Meteosat Third Generation (MTG) Lightning Imager (LI) calibration and 0-1b data processing

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ABSTRACT
The European Meteosat Third Generation (MTG) Lightning Imager (LI) is an instrument on the geostationary MTG Imager satellite series, for which the first satellite is scheduled for launch in 2021. The MTG series consists of six satellites in total: Four imager satellites, equipped with the Flexible Combined Imager (FCI) and Lightning Imager (LI) instruments, and two sounding satellites, with the Infrared Sounder (IRS) and Sentinel-4 UVN instruments. EUMETSAT will operate the satellites, instruments and ground facilities for MTG, including LI. The Lightning Imager will continuously provide lightning group and flashes information for almost the complete visible Earth disc from a geostationary orbit around zero degrees longitude in the time period 2021 to 2041. The instrument will measure day and night and will provide detected transient data from lightning optical pulses in the near-infrared at a spatial resolution that corresponds to 4.5 km x 4.5 km at the subsatellite point. The instrument also measures and provides background radiance images every 30 seconds. In this paper the Lightning Imager mission objectives and basic instrument detection principles will be described. In addition, the calibration (on ground and in orbit) and 0-1b data processing will be presented and discussed.

1. SUMMARY
The Meteosat Third Generation Lightning Imager (MTG-LI) instrument and mission will be described in detail. Section 2 will provide some background for the MTG mission. Section 3 will describe a number of important aspects of the LI instrument and system design and the principles of the lightning detection. Section 4 will discuss the LI 0-1b data processing software. The on-ground calibration is discussed in section 5, the in-orbit calibration in section 6. The conclusions are presented in section 7.

2. INTRODUCTION
The Lightning Imager (LI) instrument is an instrument on board of the Meteosat Third Generation (MTG) Imaging geostationary Earth observation platforms, for which the first launch is planned in 2021. The LI will observe lightning optical signals in the near-infrared continuously, day and night, from a geostationary orbit at sub-satellite longitude of about 0 degrees, for a geographical coverage area that covers almost the complete visible Earth disc. The measured lightning data can be used to improve the quality of severe weather predictions and reduce the warning times for dangerous weather situations. The data can also be used for improving predictions for aviation applications, in route over land or over sea and ocean, as well as in the vicinity of airports. The LI data will also be used to improve the scientific understanding of lightning phenomena in general, along with their geophysical properties.

The LI builds on and improves on predecessor space-based optical lightning detection missions that have provided, and still provide today, invaluable information on lightning phenomena as observed from space and on instrument and system properties that are best suited to measure these:

• NASA OTD (Optical Transient Detector), 1995-2000, low-Earth orbit.
In addition, the following lightning detection missions are currently planned:

- NASA / NOAA GOES-R/S GLM (Geostationary Lightning Mapper), to be launched second half of 2016. See also Ref1.
- NASA LIS on ISS (International Space Station), to be launched / installed in 2016.
- China National Space Administration FY-4 GLI (Geostationary Lightning Imager), to be launched end 2016.

The MTG-LI will overlap partly in time with the latter 3 lightning detection systems from space.

The geostationary Meteosat Third Generation (MTG) Earth observation satellite series consists of six satellites in total, four imaging platforms and two sounding platforms. The imaging platforms are equipped with the Flexible Combined Imager (FCI) instruments, an improved follow-on instrument from the SEVIRI (Spinning Enhanced Visible and InfraRed Imager) instrument on the Meteosat Second Generation (MSG) geostationary satellite series, and with the Lightning Imager (LI) instrument, for which no heritage exists in Europe. The sounding platforms are equipped with the Infrared Sounder (IRS) and with the Sentinel-4 UVN instrument provided by the European Union Copernicus program.

The MTG satellites and instruments are developed in cooperation with the European Space Agency (ESA). EUMETSAT in Darmstadt, Germany, is responsible for all MTG mission aspects, for operating the instruments and satellites, for developing and operating the MTG ground segment, including the 0-1 and 1-2 data processing facilities, and for archiving and distribution of the level-1 and level-2 data products.

