Status of the MTG-I1 Lightning Imager commissioning activities

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EUMETSAT Conference 2023, 1-C GEO – MTG

12Sep2023, Malmö

It is estimated that storms produce lightning flashes striking about 40 times a second worldwide!

Source: https://www.noaa.gov/jetstream/lightning

LI first images release (03/07/2023)

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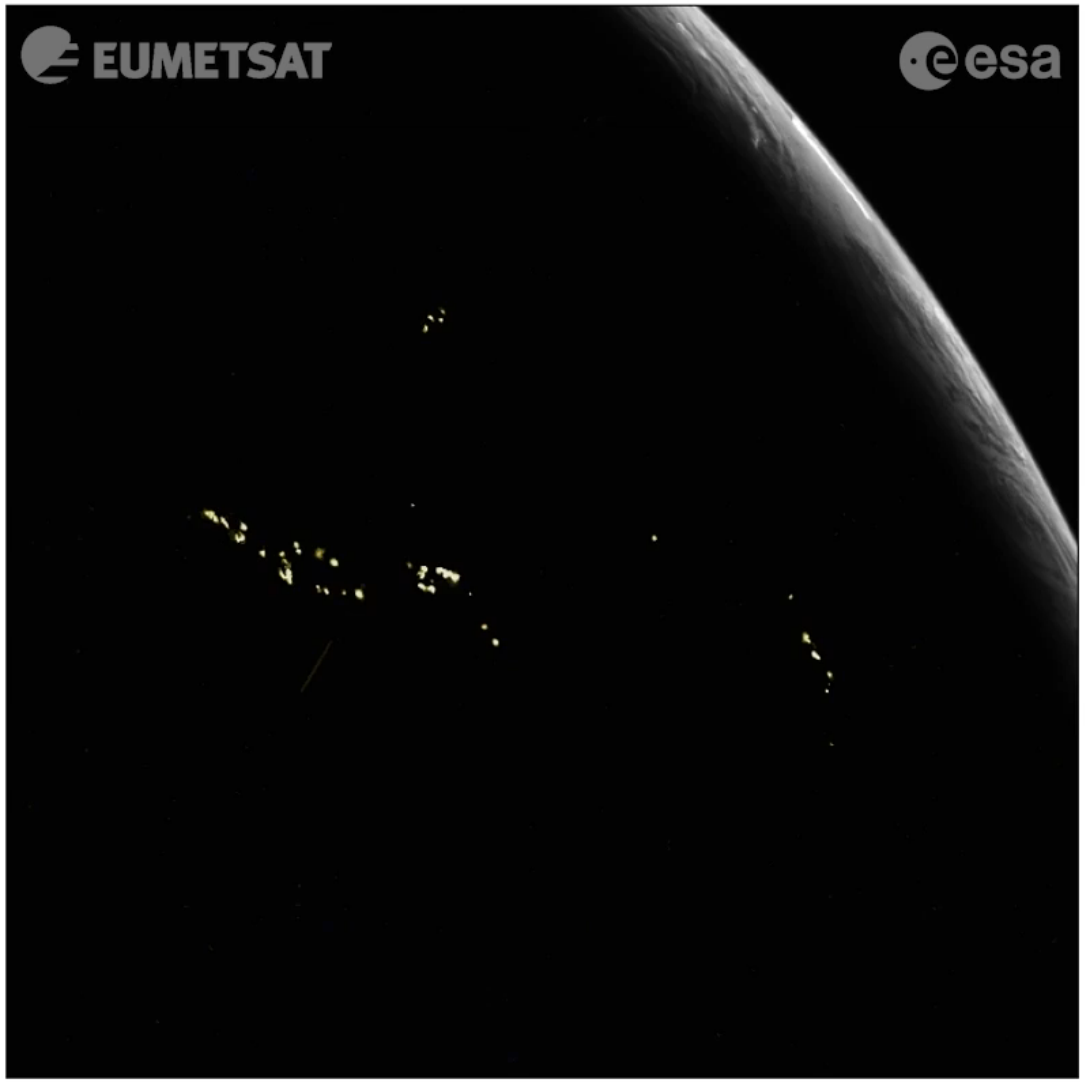

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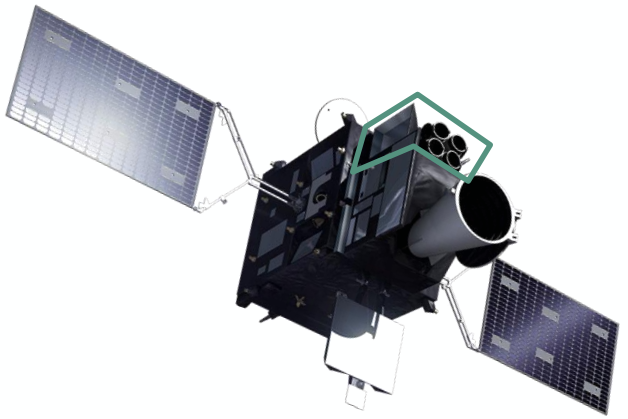
https://www.eumetsat.int/features/animations-europes-first-lightning-imager

