Phase A Space Segment
System Study for
Meteosat Third Generation

System Requirement Document
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1 Introduction

1.1 Scope and Applicability

This System Requirement Document (SRD) establishes the system requirements applicable to the Space Segment phase A study of the Meteosat Third Generation (‘MTG’ or ‘the mission’ in the text that follows) Mission

“MTG” is the generic name identifying the future European Operational Geo-Stationary Meteorological system that will replace the Meteosat Second Generation System (MSG) at the end of its operational life, currently expected by 2015.

The document includes the initial derivation of the MTG Space Segment System requirements from the mission requirements as formulated by EUMETSAT in RD[1] with support from a MTG Mission Team (MMT). The mission requirements, and thereby the space segment system requirements, may evolve during the phase A study. The study shall in turn support the consolidation of the system/mission requirements.

The document encompasses the space segment (i.e., platform and payload), It also provides interface requirements to the ground segment, the launcher and the operations. In previous system studies at pre-phase A level, mission implementation concepts have been proposed and a first allocation of performance requirements to the various subsystems has been completed. The results of these studies (see RD[3, 4]) are considered an essential input to the phase A study but the system requirements in this document, though referring to a specific system implementation concept, do not reflect any performance allocation to the architectural elements of the Space Segment System since their definition is a main objective of the current phase A study.

Unless explicitly stated, all requirements shall apply to the entire space segment system during in-orbit operating conditions up to the mission End-of-Life (EOL) with the margins specified herein.

The document contains also product assurance (PA) requirements to the extent deemed necessary to perform the tasks of the phase A study. Though PA is mainly involved in later phases of the development, proper consideration of the PA approach in the study is deemed essential to define the project cost and risk correctly.

1.2 Background

The MTG Phase A is starting following the conclusion of the MTG User Consultation Process initiated by EUMETSAT, with the support of ESA, to prepare for a future operational geostationary meteorological satellite system in the time frame 2015-2030.
The first phase of the User Consultation Process was devoted to the definition and consolidation of end user requirements and priorities in the field of Medium/Short Range global and regional Numerical Weather Prediction (NWP), Nowcasting and Very Short Term Weather Forecasting (NWC) and to the definition of the relevant observation techniques. The intermediate results of this first phase were presented to, and discussed with the user community at the first Post-MSG User Consultation Workshop convened by EUMETSAT in November 2001 and further consolidated with the support of ESA in the area of potential observation techniques and sensor concepts, including the execution of dedicated industrial studies.

A major output of the first phase was the MTG Mission Requirement Document (MRD) produced by EUMETSAT with support from an independent Mission Team and from ESA.

The core of the second part of the MTG User Consultation Process was the MTG System Architecture Studies at pre-phase A level, initiated by ESA in October 2004 and concluded in March 2006, after a short extension of the study devoted to the analysis of alternative system/instrument concepts in addition to the baseline concept approved at the Mid-Term Review and agreed in the frame of the 2nd MTG User Consultation Workshop convened by EUMETSAT in April 2005 (RD[3,4]).

The output of the pre-phase A study has been jointly evaluated by ESA and EUMETSAT to derive plans and requirements for Phase A System studies and relevant technology/pre-development activities, taking into account the recommendation issued by the MTG Mission Definition Review (MDR) at the end MTG User Consultation Process and the subsequent disposition approved by the relevant EUMETSAT delegate bodies. Additional details about the close-out of the MTG User consultation process, the Phase A preparation and the relevant disposition can be found in RD[1].

The current MTG phasing and planning assumes, following completion of the phase A studies in 2008, phase B in 2008-2009, phase C/D in 2009-2014 and a launch date for the first satellite supporting the imaging mission in 2015.

The MTG Phase A activities will be carried out by ESA and EUMETSAT. ESA will be responsible for the Phase A activities at Space Segment level. EUMETSAT will be responsible for the Ground Segment Phase A and the end-to-end system.

A Mission Team has been set up to advice EUMETSAT on the definition of the mission. The Mission Team has supported the production of the MTG Mission Requirement Document (MRD, RD [1]), which is provided as a reference for this study.

The Agency will ensure the coordination between the Phase A space segment studies and EUMETSAT.

2 Applicable and Reference Documents

The following sections define the documents that are applicable to the Space Segment Phase A studies and are therefore to be considered, fully or partially as an integral part of the Space Segment System Requirement Document, as specified in the following sections of the SRD.
The applicable documents are organised into two groups, namely MTG Mission specific documents and the normative documents. The first group provides additional requirements addressing specific elements of the MTG Space Segment.

The second group includes design and manufacturing standards that provide normative requirements to the execution of the work. As the Phase A is a phase of analyses, trade-off activities, requirements definition and of planning/costing of subsequent development phases, the applicability of design/manufacturing standards is rather limited. However, they have to be taken into account for establishing design constraints/redundancies, to establish the development approach and for the cost estimation exercise.

2.1 Applicable Documents

The applicable documents are grouped in two categories: MTG Mission Specific Documents and Normative Documents.

2.1.1 MTG Mission Specific Documents

The mission specific documents are identified within this SRD as AD[xx].

The account can be accessed via a web-browser with the URL:
ftp://mtgdoc-a@ftp.estec.esa.int - This will then prompt for the ID/password
ID: mtgdoc-a
Password: mtg-pa55


2.1.2 Normative Documents

ECSS standards are available for download at: http://www.ecss.nl. The other documents are either older PSS ESA standards or well-known space engineering documents that are assumed to be familiar to the bidder.

In case of conflicts between this document and the normative documents the conflict shall be brought to the attention of the Agency for resolution. The latest issue of the applicable document shall apply, unless otherwise identified. The applicability of Level 1 ECSS standards (Policy and Principles) extends implicitly to the lower level standards. In some cases the applicable document list refers explicitly to lower level standards.