Table 1 provides a correspondence between the various physical phenomena related to lightning, and the parameters measured by the LI instrument.

The LI total mass (optics and electronics) is 100 kg, the power consumption about 300 W and the data rate to ground 30 Mbps.

### Table 1: Relationship between lightning physical phenomena and parameters as measured by the instrument.

<table>
<thead>
<tr>
<th>Physical phenomenon</th>
<th>Measured by the instrument</th>
<th>Data level</th>
</tr>
</thead>
<tbody>
<tr>
<td>-</td>
<td>Detected Transients (DTs)</td>
<td>Level-0 / Level-1b</td>
</tr>
<tr>
<td></td>
<td>(detector pixel)</td>
<td></td>
</tr>
<tr>
<td>Lightning Stroke /</td>
<td>Group (of detector pixels)</td>
<td>Level-2</td>
</tr>
<tr>
<td>Lightning Optical</td>
<td></td>
<td></td>
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<tr>
<td>Pulse</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lighting Flash (collection of Lightning Optical Pulses in time)</td>
<td>-</td>
<td>Level-2</td>
</tr>
</tbody>
</table>

### 3. DESCRIPTION OF THE INSTRUMENT AND THE DETECTION TECHNIQUE

The LI instrument aims to measure lightning optical pulses of specified minimal radiance (7 mW/(m².sr) during night conditions, 17 mW/(m².sr) in day conditions with clouds) and size (10 km diameter) with an average detection probability of 70% over the coverage area, whilst at the same time restricting the false Detected Transients DTs rate (generated by effects other than lightning optical pulses) to values below 35000 per second on average (equivalent to 35 per 1 ms frame on average). Relevant lightning characteristics for the LI instrument have been discussed previously in Ref2.

A lightning flash is defined as a (time) sequence of various lightning optical pulses, each two spaced by no more than e.g. 300 ms, occurring at approximately the same location (e.g. within 50 km). A lightning flash can consist of only one lightning optical pulse, or of several lightning optical pulses, up to as many as 20. A lightning flash duration is typically up to 1-1.5 seconds.

The LI instrument, being an optical sensor, cannot distinguish between cloud-to-cloud flashes and cloud-to-ground flashes, as it just measures the lightning optical pulse signal from the top of the atmosphere.

The LI measures the spectral radiance from the triplet of emission lines from the $3p^3P_{1,2,3} \rightarrow 3s^5S_2$ transitions of neutral atomic oxygen at vacuum wavelengths of the emission peaks at 777.408 nm, 777.631 nm and 777.753 nm.

The LI instrument detects lightning day and night. The most challenging scenario for the LI is when a weak lightning optical pulse occurs over a bright cloud. In that case, the background signal is very high, and so is the shot noise from that cloud background signal, whereas the useful signal from the lightning optical pulse is low. Hence, the detection thresholds that can be
set to detect lightning optical pulses over clouds, depend strongly on the background radiance level in order to avoid system saturation due to false events originating from noise. For the LI the lightning optical pulse radiance is typically between 17 mW/(m²·sr) and 670 mW/(m²·sr) for daytime clouded conditions. These lightning optical pulses are required to be detected with a certain average detection probability as described above. The maximum background spectral radiance to be measured without saturation by LI is 500 W/(m²·µm·sr) for scenes with bright clouds.

The spatial extent of the minimal lightning optical pulses to be detected with a specified detection probability is 10 km diameter (area 78 km²) for round lightning optical pulses. Towards the edge of the Earth the lightning optical pulses as observed from geostationary orbit become elliptically shaped and it becomes more difficult to detect them (the detection probability decreases).

The key question is thus how to discriminate between a bright cloud (background) and a lightning phenomenon? For the LI, as for other comparable optical lightning detection systems/instruments from space, this is accomplished by:

1. Spectral discrimination: Detect the oxygen atom triplet at 777.6 nm (vacuum wavelength) lightning emission signal using a narrow spectral band pass filter with a spectral width of about 1.9 nm full width at half maximum. This reduces the detected system noise originating from shot noise of the underlying white cloud.