The Lightning Imager Mission

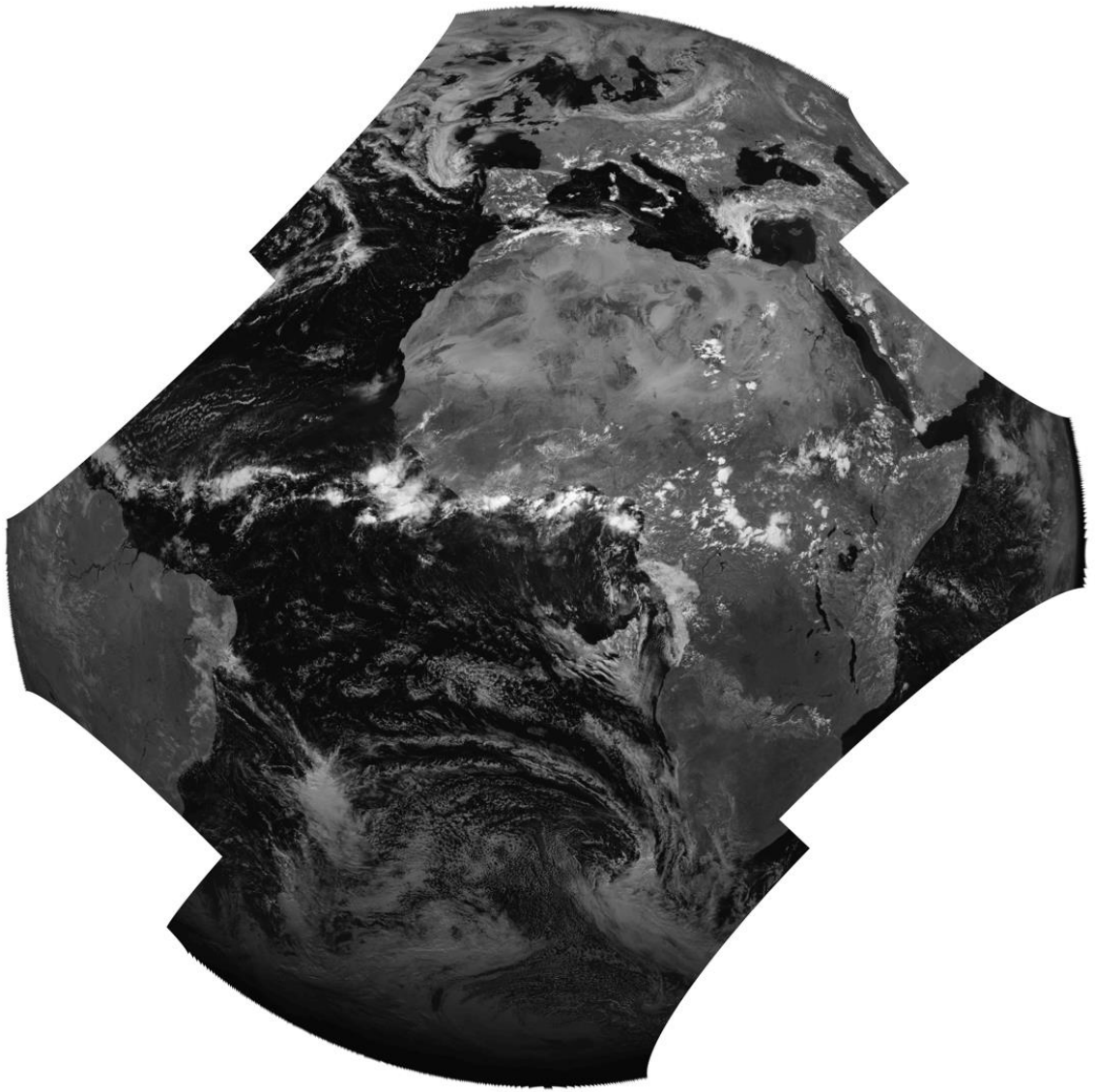
- The Lightning Imager (LI) instrument is a payload on-board the MTG-I satellites
- Meteosat Third Generation (MTG) is the next generation of European meteorological geostationary satellites, comprising six satellites: four MTG-I (Imager) and two MTG-S (Sounder)



MTG-I (artist impression)

- The LI will provide continuous lightning (cloud-to-cloud and cloud-to-ground) detection and optical observation
- The LI products will be used for near real-time monitoring and short range forecast of severe weather phenomena and for long term climate observations
- The LI instrument is built by *Leonardo* (Florence, Italy) under the industrial prime contractor *Thales Alenia Space* (Cannes, France)
- The first LI instrument fly on MTG-I-1, launched on 13 December 2022.