The normative documents are identified within this SRD as ND[xx].
[1] ECSS-E-00A Space Engineering - Policy and Principles
[3] ECSS-M-00-02A. Tailoring of space standard
[4] ECSS-P-001B. Glossary of Terms
[5] ECSS-E-10-02A Verification
[7] ECSS-E-10-04A Space Environment
[8] ECSS-E-10-05A Functional Analysis
[10] ECSS-E-10 Part 7A System engineering, Part 7: Product Data Exchange
[12] ECSS-E-30 Part 1A Mechanical: Thermal Control
[15] ECSS-E-30 Part 5.1A Mechanical: Liquid and electric propulsion for spacecraft
[17] ECSS-E-30 Part 7A Mechanical - Part 7: Mechanical parts
[18] ECSS-E-30 Part 8A Mechanical - Part 8: Materials
[20] ECSS-E-50 Part 1A Communications Principles and Requirements
[22] ECSS-E-50-05A Radio Frequency and Modulation
[25] ECSS-E-50-03 Draft 1 Packet Telemetry
[26] ECSS-E-50-04 Draft 1 Packet Telecommand
[27] ECSS-E-60A Control Engineering
[28] ECSS-E-70-41A Ground Segment and Operations Telecommand and Telemetry Packet Utilization
[29] European Code of Conduct for Space Debris Mitigation
[30] CCSDS 701.0-B-3 Advanced Orbiting Systems, Network and Data Links
[31] CCSDS 301.0-B-3 Time Code Formats
[32] CCSDS 121.0-B-1 Lossless Compression
[33] CCSDS 727.0-B-2 CCSDS File Delivery Protocol (CFDP)
[34] PSS-01-202 Preservation, Storage, Handling and Transportation of ESA Spacecraft Hardware
[35] ECSS-Q-30-02A Failure modes, effects and criticality analysis (FMECA)
[36] ECSS-Q-40-02A Hazard Analysis
[37] PSS-01-402 Design Safety Requirements
[38] PSS-01-403 Hazard Analysis and Safety Risk Assessment
[40] ECSS-Q-40-04 Part 2A Sneak analysis - Part 2: Clue list
[41] ECSS-Q-40-12A Fault tree Analysis
[42] PSS-01-608 Generic Specification for Hybrid Micro-circuits
[43] PSS-01-605 Capability Approval for hermetic thin film hybrid micro-circuits
[44] PSS-01-606 Capability Approval for hermetic thick film hybrid micro-circuits
[45] ECSS-Q-60-11A Derating and end-of-life parameter drifts - EEE components
[46] ESA Tailoring of ECSS-Q-60-11A (TEC-Q/04-6649/QCT)
[47] ECSS-Q-70A Materials, mechanical parts and processes
[48] PSS-01-700 Technical reporting and approval for materials, mechanical parts and processes
[49] PSS-01-703 Black anodising of aluminium with inorganic dyes
[50] PSS-01-705 Detection of organic contamination of surfaces by infrared spectroscopy
[51] PSS-01-706 Particle and UV radiation testing of space materials
[52] PSS-01-748 Requirements for ESA approved skills, training and certification
[53] ECSS-Q-70-71A rev. 1 Data for selection of space materials and processes
[54] PSS-02-10 Power Standard, Vol.1, Issue1
[55] ECSS-E-20-01A Multipaction design and test
[56] ECSS-E-30-01A Fracture Control
[57] MIL-STD-1522A Structural design and verification of pressurized hardware
[58] PSS-04-104 Ranging
[59] ECSS E-70- Part 2A Ground Systems and Operations Part 2; Document Requirements Definition (DRD)
[60] ECSS E-70-31A Space Engineering Ground Systems and Operations – Monitoring and Control Data Definition
[61] ECSS E-70-32A Space Engineering – Test and Operational Procedure Language
[62] ECSS-E-70-11A Space Segment Operability
2.2 Reference Documents

The reference documents are identified within this SRD as RD[xx].
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3 The MTG Mission

This chapter provides an overview of the end-to-end MTG mission. Limitations applicable to the MTG Space Segment Phase A are identified.

3.1 Mission Objectives

The objective of the MTG mission is to provide Europe and, by extension, the International Community, with an operational satellite system able to support accurate prediction of meteorological phenomena and the monitoring of climate and air composition through operational applications for the period of time between 2015 and 2030.

The MTG mission shall capitalise on the continuation and enhancement of the MSG capabilities and on the effort of specialised communities of expert in the main application areas (Nowcasting, Global/Regional Numerical Weather Prediction, Climate and Atmospheric Chemistry Monitoring) who supported the definition of the essential improvements required for the future geo-stationary observing system.

3.1.1 Observation Missions

The detailed analysis of the mission objectives (see RD [1]) has led to the definition of the observing mission requirements that have been categorised in the following five primary groups:

- **High Resolution Fast Imagery Mission**

  The High Resolution Fast Imagery (HRFI) mission stems from the MSG High Rate Visible mission and is designed to meet the requirements for information on rapid development, particularly related to cloud development characterising the fast component of the hydrological cycle.

  Its goal is to meet the key/user service needs of nowcasting application on convective forecast techniques and to support estimates of two-dimensional wind profiles by tracking cloud systems.

  On the basis of the user/service needs the mission is characterised by requirement on high temporal and spatial resolution and on observations to be performed on a limited number of channels in the visible and infrared part of the spectrum over selectable portions of the full disk.

  Furthermore, the HRFI mission shall complement the MTG Full Disk High Spectral resolution Imagery (FDHSI) and Infra-Red Sounding (IRS) missions by providing more detailed “targeted” observations over selected regions concerned with the development of active weather patterns.

- **Full Disk High Spectral Imagery Mission**

  The Full Disk High Spectral Imagery Mission (FDHSI) stems from the MSG full disk operational mission and is designed to meet the key user/service need of nowcasting/very short-term forecasting, global/regional Numerical Weather Prediction and Climate Monitoring applications.
To achieve the mission objectives the requirements on temporal and spatial resolution are less demanding than the HRFI’s but the coverage of a wide range of applications requires a larger number of spectral channels from the visible to the thermal infrared portions of the spectrum that require to be exploited simultaneously.

- **Infra-red Sounding Mission**

  The primary objective of the Infra-Red Sounding (IRS) mission is to meet the key user/service needs of Global/Regional NWP through the provision of:

  - Atmospheric Motion Vectors (AMV) with higher vertical resolution in clear air, to be extracted from the tracking of three-dimensional water vapour patterns;
  - More frequent information on temperature and water vapour profile

  Furthermore, the IRS mission shall contribute to the NWC and global/regional NWP needs concerning instability, convective and down draught convective available potential energy (CAPE & DCAPE), height assignment of atmospheric wind tracers and cloud microphysics.

  Sounding measurements with high spatial resolution (better than 10 km horizontal and 1 km vertical) and temporal resolution better than one hour will enhance the ability of National Meteorological Services (NMSs) to initialise models with more accurate observations of temperature, moisture and winds. For global models the high temporal resolution will increase the likelihood of clear sky soundings and significantly reduce the gaps from the radiosonde network over dynamically important region like e.g. the North Atlantic. Regional models and forecasters will take advantage of the high temporal sampling to better identify areas of rapidly developing atmospheric instability responsible for vertical motion, convection and precipitation development.

- **Lightning Imagery Mission**

  The primary objective of the Lightning Imagery (LI) mission is to add complementary information relevant to the detection and location of cloud-to-ground and cloud-to-cloud lightning to those provided by existing/planned ground based lightning detection systems. The highest benefits will be provided in areas not covered by ground observations, particularly when located upwind of densely populated areas. The targeted detection efficiency will allow offering a consistent level of service thus providing a “space truth” reference for different ground based lightning observation system over Europe.

