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Meteosat Third Generation: a System change to bring MTG-I1 in Routine Operations

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Abstract

Building on the decades-long legacy of Meteosat's first and second-generation satellites, the Meteosat Third Generation (MTG) system aims to provide more precise and more frequent data to forecast rapidly developing and high-impact weather events. By improving nowcasting, or very short-range forecasting, MTG will also help improve the accuracy of longer-range forecasts. MTG is one of the most complex and innovative geostationary meteorological satellite systems ever built. The complete constellation consists of three spacecraft: two imaging satellites (MTG-I) and one sounding satellite (MTG-S). The first of the new satellites, MTG-I1, was launched December 2022.

The Flexible Combined Imager (FCI) is one of the main instruments on board of the MTG-I satellites and provides state-of-the-art observations of Europe and Africa for forecasting severe weather, and near-real-time monitoring of our changing atmosphere, land surfaces and oceans. The FCI is essential for monitoring and forecasting severe weather events, such as storms. It will also provide more precise information about fog, volcanic ash, air mass characteristics, clouds and aerosols and will assist in the detection and monitoring of fires.

The FCI on the MTG-I satellites will continue the very successful operation of the Spinning Enhanced Visible and Infrared Imager (SEVIRI) instrument on Meteosat Second Generation (MSG) satellites.

During the MTG-I1 System Commissioning a failure was experienced on the FCI Calibration and Obturation System. The Calibration and Obturation System for the FCI instrument provides optical source selection for observation, calibration (Infra-red IR by a black body and Visible and Near Infra-red VNIR by a Metallic Neutral Density (MND) filter) and obturation tasks by inserting the appropriate optical elements in the light path. By not operating the Calibration Obturation System anymore, FCI loses its main on-board calibration sources for the Visible and Infrared channels.

The mitigation action put in place by EUMETSAT rely on the offline Mission Integrated Calibration Monitoring and Inter-Calibration System (MICMICS), able to retrieve collocated acquisitions from the Infrared Atmospheric Sounding Interferometer (IASI) carried on the MetOp satellites and use them for external calibration of FCI radiometry with an acceptable accuracy. Several challenges have been addressed for the implementation of such change in the MTG System, from the interface change allowing the new calibration data to arrive to the EUMETSAT Data Processing Facility to the "upgrade" of the MICMICS tool, initially foreseen for off-line calibration monitoring, to a more prominent role towards operations. This presentation describes the change to the MTG System in terms of design and operation for the implementation of the selected solution.

Keywords: EUMETSAT, System Engineering, Flexible Combiner Imager, Data Processing.

Acronyms/Abbreviations

COM	Calibration and Obturation Mechnanism
CrIS	Cross-Track Infrared Sounder
ESA	European Space Organisation
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
FCI	Flexible Combiner Imager
FDIR	Failure Detection Isolation and Recovery
GSICS	Global Space-based Inter-Calibration System
IASI	Infrared Atmospheric Sounding Interferometer
IDPF	Instrument Data Processing Facility
IQT	Instrument Quality Tool
IR	Infrared
L2PF	Level2 Data Processing Facility
LEOP	Launch and Early Orbit Phase
LI	Lightning Imager
MASIF	Monitoring and Supporting Infrastructure Facility
MICMICS	Monitoring and Inter-Calibration System
MND	Metallic Neutral Density
MSG	Meteosat Second Generation
MTG	Meteosat Third Generation
RF	Radio Frequency
SEVIRI	Spinning Enhanced Visible and Infrared Imager
SMART	Service Monitoring and Reporting Tool
TRR	Test Readiness Review
TRB	Test Review Board
VNIR	Visual-Near Infrared

1. Introduction

The goal of this paper is to offer a comprehensive overview of the system changes that EUMETSAT implemented in response to a satellite anomaly that was discovered during the commissioning phase of the MTG-I1 satellite. The various System modifications were put in place at satellite and ground segment level, addressing this unexpected issue and ensuring the completion of the Satellite and System commissioning phase and the entry in operation of the first Meteosat Third Generation satellite mission.

A key factor in the successful implementation of these changes was the close collaboration among various teams within EUMETSAT, which brought together diverse areas of expertise to understand the issue and find the appropriate mitigation solution. In addition to EUMETSAT's internal efforts, the support from ESA (European Space Agency) and the industrial partners played a crucial role in providing the necessary resources, knowledge, and technical expertise. Their contributions were vital to ensuring that the system changes were designed and implemented effectively.