Field of view



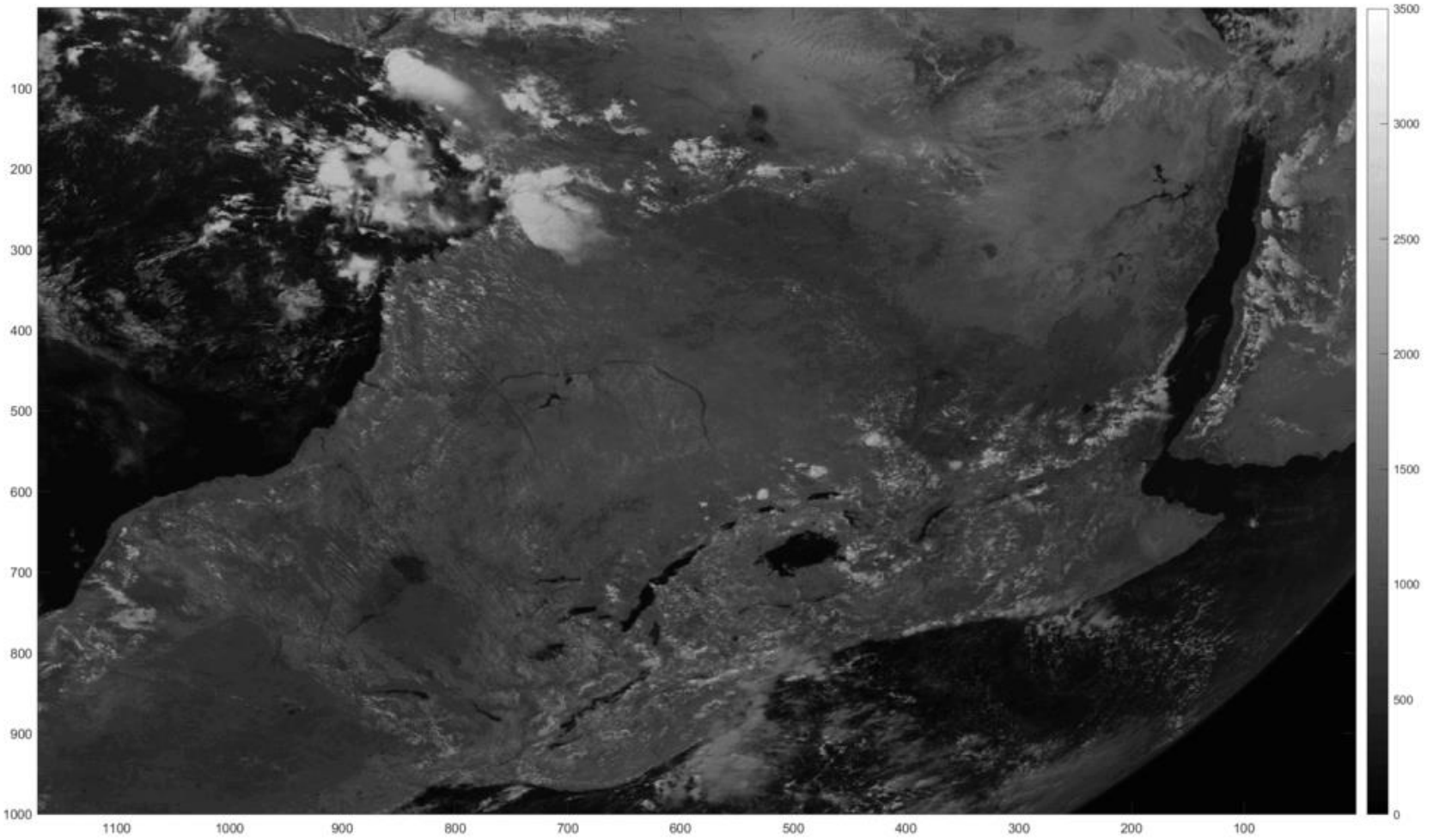
First preliminary Level1 image, courtesy: TAS

4 Cameras with 1000x1170 pixels:

- Acquisition every 1 ms
- 2-nm bandwidth around 777.4 nm
- FOV = 84% of the visible disk from GEO
- Pixel size = 4.5 km at sub-satellite point

Detecting lightning from space, not an easy job

Can you spot the lightning?