  Due to the correlation between lightning and storm-related phenomena, a further objective of the LI mission is to serve as a proxy for intensive convection related to ice flux, updraft strength and convective rainfall. Further objectives are the contribution to climate monitoring regarding the observation of global lightning/thunderstorm distribution and the support to atmospheric chemistry monitoring relevant to the long-term observation of lightning as an important source of nitrous oxides.

  Additional details about the link between the observing mission and the relevant user/service needs can be found in RD [1].
3.1.2 Other Missions

The MTG observing missions shall be complemented by additional missions devoted to the acquisition and dissemination of external meteorological data and bulletins transmitted by Data Collection Platforms.

Furthermore, despite all observation missions (with the exception of the Lightning Imaging (LI) mission) are specified in terms of near real time Level 1b/1c output products, it is anticipated that level 2 products shall be required by real time users of the MTG observing mission. To this end a Level 2 Product Extraction Mission has been defined.

- **External Meteorological Data Collection and Dissemination**

  The objective of the External Meteorological Data (EMD) mission is to collect data observed and/or generated by similar operational meteorological programmes whose data is relevant/needed for further processing by, and distribution to the community of MTG users and consumers. Among others, data from MSG, and next generations of GOES-E, GOES-W, GOMS, and GMS will be collected and relayed to users and will form a coherent global dataset when combined with equivalent data and products from MTG.

- **Data Collection System**

  The objective of the Data Collection System (DCS) is to receive observations and environmental data collected by platforms in the field of view of the geo-stationary satellite and forward them to users in real time.

  The relevance of the mission goes beyond operational meteorology and covers the interest of various real time environmental monitoring applications, e.g. in the context of the European GMES initiative.

  The DCS has been supported by the succession of the METEOSAT programmes since 1977.

  Beside the specific requirements and assumptions included under section 4.5.1 of this document, additional information and applicable requirements shall be found in RD [1] and AD [1,2].

- **Level 2 Product Extraction Mission**

  The Level 2 Product Extraction Mission shall provide to near real time MTG users Meteorological Products to be extracted at a central location as well as at distributed Satellite Application Facilities (SAFs) from the Level 1b/1c data available from the MTG observation missions. At the present stage of mission definition only generic indication about the meteorological products and contributing shall be provided.

- **Support to the COSPAS/SARSAT GEOSAR System**

  Similarly to Meteosat Second Generation (MSG), the MTG system shall have the capability to accommodate a GEOSAR terminal to support the Search and Rescue mission operated under the aegis of the COSPA/SARSAT system (TBC).
3.1.3 MTG User Services

The MTG User Services are meant to provide the users of the MTG system with a range of services dedicated primarily to:

- Near real time dissemination of MTG data and products
- Archiving of, and non-real time access to MTG data and products
- Provision of ancillary services to the users (on-line access to catalogues, retrieval of archived products etc.)
- Support to mission and system operations

The following definition of “users” is used in the rest of the document:

**Near Real Time Users**: users requiring access in near real time to the MTG data and products (full or subset) via specific infrastructure

**Non Real Time Users**: users of archived MTG data, not requiring near real time access

**Central Users**: users at the EUMETSAT infrastructure responsible for mission operations

Further characterisation of users into distinct groups, in accordance to the EUMETSAT data policy, can be found in RD [1].

The MTG Users services have been categorised into three groups:

- **Near Real Time Services**

The Real-time Services, in support to all missions, will ensure that selectable near real time user groups are supplied with MTG data and Level 2 products within a very tight timeline.

The service shall include capabilities and flexibility allowing the users to subscribe and receive data at either moderate or high data rates and shall provide the functionality required to control user access - including denial - and to assure the integrity of the data.

Additionally, to support the operability and dependability of the missions, the real time services will ensure that mainly central users are provided with real-time housekeeping data to monitor the elements of the system.

For the distribution or broadcast of data to users, various degrees of service will be offered to the users, including but not limited to:

a) High data rates in the order of tens of megabits per second;
b) Low data rates in the order of a few megabits per second;
c) Lossless or lossy compressed data; and
d) Clear or encrypted data.

- **Non Real Time Services**

The Non Real Time Services shall support and enable the collection and distribution of MTG data and relevant information (operational status, mission plans, scientific data) to authorised users who have no real time requirements.
These services shall cover:

- Non real time distribution of data, products and information;
- Data storage, staging, and archiving;
- Mission Data cataloguing (update and synchronisation);
- Data ordering, retrieval and dispatching;
- Users’ administration.

Besides the data retrieval, the non-real-time services will allow the end user to access newsletters and bulletin boards providing relevant information on the MTG system and its operations, including a user guide.

- **On Line Services**

The MTG on line services shall provide users with means and mechanisms to ease and gain access to the MTG mission data, products and information.

On-line service will allow user to register, navigate through the catalogue of MTG data, retrieve historical scientific mission data, browse low to moderate resolution data/products, and request data.

Standard, wide used, and low-cost access mechanism will need to be enforced to support on-line access to some MTG data and products.

### 3.2 Relevance to the MTG Space Segment Phase A

As a consequence of the recommendations issued by the MTG Mission Definition Review board and the subsequent disposition relevant to the MTG Phase A objectives, logic and planning proposed by the EUMETSAT Secretariat and approved by the EUMETSAT delegate bodies, the following limitations apply to the Space Segment Phase A:

The HRFI and FDHSI missions shall be implemented via a single Flexible Combined Imager, in line with the baseline solution studied in the course of the pre-phase A. In the frame of this document the imagery missions shall be referred to as “Flexible Combined Imagery” Mission” (FCI) encompassing HRFI and FDHSI modes.

The UV/Vis Sounding Mission (UVS) shall not be considered in the frame of the MTG Space Segment Phase A.
3.3 Mission Elements

As defined in the course of the MTG Pre-Phase A system architecture studies, the MTG system is decomposed in the following main elements:

- Space Segment (observation payload(s), supporting platform(s) and the relevant Ground Support Equipments)
- Ground Segment Elements as needed to support the operation of the space segment, the implementation of the supporting missions and the interfaces with components external to the MTG system.
- Launcher
- Communication Infrastructure

This document identifies the requirements applicable to the MTG space segment and to the interfaces with the other elements of the MTG system.
4 MTG Space Segment Requirements

4.1 Introduction and Conventions

The following sections of this document contain the functional requirements, assumptions and constraint applicable to the phase A space segment system study of the MTG mission. This document is a Functional Specification as defined by ND[9].

The requirements are identified with the following format:

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XXXX-YYY-[Level xx]
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Where:

* XXXX: acronym identifying the system element it applies to.
* YYY: progressive number within each XXXX group
* [Level xx]: applicability of the requirements to a specific data level, when relevant

Wherever relevant, comments/clarification to the requirements are to be found in italic text below the requirement body text.

In some specific cases, requirements identifying the “goal” performance of the related function/product that would significantly enhance the usefulness for the relevant application have been defined. When relevant, this is clearly specified in the requirement body.

The requirements including a TBD (To Be Defined) leave open to the Contractor the definition and subsequent proposal to the Agency of the relevant quantitative performance and/or functions.