Ultimately, this successful implementation of the System change demonstrates the strength of teamwork, the flexibility of the MTG System and the importance of a cooperative approach in space operations. The ability to adapt and respond swiftly to unforeseen challenges ensures that the MTG-I1 satellite will continue to meet its mission objectives, contributing valuable data for weather monitoring and forecasting.

2. MTG-I1 System Commissioning timeline summary

The MTG-I1 satellite was successfully launched in December 2022, marking a significant milestone in the ongoing development of the Meteosat Third Generation (MTG) program. Following the successful completion of the Launch and Early Orbit Phase (LEOP), the satellite transitioned into its commissioning phase, which began shortly thereafter. The commissioning phase was both an intense and highly rewarding experience, requiring the collaboration of multiple specialized teams, all of whom worked together seamlessly to ensure the satellite's operations were fully understood and optimized.

Throughout this period, teams from various domains within EUMETSAT, as well as external partners, played crucial roles in expanding their knowledge and expertise regarding the new satellite's behaviour. They focused on both the operational and technical aspects of the MTG-I1, becoming deeply familiar with its unique capabilities and specific operational requirements. This process not only required intense focus and coordination but also provided an invaluable opportunity to refine the understanding of how the satellite's complex systems interact and perform in a real-world environment.

The commissioning phase was initiated with the Radio Frequency (RF) phase, a critical first step in characterizing the communication systems on board the MTG-I1 satellite. This phase involved in-depth testing and analysis of both the S-band and Ka-band frequencies used by the satellite for transmitting housekeeping telemetry, sending telecommands, and for the reception of payload data on the ground.

After the successful completion of the Radio Frequency (RF) phase, the commissioning activities for the MTG-I1 satellite progressed to the next crucial stages, focusing on the satellite platform checks and on the activation of both of the satellite's instruments: the Flexible Combined Imager (FCI) and the Lightning Imager (LI).

The initial steps in this phase involved thorough checks of the satellite platform to ensure that all systems were operating as expected. This included verifying the health of the satellite's platform components, such as power, thermal, to ensure that the satellite was fully ready for the activation of its payload instruments.

For the FCI, a decontamination process was carried out, which is a standard procedure to remove any residual contamination that may have been left after the satellite's manufacturing and launch phases. This decontamination step is crucial to ensuring the integrity and best performance of the instrument's optics and sensors, which are highly sensitive and essential for capturing high-quality imagery for weather monitoring.

Following the successful activation and decontamination of the instruments, a significant phase of Level 0 data acquisition began. During this phase, the commissioning team worked diligently to acquire and store data from the FCI and LI, enabling them to assess the instruments' performance under actual operational conditions.

At this stage, the commissioning team was able to begin a detailed characterization of the instruments' performance in relation to the mission's requirements. This process involved comparing the collected data with the predefined performance specifications to ensure that the instruments were functioning as expected and meeting the scientific objectives of the mission. Calibration activities were also carried out at the satellite level, allowing for the fine-tuning of the instruments.

Additionally, the commissioning of the entire ground segment was completed during this period, ensuring the reception, processing, and distribution of data to the final user was successful.

By the end of this phase, the commissioning team had successfully characterized the instruments' performance, completed calibration activities, and ensured that the ground segment infrastructure was fully operational, positioning the MTG-I1 satellite for its upcoming operational phase.

3. The FCI Calibration and Obturation System Anomaly

Towards the conclusion of the System Commissioning phase and just before transitioning into the nominal routine operations, the MTG-I1 satellite was relocated from its commissioning position to the operational position at zero degrees longitude in the geostationary orbit.

Just prior to initiating the relocation maneuver, on DOY 013 2024, an unexpected anomaly occurred that impacted the Flexible Combined Imager (FCI). In response to the anomaly, the FCI Failure Detection Isolation and Recovery (FDIR) mechanism was triggered in order to protect the instrument from potential damages.

As part of the protective response, the FCI autonomously reconfigured itself, transitioning into a protective "Survival Mode" and actuating the Calibration and Obturation Mechanism (COM) to “Shutter” position (e.g. avoiding any light path to enter the instrument). The root cause analysis has not led to identify a unique cause for the anomaly, moreover a premature aging of the component could not be excluded. There is no impact on the recurrent satellites.