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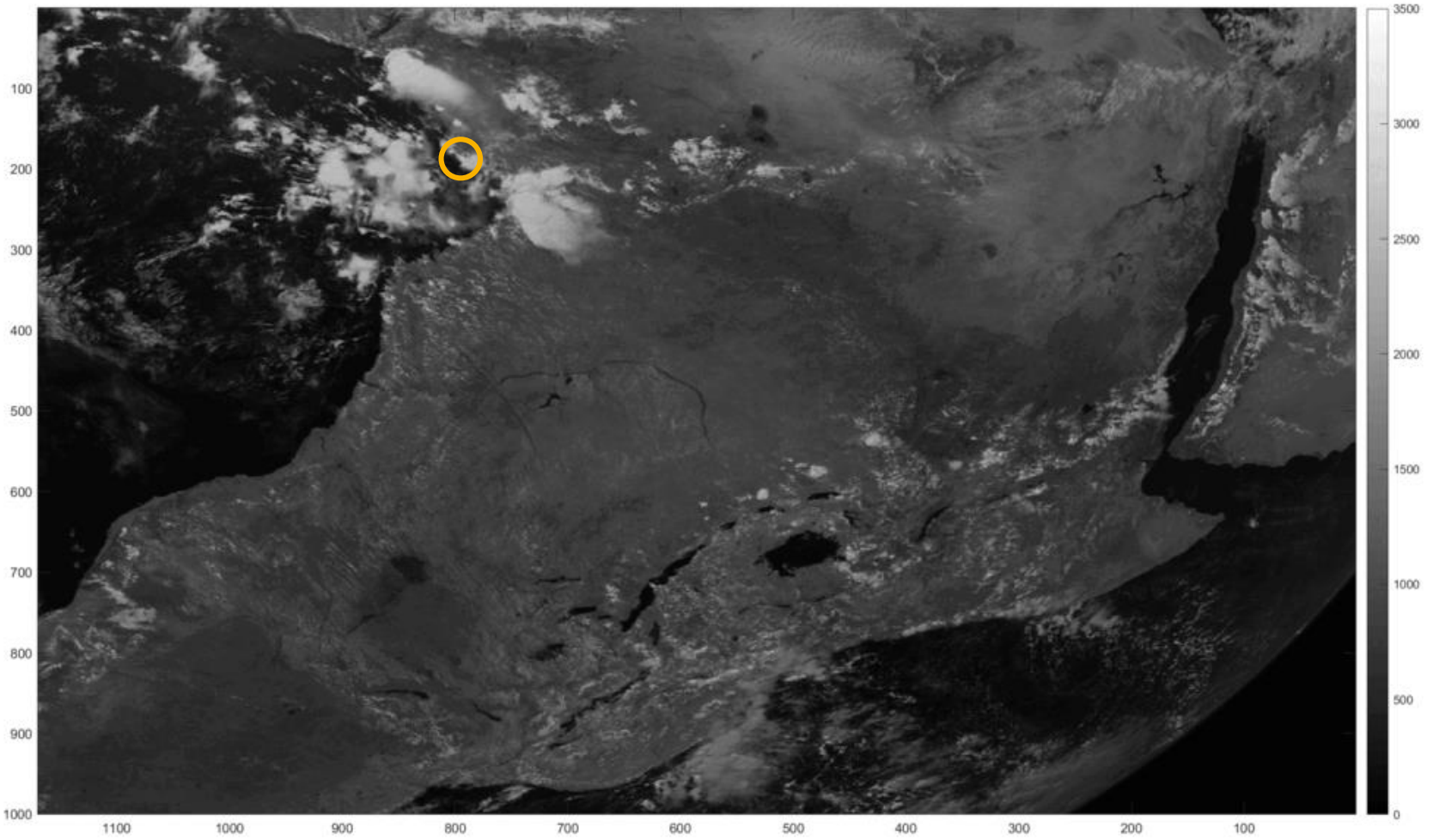
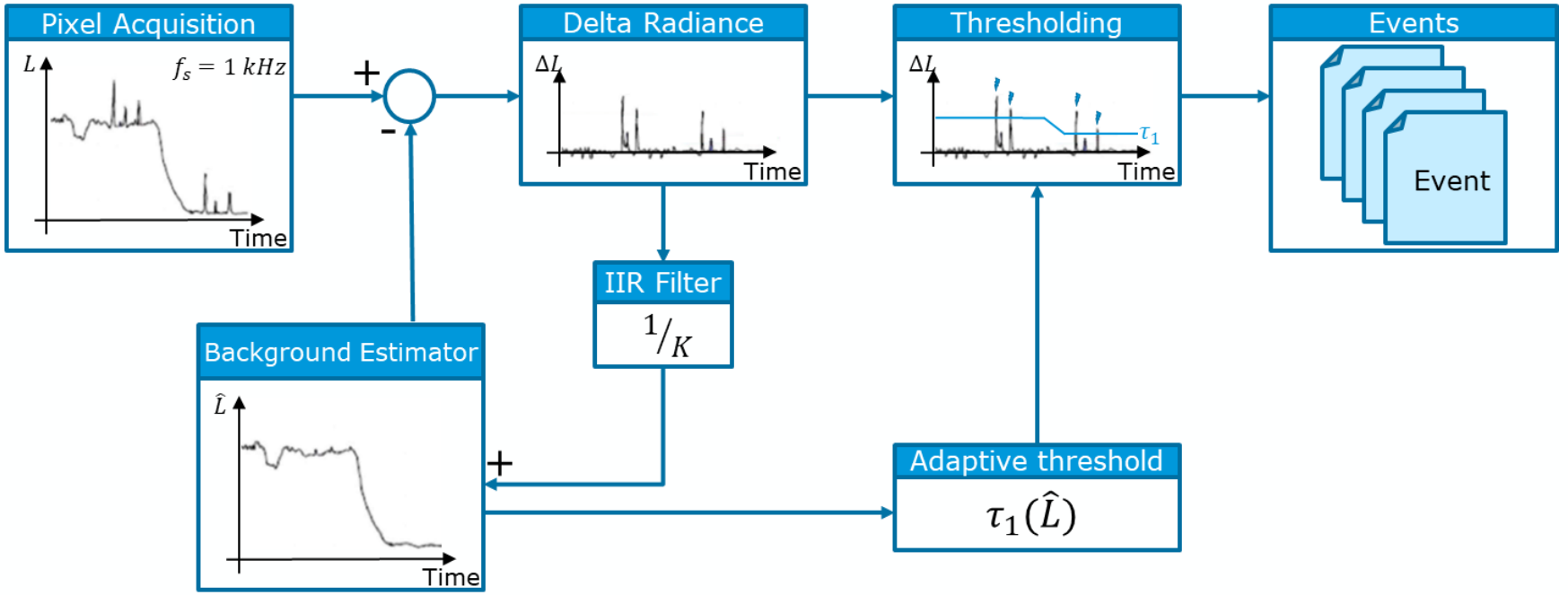


NB: this is a series of successive calibration images with a lightning occurring serendipitously on one of them.
=> In normal observation mode, the full images are not downloaded every ms but every ~60s. Only on-board detected lightning events are downloaded every ms

Data processing

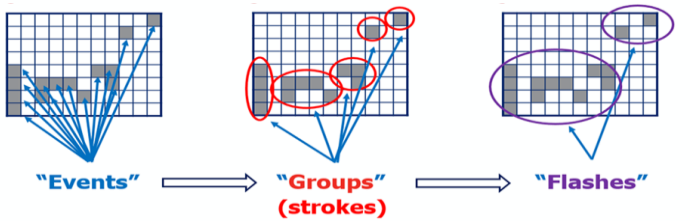
On-board Lightning Event Detection

The LI detection principle consists in triggering events on pixels where and when a sudden increase of energy is measured over the background level.



Further Processing

- On-board and on-ground filters remove false Events created by shot noise, jitter movements or other noise sources
- A Level-2 processor aggregates adjacent Events occurring during the same time frame into groups, and further consolidate groups that are in close temporal and spatial proximity to each other to form flashes (end-user data product).