The requirements including a TBC (To Be Confirmed) are to be confirmed by the Agency in the course of the study. The Agency will aim at closing all TBCs by the kick-off of the study.

As a general rule and taking into account the priorities given to the relevant end users application, the observing missions’ priorities are the following (in order of importance):

1) Imagery Missions
2) IR Sounding Mission –with emphasis on meteorology instead of chemistry
3) Lightning Imagery Mission

It shall be noted that, due to the nature of the study, the generic priorities given here above as well as the specific ones provided in dedicated section of the documents, shall be used solely to rank alternative concepts and architectural solutions. The priorities shall by no means limit the analysis of the requirements, the definition of the relevant implementation concepts and the justification thereof.
4.2 Definition of Terms and Abbreviations

Data Level
The following definitions of data levels are used, see Figure 4-1:
- Observation Level 0: Raw data after restoration of the chronological data sequence for the instrument(s) operating in observation mode.
- Level 1a: Level 0 data with corresponding radiometric, spectral and geometric (i.e. Earth location) correction and calibration computed and appended, but not applied.
- Level 1b: Level 1a data radiometrically corrected and calibrated in physical units. Earth location is appended for every sample, but data is not resampled.
- Level 1c: Level 1b data resampled to a specified fixed reference grid
- Level 2: Earth located pixel values converted to geophysical parameters.

Figure 4-1 MTG Data Level Flow Diagram
**Image Rectification**
The image rectification function is where the image geometric deformation correction is applied to create Level 1c image with the property in which there is a well-defined and invariant relationship between image coordinates (lines and columns) and the Earth location (geodetic latitude and longitude). For that the level 1b image has gone through re-sampling to a grid (as specified) and interpolation processes, using a commonly agreed tool (between ESA/EUM and satellite prime contractor).

**Fixed Reference Grid**
The fixed reference grid defines the geo-referenced position of the image pixels centroids at level 1c. The grid projection(s) are defined in the MTG SRD, AD [3]. The grid angles are defined as following:
- rotation from the North-South angle along the direction defined by s2 in the definition of the satellite frame of MTG SRD, AD[3];
- rotation from the East-West angle along s3.
The grid steps are equiangular both in North-South and East-West direction and equal to the Spatial Sampling Distance (SSD) of the considered channel.

**Auxiliary data**
The auxiliary data consist of satellite data extracted from the sensors implemented onboard the satellite and its equipments to allowing radiometric, geometric and any other necessary corrections for the satellite system performances. There are two types of auxiliary data: constant data (changing per image repeat cycle, or longer time); variable data (changing at each swath in both E/W or S/N directions). The auxiliary data are delivered with each image to allow necessary corrections.

**Sample**
A sample is a radiometric measurement taken at a geographical location on the earth. Level 1a and Level 1b data consists of samples, i.e. Level 1a expressed in digital counts and Level 1b converted to physical radiometric units. The centre of the sample is the system PSF barycentre.

**Pixel**
Image pixels (picture elements of a spectral channel) are defined as image data samples after re-sampling (Level 1c and/or above) during ground-processing registered to regular grid in terms of radiance or brightness temperature.

**Spatial Sampling Distance (SSD)**
The centroid-to-centroid distance between spatially adjacent samples (of a spectral channel) on the Earth’s surface as measured at the sub-satellite point (SSP).

**Spatial Sampling Distance Error (SSDE)**
In both E/W and N/S, the difference between the actual E/W SSD (respectively N/S SSD) and the ideal E/W SSD (respectively N/S SSD) is the Spatial Sampling Distance Error (SSDE).

**Spatial Sampling Angle (SSA)**
The angle subtended by the spatial sampling distance, as seen from the satellite.
Detector element
A device that provides an electric output as a measure of the radiation which is incident to the device.

Chain
A group of elements that comprises the overall electro-optical components from the detector element, the amplifiers and the processing electronics up to the delivery of the signal to the S/C data handling.

Image
An image is defined as the overall scene acquired in an acquisition cycle. It may consist of samples (Level 1b) or pixels (Level 1c)

Imagette
A defined portion of an image (which is always smaller than the image).

Image Line
Image Lines are defined as the sequence of adjacent either horizontal or vertical pixels/samples spanning along the image array.

Site
The site is the geographic location of a sample or pixel on the Earth surface and is usually expressed in terms of latitude and longitude.

Actual Site (AS)
This site corresponds to the intersection of the line of sight (response’s CoG) with the the Earth surface at the instant that the sample was taken.

Reference Site (RS)
The reference site is the actual or true geographical location of an image pixel in the Fixed Reference Grid.

Measured Site (MS)
This site is the best estimate for the actual site (AS) of a sample and is derived from instrument/satellite auxiliary data and geometric quality analysis. It is part of the appended Level 1b data.

Corrected Site (CS)
The corrected site is the geographical location of an image pixel at level 1c. i.e. after geometric correction, image rectification and resampling onto the fixed reference grid.

Absolute Sample Position Error
The Absolute Sample Position Error (ASPE) is defined as the difference, expressed as a fraction of SSD at SSP, between the Measured Site and the Actual Site: ASPE = MS-AS. The APSE applies to Level 1a and Level 1b.
**Absolute Pixel Position Error (APPE)**

The positioning pixel error is defined as the difference, expressed as a fraction of SSD at SSP, between the Corrected Site and the Reference Site: \( \text{APPE} = \text{CS-RS} \). The APPE applies to Level 1c.

**Relative Position Error**

The Relative Position Error (RE) is the difference between the APPE of 2 corresponding pixels (i.e. having the same position \((i, j)\) in the reference grid) belonging to different images \(r, r'\) of the same channel \((k=k')\) or to different channels \(k, k'\) of the same image \((r=r')\). It is defined as the difference of the relevant Absolute Pixel Position Errors:

\[
\text{RE}(i, j, k, k', r, r', d) = \text{APPE}(i, j, k', r', d) - \text{APPE}(i, j, k, r, d).
\]

The RE applies to Level 1c data and is expressed as a fraction of SSD at SSP.

**Inter Channel Co-Registration Accuracy**

The Inter Channel co-Registration Accuracy (ICRA) between images corresponding to any pair of different spectral channels \((k_1 \text{ and } k_2)\), taken during the same repeat cycle is defined as the maximum separation of the PSF’s barycentre (the barycentre being the centre of gravity of the point spread function) of samples pairs looking at the same target on Earth. It is applicable at Level 1a and Level 1b.

**Absolute Positioning Accuracy**

The Absolute Position Accuracy (APA) is defined as the RMS of the Absolute Sample Position Error ASPE of all samples within the image.

**Absolute Geometric Accuracy**

The Absolute Geometric Accuracy (AGA) is defined as the RMS of the Absolute Pixel Position Error APPE of all pixels within the image.

