will be explained in the presentation. RM2 is suited for long-range detection as presented in Figure 1. RM3 is an experimental readout mode based on depletion width modulation by externally controlled corner diodes of the pixel, combining fast gating with CDS-based noise reduction.

The sensor integrates radiation-hardened-by-design (RHBD) techniques across pixels, digital blocks, and analog readout chain. Measured results from heavy-ion radiation campaigns confirm resilience against single event upset (SEU) and latch-up (SEL) with a linear energy transfer (LET) up to 61.3 $\text{MeV}/\text{cm}^2/\text{mg}$. Following total ionization dose (TID) testing with ^{60}Co up to 100 krad (Si) and protons up to $1 \times 10^{11} \text{ p}/\text{cm}^2$ at 60 MeV, the sensor remains fully operational. It maintains critical functionality despite observable performance degradation in dark current and quantum efficiency. Field tests under direct sunlight further validate the sensor's robustness. The sensor maintains its relative depth resolution and there is no observable damage from direct solar exposure.

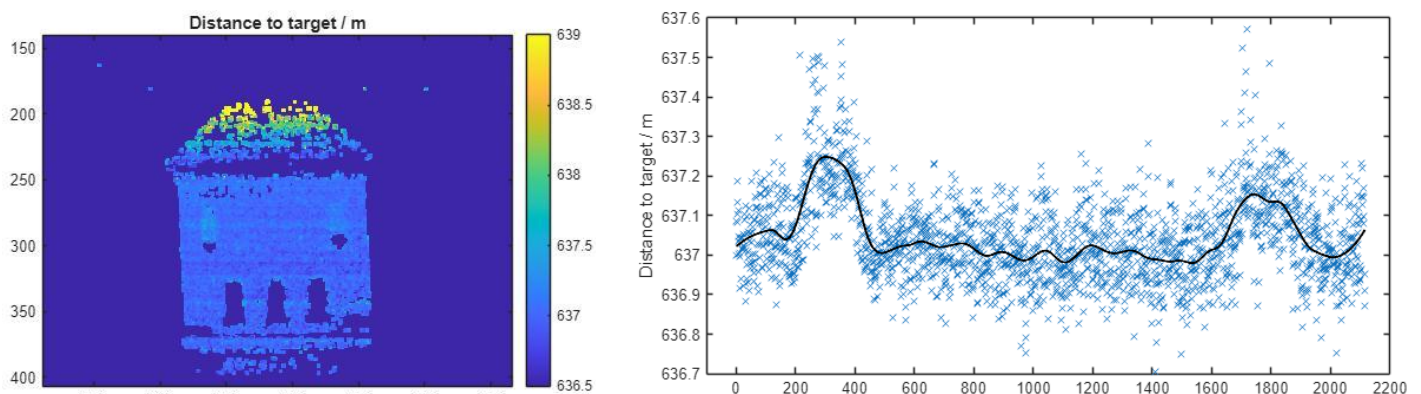


Figure 1. On the left is a range image of Ris Church in Oslo at a distance of 630 m and depth noise of 8 cm under bright sunlight. On the right is a cross-section at $Y \approx 300$ of the range image, showing the 20 cm deep niches.

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