Level 2 Aggregator Processor (Credits EUMETSAT)

LI space segment commissioning timeline

13Dec2022: MTG-I1 Launch from Kourou

Apr/May2023: Functional commissioning

- Testing all LI modes and flow of data through the ground systems, first images, first lightning events in low sensitivity configuration

Jul/Aug2023: Calibration & performance assessment

- Full “performance” configuration; Image Navigation and Registration (INR), radiometry, false alarm filtering, dynamic range… assessment with respect to space segment requirements

End2023: System Commissioning (EUMETSAT)

- End-to-End system, Level-2 processing…

Jan2023: First LI switch-on

- Tuning of the procedures, thermal settings optimisation and dealing with SW clock issues

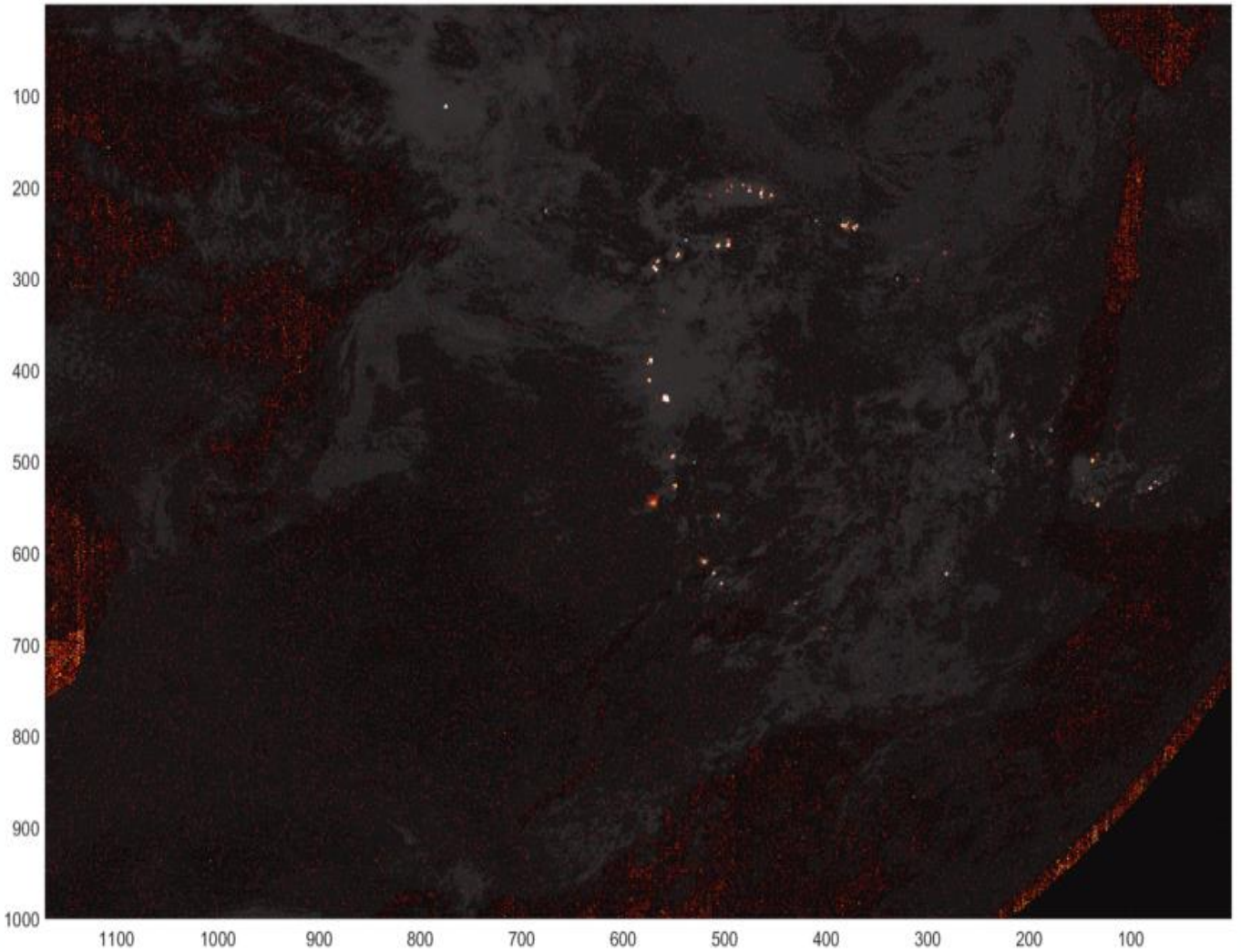
June2023: Fine tuning

- checking that data looks like what was predicted by the performance simulator and determine the on-board “performance” configuration

Sep/Oct2023: Commissioning Result Review

- Finishing the space segment commissioning

Level-0 and Level-1 data, false alarm filtering



GIF: Level-0 and Level-1 filtered heat map of lightning events location, accumulated over 10s "East" camera (01Aug2023 11:54 UTC)

- As designed, most of the lightning events downloaded to the ground are false alarms
- Level-1 processor discards ~95% events (almost exclusively false events as can be checked on the map)
- The vast majority of false events are due to random noise. This can especially be seen via the many events on dark scenes, such as the sea or deep space, where detector noise is proportionally larger with respect to the applied detection threshold
- Jitter (micro-vibrations of line-of-sight) is much less severe than once thought, no obvious false events on coastline/cloud edges => good news!
- A few energetic particles hitting the detector and leaving 1-frame streaks of events, easily recognizable (not seen on this dataset)
- More filtering foreseen at level-2, but data at level-1 is already very good!