2. Spatial discrimination: A typical small lightning optical pulse has a diameter of 10 km, whereas the underlying cloud is typically bigger. The LI implements a ground sampling distance at the subsatellite point of 4.5 km x 4.5 km. This implies that the smallest lightning optical pulses required to be detected will trigger typically 2 ground samples, which helps in distinguishing between false and real (from lightning) Detected Transients (DTs). The price to pay is that at instantaneous (near) full Earth disc viewing about 4.7 million ground pixels have to be processed on board for each observation frame.

3. Temporal discrimination: Lightning optical pulses as observed from space have a typical duration of 0.6 ms. The LI uses a frame refresh time of 1 ms in order to allow distinguishing between transient and more constant (in time) signals.

4. Background subtraction per detector pixel: By subtracting from each measurement frame a signal that represents the background signal (i.e. without transients) a differential measurement technique is implemented. The background corrected signals are compared, for each detector pixel (ground sample) to thresholds that depend on the background signal. In this way accurate and representative event detection can be obtained.

All of the above detection steps are implemented in the LI instrument, in the optics and/or in the on-board detectors and/or electronics. The LI has 4 optical cameras (Figure 1) to cope with the relatively large geographical coverage area. Each optical camera is equipped with:
- a CMOS detector, operated around 293 K, 1170x1000 pixels.
- a Solar rejection filter.
- a spectral band pass filter (about 1.9 nm).
- an optical system with F# 1.73, 110 mm entrance pupil diameter and 191 mm effective focal length, Field Of View 5.1 degrees.

The resulting geographical coverage area on the Earth is shown in Figure 2.
In case a detector pixel (corresponding to a ground sample) exceeds a threshold we speak of a Detected Transient (DT). DTs may be real, originating from real lightning optical pulses and flashes, or they may be false, originating from other sources, such as:
- Noise.
- Spacecraft / LI optical head microvibrations in combination with scene contrast.
- Cosmic particles hitting the detectors.
- Solar glint on open water, lakes or rivers.
- Etc.

One of the main challenges for the LI instrument / system, like for any lightning detection system from space, is to maintain a proper balance between False DTs and Real (lightning) DTs on one hand and the Lightning Detection Efficiency on the other hand. The LI frame collection period is 1 ms. So basically every 1 ms 4.7 million pixels have to be processed on board. Then, in a number of on-board processing steps, the number of false events need to be reduced considerably to fit within the various data rate limitations within the instrument electronics, whilst these processes need to ensure that Detected Transients (DTs) originating from real lightning are maintained. Once the data reach the ground the process of distinguishing false and real DTs continues in the 0-1 and 1-2 data processing software, until the applicable requirements at level-1 (DTs) and level-2 (groups and flashes, see Table 1) are obtained.

In order to detect the Detected Transients on board a number of algorithms are implemented. This is schematically depicted in Figure 3. The signals measured by each detector per optical camera are digitized on chip in the detector (12 bits) and processed by 4 ASICs per optical camera. In the ASICs the measured signals are corrected for a running average of the background signal per pixel (14 bit). Thus the ASIC is maintaining this background signal and subtracting it from the measured signals in each 1 ms frame. Then the corrected signals are compared with thresholds that depend on the background signal: a higher background signal will yield more signal-shot-noise and hence a higher threshold. The thresholds are retrieved from a (configurable) lookup table in the ASIC. If the background-corrected-signal exceeds the threshold, the measurement will be registered as a Detected Transient (DT). These processes described so far are the so-called Real-Time Pixel Processor in Figure 3. The FPGA collects the various DTs in the 1 ms time frame and passes the following information on to the next stage for each DT:
- DT signal, plus signal from 8 detector pixels that surround the DT, plus DT row and column coordinates in the detector.
- Background signal for DT and 8 surrounding detector pixels from the average background signal (as described above) at the time of the DT detection.
- The threshold that was used to detect the DT.

Next, the DTs are transferred from the Front-End Electronics (FEE, left hand side in Figure 3) to the LI Main Electronics (LME, right hand side in Figure 3), where a processing board implements two additional algorithms in software:
- Single-Detected-Transient filter.
- Microvibration / Jitter filter.