The Calibration and Obturation Mechanism (COM) for the FCI instrument, which is part of the Calibration and Obturation System, provides optical source selection for observation, shutter protection and calibration by inserting the appropriate optical elements in the light path, such as a blackbody for IR calibration and a Metallic Neutral Density (MND) for VNIR calibration. By not being able to operate the COM anymore FCI loses its main on-board calibration sources.

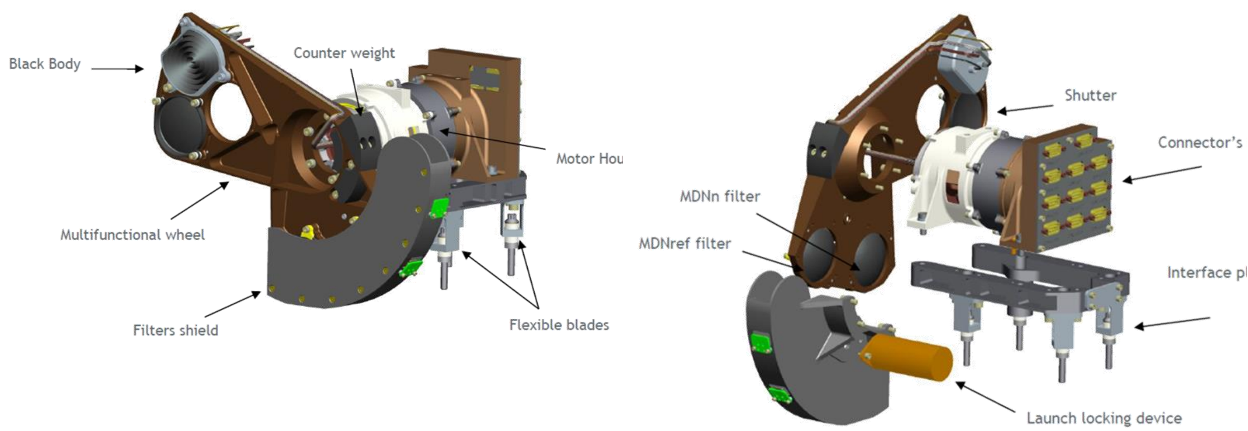

Fig.1 The FCI Calibration and Obturation System

4. The mitigation action

The mitigation action put in place by EUMETSAT is at System level, involving Satellite and Ground Segment.

At the satellite level, a specialized task force was formed, composed of teams from EUMETSAT, the European Space Agency (ESA), and the satellite’s industrial partners. This collaborative effort aimed to address the anomaly and implement solutions to ensure the success of the MTG-I1 mission.

The nominal side of the FCI COM was considered as "failed" and the operational approach for the MTG-I1 satellite was modified aiming to rely on the redundant electronic board and to reduce the number of movements requested from the FCI COM, by keeping the FCI in Observation mode during manoeuvres, avoiding moving the FCI COM during mode changes and modifying the on-board Fault Detection, Isolation, and Recovery (FDIR).

At Gound Segment level, the mitigation action put in place by EUMETSAT rely on the offline Mission Integrated Calibration Monitoring and Inter-Calibration System (MICMICS). This processing tool retrieves FCI-collocated acquisitions from the Infrared Atmospheric Sounding Interferometer (IASI) carried on the MetOp satellites and use them to compute an external source of calibration against which compare FCI radiometry in order to monitor and correct for the normal FCI radiometric gains evolution.