Conclusions

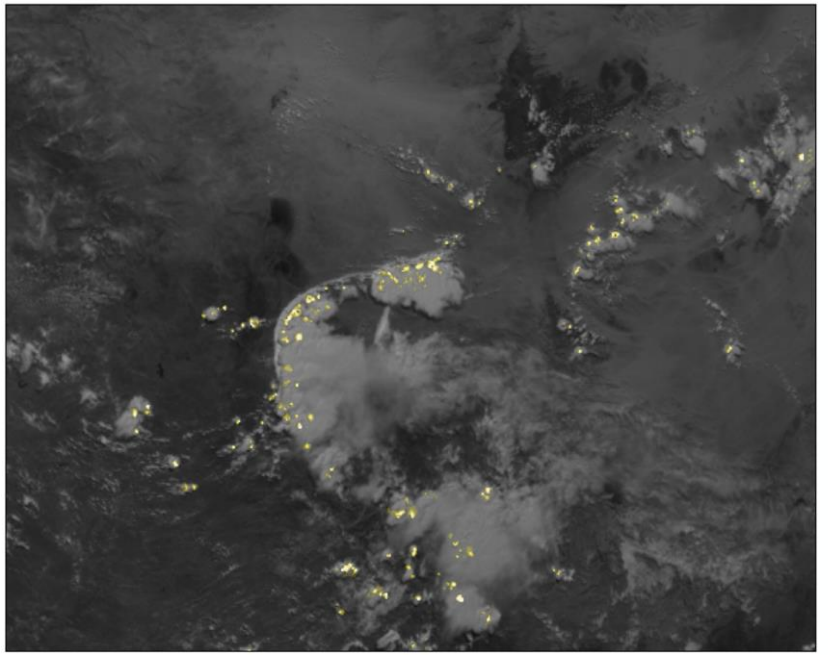
Space segment commissioning is coming to an end with the Commissioning Results Review currently ongoing.

Despite many challenges over the years, the LI is up there flying and delivering high-quality data!

LI is expected to be fully compliant to its lightning detection requirements, with significant margin.

Next steps:

- CRR review + correction of some issues left open
- (EUMETSAT) Level-2 processing, iterations with end-users, potential for even extra performance?
- 3 more LI instruments flying in the next decade aboard MTG-I2/3/4



Long live the Lightning Imager! Up to the science/meteorology community to make the best use of it.

Thank you for your attention

And congratulations to the whole LI team for this European success!

Main contributors and organisations:

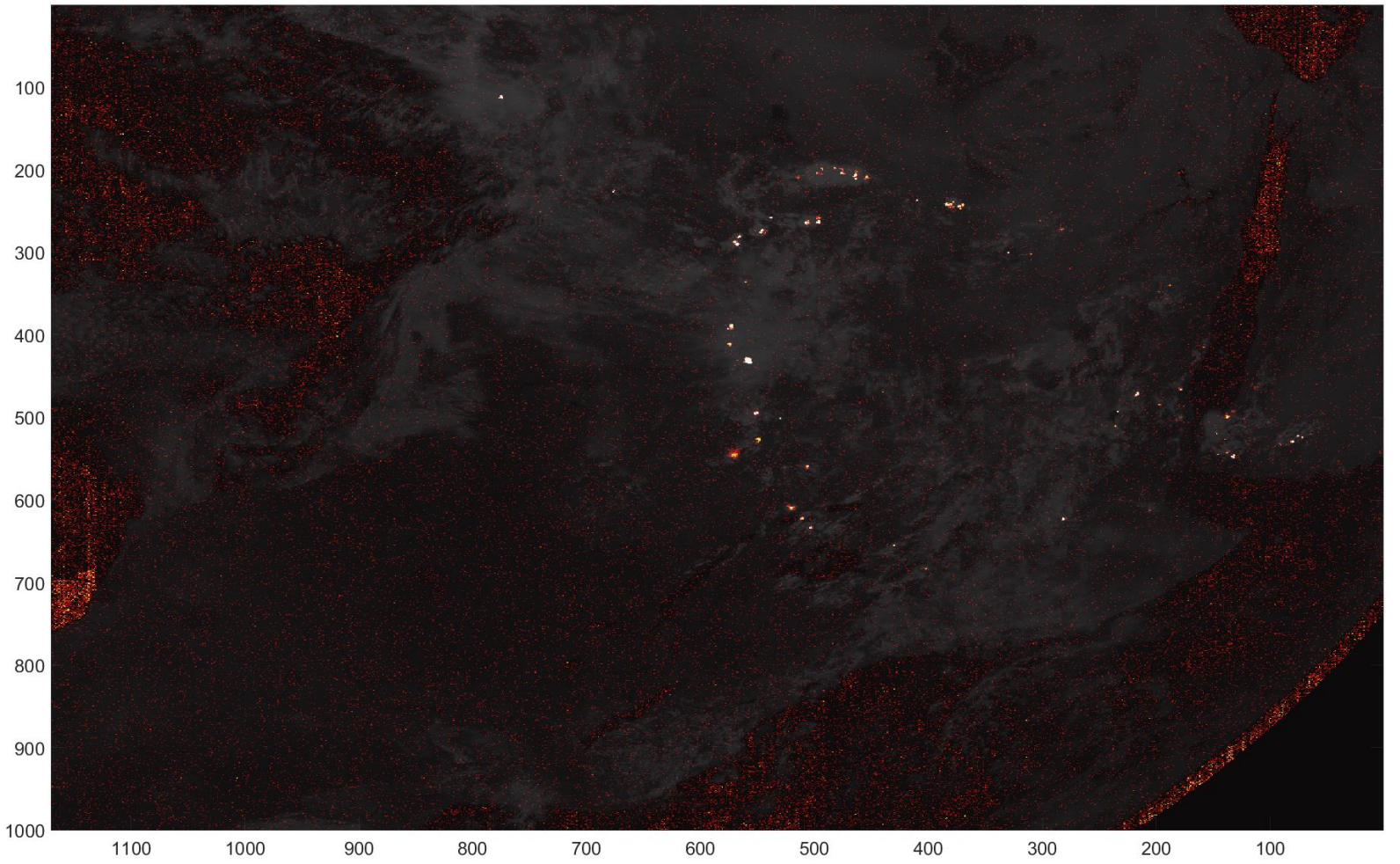
- *ESA*: Pierre Kokou, Mark Wilson, Philip Willemsen, Pieter van den Braembussche, Donny Aminou
- *Leonardo*: Lorenzo Giunti, Beatrice Ponticelli, Simone Brilli, Guia Pastorini
- *Thales Alenia Space*: Marine Claeyman, Sebastien Lambert, Cécile Monfort, Francis Olivier, Vincent Soulignac, Guillaume de Roquefeuil
- *Intecs Solutions*: Riccardo Marraci
- *EUMETSAT*: Gary Fowler, Fabian Mueller

+ many more..!