The Single-Detected-Transient filter uses the fact that the lightning optical pulses with minimal size (10 km diameter) are larger than the instrument spatial sample distance (4.5 km x 4.5 km at subsatellite point). Hence, for a real DT it is expected that lightning pulse signal is measured also in the pixels surrounding the DT, which is less likely the case for false DTs. This filter checks for this with predefined thresholds. The on-board microvibration filter will be discussed further below.

The on-board filtering algorithms / steps are mandatory to ensure that the amount of DTs is not too large for the downlink bandwidth to the ground (30 Mbps). On the ground further DT flagging algorithms are implemented in the 0-1b data processing software, as indicated in Figure 4, which shows the three on-board DT filtering algorithms on top and the various on-ground DT flagging algorithms at the bottom. Note that on-ground
algorithms are still under discussion and their exact contents have not been consolidated at the current stage. Note also that on ground the DTs are flagged, not filtered/deleted, as data rate restrictions are not applicable here as on board and it is important to retain the DT statistics.

Figure 3: Schematic overview of LI on-board Detected Transients (DTs) data processing (false and real DTs). The false DTs are removed as much as possible, whilst the real DTs are maintained as much as possible.

Figure 4: Schematic overview of LI on-board and on-ground Detected Transients (DTs) data processing (false and real DTs). The top half 3 filtering algorithms are implemented onboard the LI electronics, whereas the bottom half 3 flagging algorithms are implemented in the on-ground 0-1b data processing software.
The process of identifying real and false DTs on board and on the ground is one of the most complex challenges for the LI instrument. Its successful implementation will strongly determine the efficiency with which the LI can detect and identify DTs from real lightning optical pulses in groups of many false DTs, where the false DTs outnumber the real ones by factors that exceed in many cases a factor 100 (i.e. less than 1% of all measured DTs is from real lightning). For these reasons the on-ground 0-1b DT processing will provide various flags that indicate why a certain DT is false or not. In addition, it is also essential to indicate the probability of a certain DT being real or false. This too will be part of the on-ground 0-1b DT processing software.

Besides Detected Transient (DT) data the LI also measures and provides background radiance images over the geographical coverage area at least every 30 seconds. Note that these background radiance images are different from the estimated DT background at the time of DT detection as discussed above. These background radiance images, provided as level-1b data products, are used for geolocation purposes and for instrument throughput and detector monitoring / calibration. This will be discussed in more detail below.

4. LIGHTNING IMAGER 0-1B DATA PROCESSING SOFTWARE

The instrument will use the concept of MeasurementClass, Instrument Configuration Identifier (ICID) and ICID Version (ICIDVER) for operating the instrument and regulating the 0-1 data processing algorithm flow, i.e. which algorithms to apply for each measurement and in which order. The MeasurementClass distinguishes between e.g. DT data, background radiance image data and certain types of calibration data (see for more details section 6). The 0-1 processing can be further optimised based on ICID and ICIDVER. The MeasurementClass, ICID and ICIDVER parameters are also available in the level-0 and level-1b data.

The LI 0-1b data processing software will provide the following level-1b data products:
1. Level-1b Detected Transients (DTs) data product.
2. Level-1b background radiance images data product.
3. Level-1b calibration data product.
4. Level-1b Data Processing Parameters File (DPPF) data product.