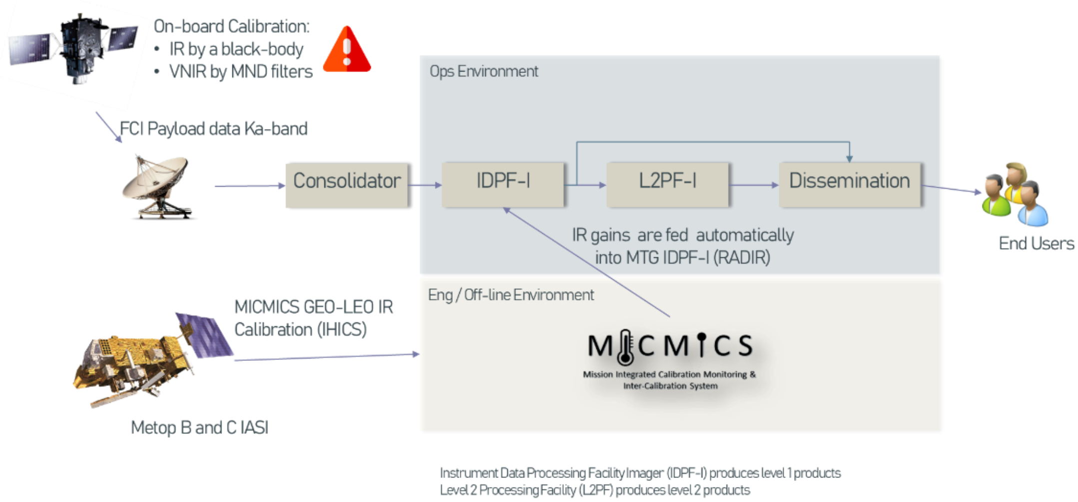

Fig.2 The Data Processing upgrade

The Mission Integrated Calibration Monitoring and Inter-Calibration System (MICMICS) plays a critical role in ensuring implementation of the mitigation solution. MICMICS is responsible for generating average infrared (IR) channel gains. This system uses data from the Infrared Atmospheric Sounding Interferometer (IASI) instruments on both Metop-B and Metop-C satellites, which serve as reference instruments for calibration.

To ensure the quality and accuracy of the gains generated by MICMICS, the estimated gains are subjected to an independent validation process. This validation is done by comparing the MICMICS-IASI-generated gains against data from other advanced instruments, specifically the Cross-Track Infrared Sounder (CrIS) instruments aboard the NOAA-20 and NOAA-21 satellites. These instruments are also highly accurate and provide valuable independent verification of the gain estimates, helping to ensure that the calibration process is precise and reliable. This cross-checking method serves as an additional layer of confidence in the data, verifying that the calibration measurements are consistent and accurate.

In order to address potential gaps or disruptions in the availability of source data, the MICMICS system is designed to be robust and resilient. When data from the reference instruments is unavailable, the system is able to generate predicted calibration gains for the upcoming period.

The predicted IR channel gains are then converted into pixel-to-pixel gain adjustments using the known pixel-to-pixel non-uniformity. These pixel-level adjustments are automatically ingested in the Data Processing Facility and applied to the raw data captured by the satellite's instruments to generate synthetically calibrated data at Level1.

Fig.3: FCI new calibration method implementation

5. The overall MTG System Change

The Mission Integrated Calibration Monitoring and Inter-Calibration System (MICMICS) was originally created as an off-line tool, meaning that requirements for availability were not of a primary importance. With the new approach of providing external calibration for MTG-I1 on a regular basis, the role of this tool, its availability and deployment in a dedicated environment become of a paramount importance.

Following a successful Kick Off meeting on the 11th of July, the implementation of the agreed solution has been conceived in two phases:

- Phase 1: implementation based on an automation of the transfer from the Off-line Tools (MICMICS) Prototype hosted in the Technical Computing Environment
- Phase 2: implementation based on the deployment of an updated MICMICS within a Multi-mission Monitoring environment

This project was coordinated by the System Engineering Team at EUMETSAT, the impacted requirements at System and Ground Segment level were analysed in order to start with the overall design definition, interface change and operational analysis phase.

The first milestone was the implementation of an automatic transfer of MICMICS calibration data to the Data Processing facility (IDPF), with a configurable transfer frequency and optimized to the mission needs. The monitoring functionalities of this new data transfers in the EUMETSAT Ground Segment are implemented using the EUMETSAT operational Multi Mission tools (e.g. SMART, GEMS).

In order to ensure full compliance with EUMETSAT's operational standards and requirements, all relevant procedures and operational guides have been updated. This process involves a comprehensive review and revision of existing documentation to align with the new operational practices.

At the conclusion of the implementation phase, a comprehensive end-to-end (E2E) system testing campaign was organized to thoroughly validate the new system's performance and functionality. This testing phase is critical to ensuring that the system operates as intended across all components and interfaces, providing assurance that all parts of the system are integrated seamlessly and performing optimally.