**Relative Geometric Accuracy**

The Relative Geometric Accuracy (RGA) between two consecutive images is defined as the RMS of the RE for all pixels within an image at 2 consecutive repeat cycles.

**Repeat Cycle**

The Repeat Cycle is defined as the time elapsed between the start of two consecutive sets of images taken in all channels/bands, taken over a defined geographical region (i.e. with same coverage).

**Coverage**

The Coverage is defined as the geographical region covered by one full set of images taken in all channels, for a given Repeat Cycle.

**Full Disk Coverage (FDC)**

The Full Disk Coverage is defined as a 18-degree diameter circle centred at nadir, as seen from the satellite.
**Limited Area Coverage (LAC)**
The Limited Area Coverage is defined as a sub-area equal to 6-degree in South/North direction and bound in East/West direction by the 18-degree diameter circle. The preferred LAC could be the upper part of the 18-degree diameter circle covering Europe. However, any other region of 6 degree in South/North direction should be selectable.

**Spectral Channel**
For the FCI, a channel is defined by its central wavelength and width. For the IRS, the bands are composed of a set of contiguous channels and the number of channels in a band is the bandwidth of the band divided by the spectral sampling interval. The spectral sampling interval is determined by the maximum optical path difference (MOPD).

**Sounding**
A sounding is defined as the spectrum derived from all sounder spectral channels for any but fixed spatial sample position within the coverage of the repeat cycle.

**Spatial cluster of soundings**
A spatial cluster of soundings is defined as a grouping of \( N_{\text{cluster}} \) spatially contiguous soundings in any direction within the area covered over the repeat cycle.

**FCI Spectral Response Function**
For the FCI, the spectral response function \( \Phi(\lambda_0, \lambda) \) relates the radiometrically calibrated spectrally integrated radiance \( L(\lambda_0) \) measured in any spectral channel \( \lambda_0 \) with the spectral radiances \( L(\lambda) \) emanating from a spatially homogeneous scene. The spectral response function \( \Phi(\lambda_0, \lambda) \) is normalised such that its spectral integral yields 1 and is defined by:

\[
L(\lambda_0) = \int_{-\infty}^{\infty} \Phi(\lambda_0, \lambda)L(\lambda)d\lambda
\]

giving \( L(\lambda_0) \) in units of \( \text{mW/(m}^2 \text{ sr} \mu\text{m}) \).

**IRS Spectral Response Function (ISRF)**
The ISRF relates the radiometrically calibrated, spectrally integrated radiance \( L(\nu_o) \) measured with the spectral radiance \( L(\nu) \) emanating from a spatially homogeneous scene. The ISRF is normalised such that its spectral integral yields 1. ISRF is defined by:

\[
L(\nu_o) = \int_{-\infty}^{\infty} ISRF(\nu, \nu_o)L(\nu)d\nu
\]

\( L(\nu_o) \) is given in units of \( \text{mW/(m}^2 \text{ sr cm}^{-1}) \).

**ISRF Shape Index**
The ISRF Shape Index is the integral of the absolute value of the difference of the modelled \( ISRF_{mod} \) and the actual ISRF:

\[
\int_{-\infty}^{\infty} |ISRF_{mod}(\nu, \nu_o) - ISRF(\nu, \nu_o)|d\nu
\]
ISRF\textsubscript{mod} is calculated through an instrument model, called ISRF Estimation Model (ISRF EM).

**Spatial Resolution**

The spatial resolution $\Delta X$ [km] of the FCI instrument is expressed using the MTF template (see figure 4-3 for HRFI channels and Figure 4-4 for FDHSI channels), via the ‘normalised spatial frequency’ $K_N$. The normalised spatial frequency is defined by, $K_N = \frac{\kappa}{\Delta X}$, where $\kappa = 1/d$ [km$^{-1}$] is the spatial frequency and $\Delta X$ [km] the spatial resolution.

**Modulation Transfer Function**

The Modulation Transfer Function (MTF) - specified only for the FCI - is the normalized amplitude of the Spatial Frequency Response (SFR) of the instrument. The SFR is defined as the ratio of the output radiance to the scene radiance variation and given for chain $j$ as:

$$SFR_j(v) = 2 \frac{A_j(v)}{L_0} e^{i\varphi_j(v)}$$

where $L_0 = k_B B(\lambda_0,T)$ and $B(\lambda_0,T)$ the Planck function at a given wavelength and temperature, with $v$ being the spatial frequency of the target and $\varphi_j(v)$ the phase. Hence, the MTF can be expressed by

$$MTF_j(v) = \frac{A_j(v)}{A_j(v_{min})}$$

where $A_j$ is the amplitude and $v_{min}$ the minimal spatial frequency (usually $v_{min} = 0$).

The phase of the SFR $\varphi_j(v)$ could be expressed as the sum of a linear and a non-linear terms: $\varphi_j(v) = \alpha_j \cdot v + \psi_j(v)$ with $\alpha_j \cdot v$ the slope tangent to the phase function at low spatial frequency. The slope can be obtained as the first order term of a polynomial fitting of the phase function.

The SFR contains almost only instrument parameters such as optics, detectors and electronics. For a given instrument with in-field separation, the amplitude and phase of the SFR needs to be considered in the instrument design (not applicable to phase A unless deemed relevant).

**System Point Spread Function**

For a spatial sample $i$ observing in channel $j$ with centroid $v_o$ a stable scene of spectrally integrated radiance $L_{ij}(v_o, x, y)$, the measured spectral radiance $L_{ij}^m$ is given by:

$$L_{ij}^m = \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} PSF_j(x, y) \cdot L_j(v_o, x, y) \cdot dx \cdot dy$$

where: $PSF_j(x, y)$ is the system Point Spread Function for spatial sample $i$ in a channel $j$, expressed as a function of the local Earth coordinates $(x, y)$. The system PSF is the integral over dwell time of the instantaneous PSF, including optics, detectors, electronics and nominal pointing variation during dwell time, but excluding LOS instability effects. The spatial integral of the PSF is normalised to 1.
**Dwell Time**
The dwell time is the time period required to acquire a spectral channel for a given sample.

**IFOV**
The Instantaneous Field Of View (IFOV) is the angle subtended by a single detector element on the axis of the optical system.

**Integrated Energy**
Integrated Energy (IE) is a spatial integral of the system PSF of a spatial sample i and a spectral channel j over a squared area of dimension d at SSP centred around the system PSF barycentre position $(x_0, y_0)$.

$$IE(d) = \int_{x_0-d/2}^{x_0+d/2} \int_{y_0-d/2}^{y_0+d/2} PSF_{ij}(x,y) \, dx \, dy$$

IE is the ratio of the energy measured by the instrument over a squared area to the energy measured by the instrument from the entire large and uniform target/scene.

**LOS instability**
The line of sight (LOS) instability is defined as the deviation over the dwell time of the actual pointing from the nominal pointing.