It is important that the LI instrument design and performance, the calibration on ground and in orbit, the 0-1b data processing software and the instrument operations scenarios are properly and adequately harmonized. For example, for some parameters the instrument performance may need to be corrected/improved by calibration and 0-1b data processing, depending on the requirements at level-1b.
Another example is that it makes no sense to define operational calibration measurements in orbit when the calibration and 0-1b data processing cannot properly cope with such measurements or use their results. This is not specific for LI, it is applicable to virtually all space instruments. Additionally, the exact calibration needs are determined by the needs from the 0-1b data processing algorithms. Figure 6 and Figure 7 show the 0-1b data processing algorithm flow diagrams for the LI operational 0-1b data processor for DT data and for background radiance image data, respectively. Both are preceded by a generic block of algorithms shown in Figure 5. It is not the intention of the current paper to explain all algorithms in detail, but it is important to realize that a number of algorithms (indicated in green) require calibration key parameters that will be calibrated in the pre-launch calibration and characterization phase, and some parameters can and will be updated in orbit using dedicated calibration measurements, as described in section 6. Such parameters will be stored in the so-called Data Processing Parameters File (DPPF). The DPPF contains all parameters (calibration, instrument design, algorithm settings and switches, etc.) required by the 0-1b data processor to run. Newly calculated key parameters are stored in the DPPF, which is typically created once per day. Hence the DPPF level-1b data products serve both as input to the 0-1b data processor and as output as well. The DPPF has various groups of data with different update frequencies, for example static, monthly, weekly, daily.

The on-ground 0-1b data processing software performs a number of essential tasks:
1. Process Level-0 data into Level-1b data.
2. Distinguish between false DTs from real lightning and false DTs from other sources as described in previous sections by providing quality flagging information and probability information for each DT indicating why a DT is real or false.
3. Attach a probability for each real or false DT.
4. Generate regularly (e.g. every 10 minutes) detection sensitivity maps for detecting lightning optical pulses over the full coverage area.
5. Perform all radiometric correction steps for DT data, background radiance data and (some of the) calibration data for detectors, electronics and optics.
6. Provide / calculate geolocation data for each measured ground sample.
7. Calculate, apply and provide quality information per detector pixel, spatial sample, measurement frame and data granule.
8. Recalculate calibration key parameters from in-orbit calibration measurements where possible (time-dependent calibration key parameters) in order to maintain the accuracy of the level-1b data products.
9. Calculate parameters for the L1b data products to enable performance and potential degradation monitoring.
10. Calculate and provide metadata for the various L1b data products.

The geolocation information for all ground pixels will be provided in the background radiance images data product, which will be available at least every 30 seconds.

The filtering / flagging of real and false DTs is a category of 0-1 data processing algorithms that is specific for the LI. A number of algorithms will be identified and implemented to deal with the various types of false DTs. As discussed earlier in this paper, it is essential that these algorithms maintain as much as possible all real DTs (from real lightning optical pulses), because otherwise the detection efficiency performance will be degraded. The various real/false DT flagging algorithms and their detailed implementations are currently still under development. Also the amount of flagging to be done in the 0-1b data processing software on one hand or in the 1-2 data processing software on the other hand is still under investigation.

5. LIGHTNING IMAGER ON-GROUND CALIBRATION

Looking into the needs from 0-1b data processing perspective (Figure 5, Figure 6 and Figure 7) the following calibration (key) parameters are identified:

- DT flagging (distinguish between real and false DTs).
  - Electronic readout noise.
  - Pixel-dependent noise.
  - Characterisation / calibration of potential spatial stray light ghosts.
  - Bad and Dead Pixel Map (BDPM).
  - Random Telegraph Pixel (RTS) map.
- Radiometric calibration (for both DTs and background radiance, i.e. transients and ‘constant’ in time):
  - Detector and electronics.
    - Pixel Response Non-Uniformity (PRNU).
    - Pixel-dependent offset.
    - Pixel-dependent dark current (plus its temperature dependence).
    - Pixel-dependent non-linearity.
    - (Relative) electronic gains.
  - Absolute radiometric calibration.
  - Earth and sun stray light calibration.
- Polarization characterization (not corrected in 0-1b processing).
- Geometric calibration:
  - Pixel Field Of View / PSF (2-dimensional)
  - Geolocation:
    - (Detector) Pixel Line Of Sight.
    - Geographical coverage area.
    - Line Of Sight calibration between the 4 optical cameras.
- Spectral calibration / pixel flagging:
  - Narrow band pass spectral transmission calibration (per detector pixel).