To kick off this process, a series of formal reviews were conducted, including the Test Readiness Review (TRR) and Test Review Board (TRB). The TRR ensures that all necessary preparations are in place, such as the availability of test resources, the completeness of test plans, and the readiness of the system for rigorous evaluation. The TRB, on the other hand, is a board comprised of key stakeholders, technical experts, and decision-makers who assess the results of tests and provide oversight and guidance to the testing process. These reviews ensure that the testing objectives are clearly defined and that the system is ready for the comprehensive evaluation that follows.

The goal of the E2E testing is to verify that all components of the system interact correctly, that data flows smoothly between different parts of the system, and that the system meets all performance requirements under operational conditions.

End to End new reliability and availability figure have been updated.

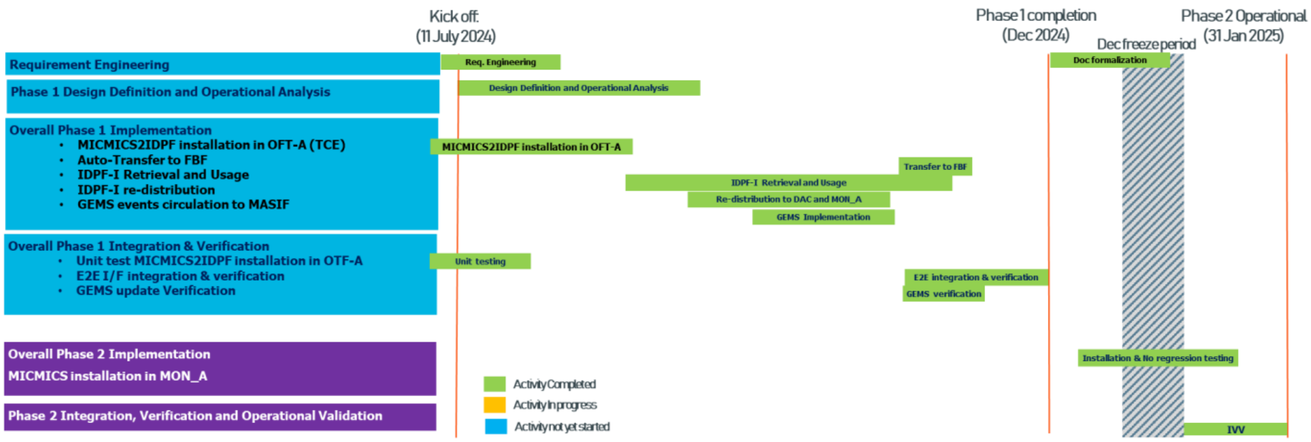

Fig. 4: MTG-I1 System Change Plan

6. Conclusions

The system change implemented to resolve the FCI anomaly was a decisive and successful intervention that not only restored the satellite's image quality performance but also enabled the MTG-I1 satellite to move forward into its routine operations. The effectiveness of this solution highlighted the resilience of the satellite's design and the expertise of the teams involved in identifying, addressing, and resolving the issue efficiently.

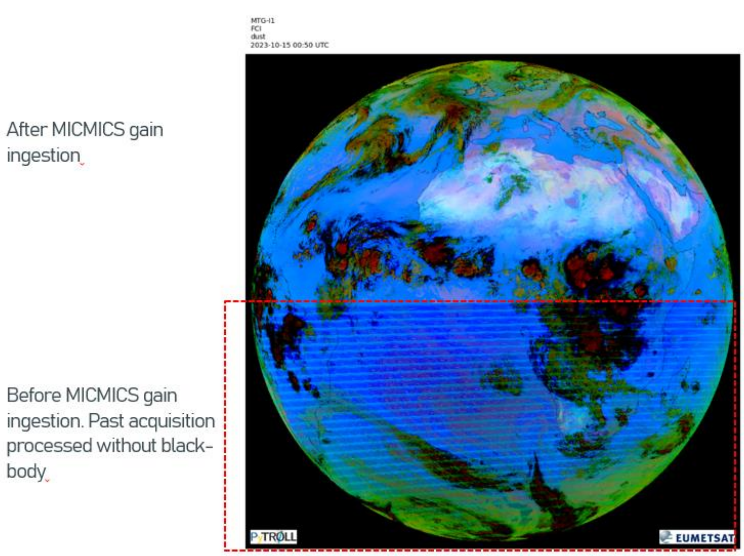

Fig.5 Ingestion of synthetic Calibration

Intercomparison against the Cross-track Infrared Sounder (CrIS) on NOAA-20 and NOAA-21 satellites, as well as the SEVIRI instrument onboard the Meteosat Second Generation (MSG) satellites, has provided strong evidence that the external calibration process for the FCI is successful. The calibration has yielded biases across all Infra-Red channels that are consistently low, with deviations well within the ±0.2 K range. These values are significantly lower than the user-defined threshold of <0.7 K, further validating the high accuracy of FCI's radiometric calibration.