**Inter-channel temporal co-registration**
The inter-channel temporal co-registration refers to the time interval separating the middle of the dwell time of any two spectral channels j and k for the same sample.

**Absolute Radiometric Accuracy**
The absolute radiometric accuracy provides the absolute knowledge accuracy of the measured radiances.

**Relative Radiometric Accuracy (repeatability)**
The relative radiometric accuracy defines the range of variability of the measured radiances $L(t)$ for the solar channels, and brightness temperatures $T_b(t)$ for the thermal channels, over a stable with time not changing scene taken at any two times $t_j, t_k$ within a specified time period $\tau$ to be defined with the calibration periods as needed:

$$\left| \frac{L(t_k) - L(t_j)}{L(t_k)} \right| \times 100 < \text{Relative Accuracy in } [\%] \text{ for the solar channels}$$

or

$$\left| T_b(t_k) - T_b(t_j) \right| < \text{Relative Accuracy in } [K] \text{ for the thermal channels}$$

**Polarisation sensitivity**
Assuming measurement of a stable, spatially uniform, linearly polarized Lambertian scene, the polarization sensitivity is defined as $P = (S_{\max} - S_{\min})/(S_{\max} + S_{\min})$, where $S_{\max}$ and $S_{\min}$ are
the maximum and minimum sample values obtained when the polarization is gradually rotated over 180 deg.

**Cross Talk**
Channel to channel cross talk is defined as the change in any channel output when one channel's illumination is changed from the minimum to the maximum of the dynamic range while all other channels remain illuminated by the minimum radiance level. The contributors to cross talk include electrical, optical, spatial and spectral parameters.

**Radiometric Noise**
The radiometric noise is the standard deviation of the values associated with the samples in one spectral channel when a stable and spatially uniform scene is acquired. All radiometric noise sources shall be included in the performance assessment, including stray light contribution (TBC). For the thermal IR channels, the radiometric resolution is specified in terms of Noise Equivalent Temperature difference (NEdT) associated with a reference blackbody temperature at which the NEdT shall be computed. For the VIS/NIR channels, the radiometric noise is specified in terms of Signal to Noise Ratio (SNR) associated with a reference signal (percentage of albedo) at which the SNR shall be computed. Both the NEdT and the SNR apply to radiometrically calibrated spectra, meaning that the calibration coefficients induced noise contribution shall be included.

**Planck Function**
The Planck function describes the spectral radiance of a black body at temperature T (in units of Kelvin). It is given by:

\[
R(\nu, T) d\nu = \frac{2 \cdot h \cdot \nu^3}{c^2} \frac{1}{e^{\frac{h \nu}{kT}} - 1} d\nu
\]

With \( \nu \) being the wavenumber, \( h \), \( k \) and \( c \) represent the Planck, Bolzmann and speed of light constants respectively. Suggested values for these constants are the internationally recommended value of the fundamental physical constants listed in the next table ([http://physics.nist.gov/cuu/Constants/](http://physics.nist.gov/cuu/Constants/))

<table>
<thead>
<tr>
<th>Variable</th>
<th>Symbol</th>
<th>Value</th>
<th>units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed of light in vacuum</td>
<td>c</td>
<td>299 792 458</td>
<td>m / s^-1</td>
</tr>
<tr>
<td>Planck constant</td>
<td>h</td>
<td>6.626 0693 x 10^-34</td>
<td>J / s</td>
</tr>
<tr>
<td>Bolzmann constant</td>
<td>k</td>
<td>1.380 6505 x 10^-23</td>
<td>J / K^-1</td>
</tr>
</tbody>
</table>

Values for the fundamental constants in the Planck function

If wavelength is used in stead of wavenumber then the Planck function is given by:

\[
R(\lambda, T) d\lambda = \frac{2 \cdot h \cdot c^2}{\lambda^5} \frac{1}{e^{\frac{h \cdot c}{k \cdot \lambda \cdot T}} - 1} d\lambda
\]
Detection Efficiency
The Detection Efficiency (DE) is the probability of detecting a lightning event for the specified event energy ranges.

Lightning event and False Alarm
A lightning event is defined as a spatially uniform optical signal, produced by an electric discharge, occurring within or below the clouds with the following mean characteristics:
- Energy: 4.0 to 400 µJ.m².sr⁻¹
- Spatial shape: square of 10 km.
- Temporal width: 0.5 ms
- Spectral width: 0.34 nm

The occurrence of a lightning event is defined as any time the total signal from a given pixel exceeds the average signal for that pixel by a predetermined amount called the threshold.

The case when a random signal exceeds the threshold level with no lightning signal present is defined as a false alarm.

A lightning flash is a group of one or more lightning events.

Operability
This is a quality metric of the proportion of operable detector element chains that are available from a given focal plane assembly. The metric is expressed as a percentage. The operability is usually described in context with its associated detector channels attributes, e.g. LWIR channel operability. During its lifetime, the instrument shall meet its operability requirement means that the detector and ROIC manufacturing tolerances are of the same order of magnitude.

Outages
Outages are defined (ref ND [4] Clause 3.142) as "the state of an item of being unable to perform its required function". Outages can be planned operations (e.g. manoeuvres, decontaminations), predictable (but not changeable e.g. eclipses) or unplanned (e.g. failures). All outages shall be considered for Operational Availability calculations at satellite level. The requirements on allowed Outages (planned and predictable) are identified in §4.12.3 Availability.

Very short term
Very short term requirements are related to in-orbit periods of temporal sampling involving clock jitter and so on.

Short term
Short term requirements are related to in-orbit periods of the repeat cycle. They include the effect of:
- temperature variation and temperature gradients
- scan mechanism and mirror motion, coolers and other mechanisms
They also include all the contributors to the very short term effects
Medium Term
The medium term are related to in-orbit periods of 24 hours. They include the effects eclipse (temperature profiles) around equinox period and also the short and very short terms contributors.
Considering a uniform scene, the medium term drift of an instrument is the maximum difference of any two image mean errors over a certain number of images, n:
\[ \delta = Max(M_i - M_j) \text{ with } i, j \in [1, n] \]
For all channels, the medium term drift shall be minimised using calibration.

Long term
Long term requirements are related to the overall lifetime, including on-ground and in-orbit lifetime. They include the effects of:
- Initial Alignment,
- Test sequences (vibrations and thermal cycling)
- Storage
- Launch environment (vibration and depressurisation)
- Gravity release
- Vacuum
- Outgassing
- In-orbit environment (thermal profile and radiation)
- Aging
They also include all the contributors to the mid-term, short term and very short term effects.

Bias and long term drift (not used)
For a uniform scene, considering the image mean errors, M_i over a sequence of images corresponding to a period of one year,
Considering the bias or mean error over one year, M, as the mean value of M_i,
The long term drift, \( \Delta \) is the maximum difference between M_i and the mean error over n images: \( \Delta = Max(M_i - M) \)

Beginning Of Life (BOL) – End Of Life (EOL)
The beginning of life corresponds to the start of nominal instrument operation, i.e. after the commissioning period.
The end of life corresponds to the end of the specified lifetime in orbit.