The performance parameters that will be characterised on the ground include the signal-to-noise, the Instrument Average Detection Probability (IADP) and the Detection Efficiency (DE), and the false Detected Transient (DT) rate. The IADP represents the LI instrument detection efficiency for lightning optical pulses (irrespective of which detector pixel detects the lightning optical pulse), while the DE represents the probability for individual detector pixels to generate DTs as a result of lightning optical pulses.

The absolute radiometric response for transient signals (DTs) and for signals constant in time (background) are calibrated to an accuracy of 10% (1σ). This will be achieved using a combination of an absolutely calibrated large integrating sphere and pulsed LEDs to simulate the background radiance and the lightning optical pulses. The absolute radiometric scale will be calibrated by varying the integrating sphere output over the specified signal dynamic range. The radiometric correction calibration parameters will be provided for each detector pixel. Pixel Response Non-Uniformity (PRNU) calibration parameters will also be derived from the radiometric integrating sphere measurements, by separating out higher spatial-frequency signal variations on the detectors (smaller than e.g. 50 pixels) that are known not to originate from the optics.

The pixel-dependent dark current and offset can be calibrated by varying the detector exposure time from very short (40 µs) via intermediate (1 ms) to long (seconds). Interpolation and fitting (per pixel) of the response vs exposure time will provide the pixel-dependent dark current and offset data. Variation of the detector temperatures will provide the temperature dependencies for these parameters.

The polarisation dependence of the instrument will be verified by theory and measurement to ensure that it remains within the required radiometric accuracy.

Stray light from the Earth and sun will be calibrated where necessary. Different types of stray light will be distinguished: uniform and spatially and spectrally varying stray light from surface roughness and contamination, stray light ghosts, etc. Characterisation / calibration of the stray light ghosts is particularly important, because real DTs from real lightning optical pulses may generate additional false DTs via stray light ghosts. The ghost calibration data will be used to identify and flag such stray light ghost false DTs, where necessary.

The Pixel Field Of View (PFOV) and Pixel Line Of Sight (PLOS) will be calibrated for each detector pixel. The PFOV will be calibrated in all relevant spatial dimensions via the spatial Point Spread Function (PSF) calibration. In addition, the line of sight differences between the 4 optical cameras will be calibrated.

The transmission characteristics of the narrow band pass spectral filter (about 1.9 nm full width at half maximum) depend on the angle of incidence on the filter and hence on the position within the coverage area. The spectral transmission will be calibrated for each detector pixel (ground pixel) individually. Depending on the angle of incidence on the filter, the useful signal from the lightning optical pulse triplet around 777.6 nm (vacuum wavelengths) is spectrally shifted within the spectral band pass transmission response curves per pixel. This parameter needs to be calibrated, because it affects the accuracy of the DT radiometric calibration, as well as the average detection probability itself.

All required calibration parameters, required instrument design parameters and 0-1 algorithm parameters will be stored in the level-1b DPPF file(s).

The employed on-ground calibration equipment will include:
- (radiometrically calibrated) integrating sphere with co-aligned optical pulse emitter(s) at 777.6 nm (vacuum wavelength).
- Precision rotary stages.
- Collimator.
- Monochromator.

The complete instrument with all 4 optical cameras will first be integrated and then placed in a sufficiently large thermal-vacuum facility. Subsequently the 4 optical cameras will be calibrated and their performances verified one after the other.

6. LIGHTNING IMAGER IN-ORBIT CALIBRATION
The possibilities for performing in-orbit calibration are rather limited for the LI. However, some possibilities exist. It is possible to vary the detector exposure time in orbit as described above for the on-ground calibration measurements. These measurements allow recalculating (within the 0-1b data processing software) the following calibration key parameters for 0-1b data processing based on in-orbit measurement data:

- the pixel-dependent dark current,
- pixel-dependent electronic offset,
- pixel dependent non-linearity,
- RTS pixel map,
- Bad and Dead Pixel Map (BDPM).
- (Relative) electronic gains.

All in-orbit calibration measurements and analyses results are stored in the level-1b DPPF data products, in case it concerns newly calculated calibration parameters, or in the level-1b Calibration data products otherwise, as calibrated level-1 data or as raw data or both.