MTG-I1 has been successfully delivering FCI operational data to all users since December 2024, marking a significant milestone in the satellite's mission. This achievement represents a critical step forward in providing accurate, high-resolution imagery for weather monitoring, environmental analysis, and climate research. The successful delivery of operational data is not only a confirmation to the capabilities of the MTG-I1 satellite but also a reflection of the exceptional teamwork and collaboration across various departments, ESA, industrial partners and other organizations involved in the mission.

The successful execution of the mission was made possible through the dedicated coordination and collaboration of multiple teams at EUMETSAT. Key teams involved include:

- System Engineering and Commissioning: This team played a pivotal role in ensuring that the satellite and systems were designed, integrated, and tested to meet all mission requirements. Their expertise was crucial in managing the complex technical aspects of the MTG-I1 satellite, ensuring that all systems functioned together seamlessly.

- Instrument Functional Chain: The Instrument Functional Chain team was responsible for ensuring that the payload and its associated systems operates effectively throughout the mission. They focused on the performance of the instrument, monitoring its functionality, and resolving any issues that arose during the operational phase, ensuring continuous high-quality data acquisition.

- Operations: The Operations team was tasked with the day-to-day management of the satellite and its systems. They ensured that all satellite operations ran smoothly, from commissioning to routine activities to responding to anomalies. Their efforts were integral in maintaining the satellite's optimal performance and ensuring that the payload remained fully operational throughout its mission.

- Remote Sensing and Product: This team was responsible for managing the data products generated by the satellite. They worked closely with other teams to ensure that the data collected by the payload was processed, calibrated, and made available to users in a timely and reliable manner. Their work ensured that the final data products met the high standards required for operational use in weather forecasting and environmental monitoring.

- Data Processing: The Data Processing team handled the complex processing of the raw satellite data, transforming it into usable products that could be disseminated to users. Their role was essential in ensuring that the processed data maintained its accuracy and relevance, which is vital for decision-making in meteorological and climate-related applications.

In addition to the exceptional efforts of the EUMETSAT teams, the support and collaboration of external partners, including the European Space Agency (ESA) and various industrial partners (Thales Alenia Space, OHB), were also key to the mission's success. ESA provided valuable expertise and resources, helping ensure the satellite's design, development, and deployment met the required specifications. The industrial partners played a critical role in building the satellite's hardware and systems, providing technical know-how and support throughout the mission lifecycle.

This successful collaboration between EUMETSAT, ESA, and industrial partners demonstrated the power of teamwork in overcoming challenges and achieving mission success. Thanks to their collective efforts, MTG-I1 is now delivering high-quality operational data to users worldwide, supporting a wide range of applications in weather forecasting, climate monitoring, and environmental management. This success also highlights the ongoing commitment to advancing satellite technology and ensuring that valuable data continues to be available for global scientific and operational use.

Metop-B/C IASI's precise calibration has been proved to be key to achieving external FCI calibration. The achievement also relied on SEVIRI and Global Space-based Inter-Calibration System GSICS heritage, the In-depth FCI instrument expertise in EUMETSAT, the EUMETSAT autonomy on the usage of Cal/Val tools, hands-on know-how on the processing libraries and the excellent Metop-B/C IASI calibration.

References

[1] INCOSE. (2023). INCOSE Systems Engineering Handbook: A Guide for System Life Cycle Processes and Activities (5th ed.). Hoboken, NJ: John Wiley & Sons. ISBN: 978-1-119-81429-0

[2] European Cooperation for Space Standardization (ECSS), *ECSS-E-ST-10C: System engineering general requirements*, Feb. 15, 2017 [Online]

[3] Mousivand, A., Straif, C., Lekouara, L., Burini, A., Debaecker, V., Hewison, T., Stock, S., and Bojkov, B. In-Flight Calibration of GEO Weather Satellites Using Alternative Methods: MTG-I1 FCI Case Study. In preparation.