Stability
The absolute stability (AS) over a given time interval is the maximum difference between the initial actual value and any actual values of the parameter within this time interval:
\[ AS_{\Delta t}(t_0) = Max|x_a(t) - x_a(t_0)| \text{ for } t \in [t_0, t_0 + \Delta t] \]
The relative stability is defined as the absolute stability normalised to the initial actual value.
Reproducibility

The reproducibility is defined as the maximum difference of the actual values for the same commanded position at different instants of time, within a given time interval:

$$Re\ p = \text{Max} |x_n(t_2) - x_n(t_1)|, t_1, t_2 \in [\text{time interval}] \rightarrow n \in [1, n_{\text{max}}]$$

Reproducibility can refer to:

- position reproducibility after mounting and dismounting on ground (i.e. during AIT);
- position reproducibility after several actuations on ground and in orbit (e.g. hysteresis);
- calibration reproducibility if the same uniform target is observed by the instrument.
4.3 General and Programmatic requirements

GEN-010

The MTG Space Segment elements shall support the imagery missions (FCI and LI), the DCS, the Infra-Red Sounding (IRS) mission and the GEOSAR terminal.

GEN-020

The nominal operational lifetime of the MTG space segment (excluding commissioning) shall be 15 years + consumables for another 5 years.

GEN-030

The target date for the operational deployment of the MTG space segment elements supporting the imagery mission is 2016 i.e. launch in 2015.

GEN-040

The observing missions shall be carried out from a nominal geo-stationary orbital position centred at $0^\circ \pm 0.1^\circ$ (lon.). Latitude control limits shall be derived from mission performance consideration.

GEN-050

In orbit spares satellites shall be placed at either $10^\circ E$ or $10^\circ W$ longitude $\pm 0.1^\circ$ (lon.) on the geo-stationary ring.

GEN-060

The MTG system shall be designed to allow operations of the imaging (FCI and LI), infrared sounding (IRS) and DCS missions from any alternative orbital location within the geostationary arc from $50^\circ W$ to $70^\circ E$ in support to the agreements with other CGMS operators.

GEN-070

The MTG system shall provide capabilities to reposition the elements of the space segment supporting the imaging (FCI and LI), infrared sounding (IRS) and DCS missions from:

- $0^\circ$ to $50^\circ W$ and back to $10^\circ E$
- and from:
- $0^\circ$ to $70^\circ E$ and back to $10^\circ W$

The MTG system shall provide capabilities to reposition the elements of the space segment supporting the imaging (FCI and LI), infrared sounding (IRS) and DCS missions 4 times during their operational life with an orbital drift rate of 2°/day. A single repositioning implies the need to support one drift start and one drift stop manoeuvre.
GEN-080

An “hot backup” (in orbit spare) strategy shall be implemented to avoid long interruption of the MTG imaging mission (FCI and LI). The spare satellite deployment strategy shall be based on availability consideration with the goal of launching the spare satellite(s) not earlier than 12 months after completing the commissioning of the nominal satellite. The hot backup shall be available not later than 18 months after the launch of the first spacecraft.

GEN-090

The MTG Satellite design shall avoid single points of failure. If unavoidable, any single point failure shall be justified and submitted to the Agency for approval.

GEN-100

The propellant and power budget of the MTG satellites shall include margins allowing an overall extension of the MTG system operations of 5 years.

GEN-110

The number of satellites required to cover the mission lifetime specified in GEN-020 shall be defined considering the Space Segment dependability requirements as specified in section 4.12 of this document.

GEN-120

Commonalities in the design, development and verification of the MTG satellites shall be exploited to the maximum extent possible with the aim of minimising the overall space segment cost and the associated development risks.
4.4 Observing Missions Requirements

4.4.1 Flexible Combined Imagery Mission

For the Imagery Mission composed of the High Resolution Fast Imagery (HRFI) and the Full Disk High Spectral Imagery (FDHSI) Missions, it is accepted that the Mission will be carried out by a single instrument which shall be able to function as an instrument which can be operated in a flexible manner (operation wise). Such an instrument is called Flexible Combined Imager (FCI) and will provide samples for at least 4 out of the total of 16 spectral channels at High Spatial Sampling/Resolution (HRFI mode) as well as samples in all of the 16 spectral channels at the nominal (lower) Spatial Sampling/Resolution (FDHSI mode).

4.4.1.1 Introduction to Mission Requirements

As the primary output of the Imagery mission is Level 1b image data available in real time, the requirements for the FCI mission address mainly:

- Spectral channels;
- Spatial and temporal sampling/resolution;
- Imaging strategy and modes defined in terms of geographical coverage and repeat cycle;
- Geometric and radiometric characteristics (accuracy, stability);
- Calibration (in particular for climate applications);
- Timeliness of Level 0 data;
- On-ground and In-Flight Characterisations.

Though not directly relevant to the MTG Space Segment, requirements addressing the higher data levels (1b and 1c) are included in the document in order to allow the definition of the auxiliary data needed to derive the higher data levels from the Level 0 data as well as for apportioning the image quality requirements on the relevant space segment components (payload and platform) and for identifying the end-to-end verification/validation approach.

Mission availability and operational constraints are addressed in a dedicated section of this document.

4.4.1.2 Applicability of the requirements

Unless otherwise stated, the observational requirements shall be met for:

- the full signal dynamic range considering uniform scenes;
- each spectral channel;
- the level defined within the specification;
- the specified mission lifetime;
- for all the samples acquired within an image or “imagette” (size TBC) for radiometric noise requirements.
- for all the pixels acquired within an image or “imagette” for geometric requirements. For off-nadir pixels the spatial requirements shall be extrapolated with distance scaled after projection on the earth and assuming constant SSA.

4.4.1.3 FCI Spectral Channels

FCI-010

*In all imaging modes, the FCI mission shall provide quasi-simultaneous observations in all sixteen (16) spectral channels, as shown in Table 4-5*

FCI-020 – [Level 1a]

For all its spectral channels, the FCI shall be able to deliver for any imaging mode all 16 channels raw data at the specified spatial sampling distance. On-ground filtering is allowed (preferred) if necessary for achieving the required spatial resolution.