The Background radiance images, obtained every 30 seconds, can be used to create histograms of Earth radiances (or rather: Earth reflectances = Earth radiance / sun irradiance) as a function of a number of parameters: illumination level (or Solar Zenith Angle), latitude, longitude, time of day, season (e.g. per month). So basically, the histograms are created per detector pixel (ground pixel), but in a predefined fixed latitude/longitude grid of e.g. 0.5°x0.5°. The illuminated histograms can be used to calibrate / verify the optical throughput and any potential degradation thereof. In the histograms the surface reflectance (at 777.6 nm) would be found at the low-reflectance side, while clouded scenarios, including Deep Convective Clouds (DCCs) would be found at the high-reflectance side of the histograms. DCCs are also used as one of the ways for the radiometric calibration monitoring of the Geostationary Lightning Mapper (GLM) on GOES-R (Ref3). The non-illuminated histograms can be used to calibrate / verify the detector properties and any potential degradation thereof. The non-illuminated Background radiance images can also be used directly to monitor / calibrate potential in-orbit detector radiation damage effects, for example resulting from high-energetic protons that are known to cause permanent lattice damage to the Silicon, resulting in increased dark current or in the occurrence of so-called Random Telegraph Signals (RTS). Detector pixels featuring RTS have multiple quasi-stable dark current levels and transitions between these levels may occur statistically. If these RTS effects occur for LI and if they are significant, they need to be monitored and possibly calibrated.

The LI instrument is also capable of observing stars with a bright enough magnitude. These measurements will be used to assess the in-orbit two-dimensional Point-Spread-Functions, initially calibrated on the ground, and provide additional input data for the Image Navigation and Registration (INR) processing.

Finally, the LI instrument will observe the moon, whenever a possibility presents itself. These data will be used to assess the PSFs, the radiometric calibration accuracy and the instrument in-orbit stray light performance.

The in-orbit verification of the LI lightning detection capabilities such as Instrument Average Detection Probability (IADP) and Detection Efficiency (DE) is a complex and time-consuming task. The LI performance will need to be compared / cross-calibrated with other satellite equipment (GLM (GOES), LIS-ISS (Ref4)) and/or ground-based lightning detection networks: ATDNet (UK), Meteorage (France), LINET (Germany), NordLIs (Scandinavia), etc. These networks cover smaller or larger regions of the globe and/or Europe.

These verification activities are obviously complicated by the fact that different satellite-based lightning detection systems observe different scenes and parameters, as well as by the fact that satellite-based lightning detection systems and ground-based lightning detection systems detect at different frequencies in the optical or radio domain and typically see, as a result, different phenomena associated with the flashes. In addition, different sensitivities of the ground-based networks as function of location on the Earth further complicate the comparisons. Some systems are more sensitive to cloud-to-cloud flashes, whereas others may be more sensitive to cloud-to-ground flashes.

A distinct validation possibility will arise when two LI instruments will be operational in orbit simultaneously. However, currently it is clear that this will not be realized prior to 2025-2026.

Further details on these verifications and comparisons will have to be worked out in the future in the LI calibration and verification plans.

7. CONCLUSIONS

The Meteosat Third Generation Lightning Imager (MTG-LI) instrument and mission have been described and discussed. The LI lightning optical pulse detection principles have been described, as well as the LI 0-1
and some of the 1-2 data processing aspects. The on-ground and in-orbit calibrations have been presented, as well as the initial plans for in-orbit verification of the LI lightning detection performance. The various aspects show that the development of the LI system and instrument is technically and scientifically challenging. The MTG-LI system and instrument development is well under way for launch on MTG-I1 in 2021.

8. REFERENCES


Figure 5: Generic 0-1b data processing algorithm block. Algorithms / corrections requiring input calibration key data are indicated in green.
Figure 6: 0-1b data processing algorithm block for Detected Transients (DTs). Algorithms / corrections requiring input calibration key data are indicated in green.
Figure 7: 0-1b data processing algorithm block for background radiance images. Algorithms / corrections requiring input calibration key data are indicated in green.