The Moon as observed by LI

Back-up slides

Level-0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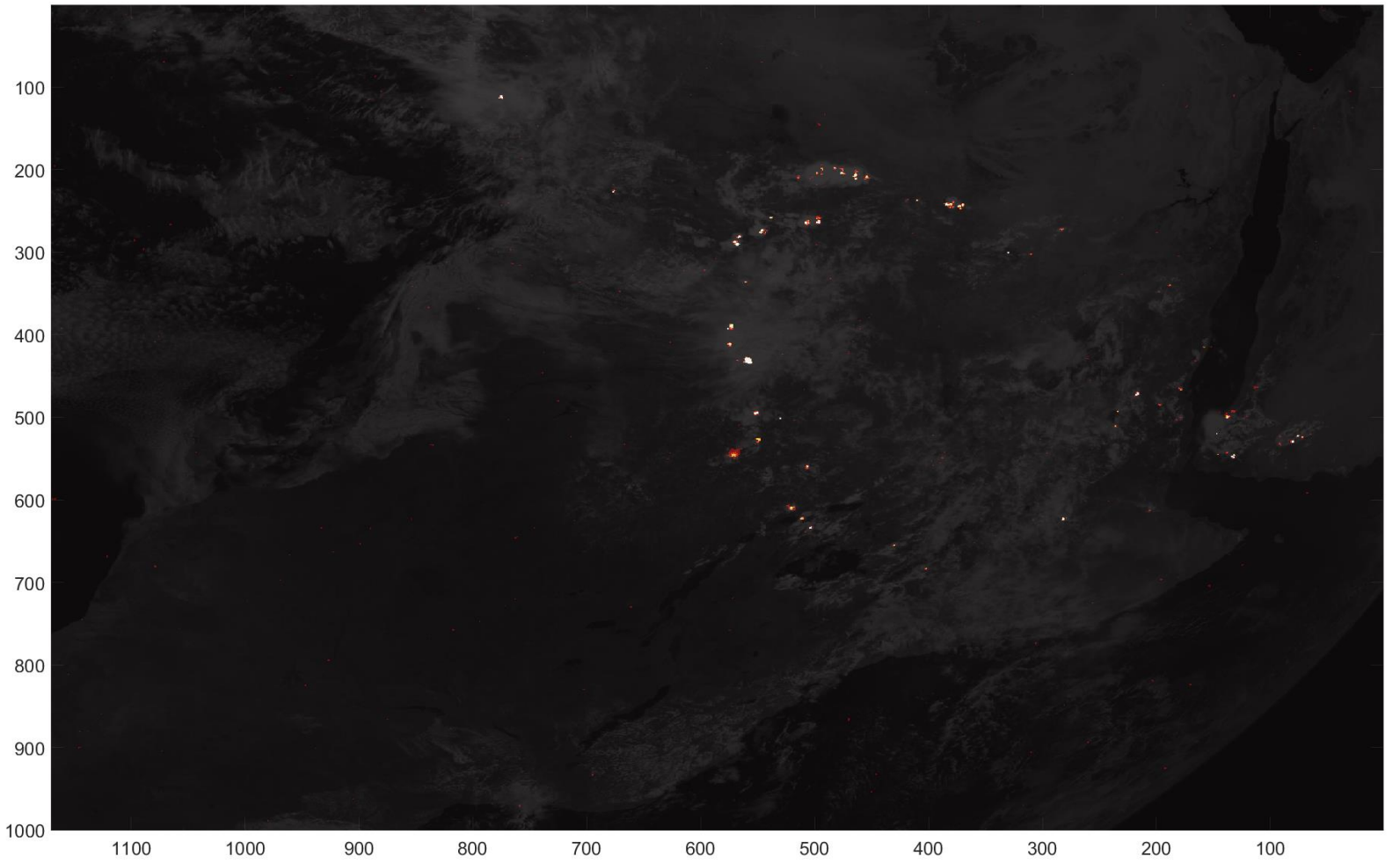
Level-1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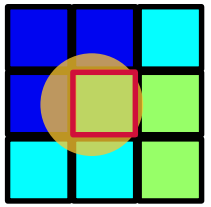
LI products and data processing

II. On-board Lightning Event Detection

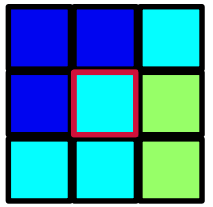
The LI basic data product sent to ground is the **Lightning Event**.

A Lightning Event is described by:

- Coordinates of the triggering pixel
- Identifier of the temporal frame
- Instantaneous measured radiance and estimated background level for the triggering pixel and its eight surrounding neighbours

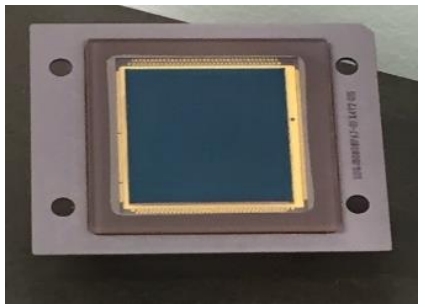


Instantaneous Measured Radiance

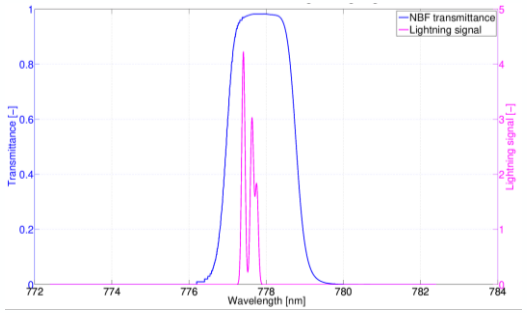


Estimated Background Level

Design and key technologies



Detector



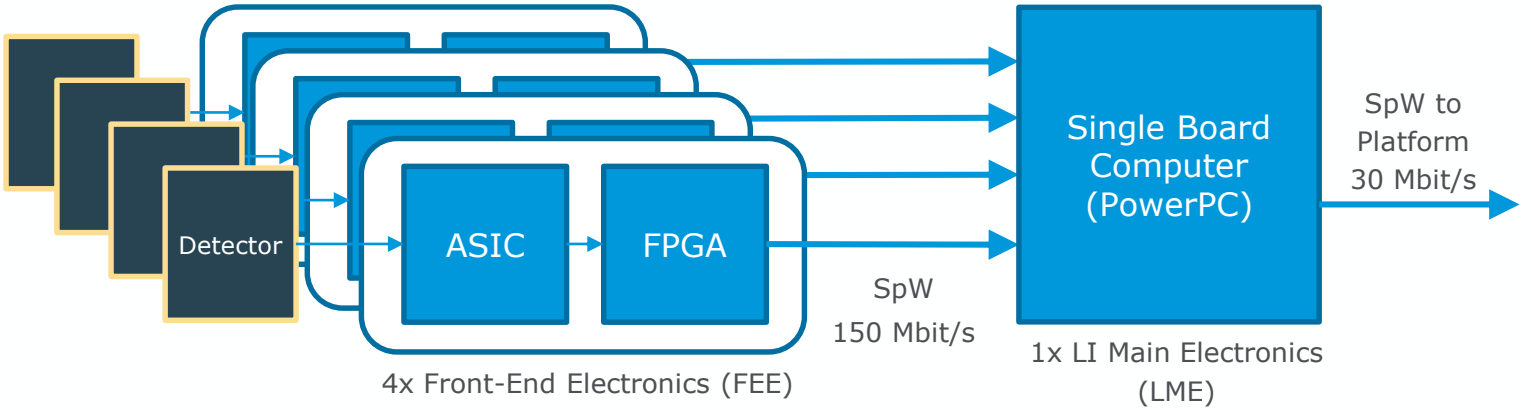
NBF transmittance vs lightning signal

The Lightning Imager (LI) instrument is made of 4 identical cameras (LOH) and one main electronics (LME)

- **Detectors:** CMOS, back-thinned & back illuminated, 100% fill factor, 24µm x 24µm pixel size, 1000x1170 pixels, on chip 12 bit ADC, 60 parallel LVDS outputs at 250Mbit/s each

- **Spectral filters**: Solar Rejection Window (SRW) + Narrow Band Filter (NBF) selecting a band of 1.9 nm centred at 777.4 nm

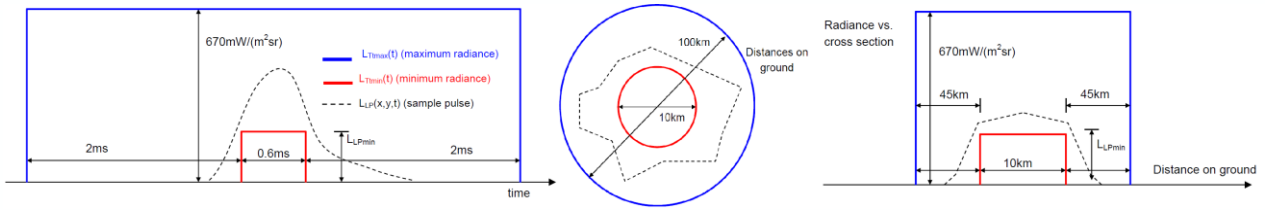
- **On-board data reduction**: data reduction factor of ~250 achieved through a cascade of false events filters implemented in ASICs, FPGAs and a single board computer (PowerPC)



Performance

- The main performance indicator for the LI is the lightning detection performance
- The detection performance is assessed using an end-to-end performance simulator correlated to on-ground measurements on flight hardware (detector QE, noise, spectral filter responses, blinking pulse tests…)
- Artificial lightning pulses are introduced in the Earth scenes. They are circular, with diameter of 10km, and rectangular in time
- Energy of the simulated pulses is tied to the background level on which the lightning is simulated by the following equation:

$$L_{LP\min} = 6.7\sqrt{1+0.02L_{bkg}}\, mW/(m^2 sr), \text{ with } L_{bkg} \text{ in } Wm^{-2}sr^{-1}\mu m^{-1}$$



Lightning template used for detection performance assessment

- At level 1, detection performance is measured via the Instrument Averaged Detection Probability (IADP), i.e. the capability of the instrument to detect a small pulse placed randomly in space and time

Scenario	IADP
Day	78%
Night	85%

Detection performance averaged over full FOV

- Absolute radiometric accuracy: 10%
- False alarm rate: max 35k/s false events at Level1 and ~2/s false flashes at Level2