4.4.1.4 FCI Spectral Response

FCI-030 – [Level 1a]

The spectral response envelope (see spectral response envelope plotted in Figure 4-2) of the FCI channels shall be as given in Table 4-5 with respect to their central wavelength and width defined in the same table, where the normalised spectral transmittance, \( T(\lambda_0, \lambda) \), is related to the spectral function \( \Phi(\lambda_0, \lambda) \), by

\[
T(\lambda_0, \lambda) = \frac{\Phi(\lambda_0, \lambda)}{\max(\Phi(\lambda_0, \lambda))} \quad \text{With} \quad \int_{-\infty}^{\infty} \Phi(\lambda_0, \lambda) d\lambda = 1
\]

FCI-040 – [Level 1a]

The spectral response function \( \Phi(\lambda_0, \lambda) \) of each channel shall meet the out of band requirement specified below:

\[
1.0 \geq \int_{A}^{A'} \Phi(\lambda_0, \lambda) d\lambda \geq 0.99 \int_{-\infty}^{\infty} \Phi(\lambda_0, \lambda) d\lambda
\]

Where \( A \) and \( A' \) are the co-ordinates of the spectral response template defined by Figure 4-2.
Co-ordinates and Amplitudes of Template Points
(50% = Width specified in Table 4-5)

<table>
<thead>
<tr>
<th></th>
<th>A/A'</th>
<th>B/B'</th>
<th>C/C'</th>
<th>D/D'</th>
<th>E/E'</th>
<th>F/F'</th>
</tr>
</thead>
<tbody>
<tr>
<td>Position [%]</td>
<td>±50</td>
<td>±30</td>
<td>±30</td>
<td>±20</td>
<td>±20</td>
<td>±10</td>
</tr>
<tr>
<td>Position [Width]</td>
<td>±1.0</td>
<td>±0.6</td>
<td>±0.6</td>
<td>±0.4</td>
<td>±0.4</td>
<td>±0.2</td>
</tr>
<tr>
<td>Amplitude</td>
<td>2%</td>
<td>50%</td>
<td>100%</td>
<td>0%</td>
<td>50%</td>
<td>80%</td>
</tr>
</tbody>
</table>

Figure 4-2 FCI Spectral Response Envelope.

FCI-050 – [Level 1a]

For any spectral channel of the FCI, the spectral position and shape of the actual spectral response function \( \Phi(\lambda_0, \lambda) \) in flight over the complete life time shall not change from the one characterised before launch \( \Phi_{\text{characterised}}(\lambda_0, \lambda) \) by more than 30% (TBC) for VIS and NIR channels, 20% (TBC) for IR channels.

\[
\int_{-\infty}^{\infty} |\Phi(\lambda_0, \lambda) - \Phi_{\text{characterised}}(\lambda_0, \lambda)| d\lambda \leq 0.3 \quad \text{all VIS and NIR channels of Table 4-5}
\]

\[
\int_{-\infty}^{\infty} |\Phi(\lambda_0, \lambda) - \Phi_{\text{characterised}}(\lambda_0, \lambda)| d\lambda \leq 0.2 \quad \text{all IR channels of Table 4.5}
\]
4.4.1.5 Coverage and Repeat Cycle

4.4.1.5.1 Nominal imaging mode

FCI-060

In the nominal imaging mode, the FCI shall be able to provide over its complete lifetime Baseline Repeat Cycles (BRC) of less than or equal to 10 minutes for the Full Disk Coverage (FDC) applications (18° diameter centred at SSP).

The FCI shall also be able to provide during its lifetime alternative repeat cycles of BRC/n minutes for Local Area Coverage (LAC) applications (with n=1, 2, 3 or 4). The alternative repeat cycle of BRC/n minutes shall be applicable over a coverage of 18°/n in South/North (S/N) direction and 18° in East/West direction, with the flexibility to position the image anywhere within the 18° of the Earth disk, using ground command. See also notes 1.

Notes 1:

a- Extended area scanning can be accepted up to 22° x 22° centred at SSP, in case it eases image navigation.

b- Alternating E->W, W->E scanning mode is acceptable if compatible with the repeat cycle requirement.

c- The scan shall start at either the northernmost or southernmost point of the earth, and be repeatable (meaning should start from the same pole and should scan the Earth in the same direction in terms of columns and rows) for the duration of the mission.

FCI-070

Assuming both the HRFI and FDHSI requirements are to be fulfilled with a single FCI Instrument then the data shall be transmitted to ground at full resolution and for all channels in both nominal (FDC) and reduced scan (LAC) modes. i.e. allowing HRFI and FDHSI missions to be fulfilled simultaneously for LAC. See also notes 2.

Notes 2:

a- Nominal operation mode: the Imagery Mission is based on the use of two satellites (two imagers). One satellite is performing rapid scanning over the northern quarter of the full disk (~ Europe) with a BRC/4 minutes temporal resolution, while the second satellite is doing FD scanning with a BRC temporal resolution. The FD scanning would thus serve the global NWP (winds, etc.) and NWC Africa missions. With the two-satellite scanning, some information is duplicated, but this is deemed very useful for cross calibration purposes.

b- Fall-back concept for situations with only one imager: In cases when only one satellite should be available, one possible backup operation scenario was developed. It consists of two consecutive rapid scans over the northern quarter of the full disc with a BRC/4 minutes temporal resolution each, followed by a FD scan with a 10 minutes temporal resolution. The FD repeat cycle would therefore be 3*BRC/2 minutes. The first quarter of the FD scan would serve as a third rapid scan with the BRC/4 minutes temporal resolution. Such a fall-back solution would, however, neither be fully compliant with the most demanding rapid scan or NWP requirements nor fulfil the requirement on the FDHSI repeat cycle. Other fall-back scenarios could be developed in the future.
FCI-080

A sensor facility shall be provided in order to allow verifying that each commanded step of the scanning system is correctly executed and that the scan mirror position is known with absolute accuracy better than one HR-VIS0.6 image line (TBC) in both E/W and S/N directions with respect to the reference interface plane of the line of sight, at any time during the satellite lifetime.

A reference position sensor shall be provided to allow indicating to the ground the position of the scan mirror (in both E/W and N/S directions) that can be used as the reference for both:

- determining unambiguously the position of the mirror in the FCI reference frame at any time during the satellite lifetime, and
- relating the pre-launch characterisation to the in-orbit position of the scan mirror.

Telemetries allowing having the knowledge of every step made by the scan mirror shall be implemented within the auxiliary data, including:

- Line, column or swath counter in both directions
- Repeat cycle counter.

All necessary auxiliary data needed for processing of the image data on-ground (including instrument calibration, configuration and settings) shall be available in telemetry to the image processing facility prior to the start of image processing.
4.4.1.6 Geometric Requirements

4.4.1.6.1 Spatial Sampling Distance

FCI-090

The FCI shall be capable to deliver samples of a subset of the spectral channels defined in Table 4-5 and identified below in HRFI sampling (e.g. high spatial sampling/resolution) mode and FDHSI sampling (nominal spatial sampling/resolution) mode at the same time.

Note that it is acceptable to deliver all of the 16 channels at HRFI sampling mode and then using on-ground processing (adapted spatial filtering, spatial binning) allowing to achieve the nominal FDHSI sampling for all 16 channels.

FCI-100 – [Level 1a]

The FCI shall deliver a subset of channels specified in Table 4-5 and identified in Table 4-1 in HRFI sampling mode, where in HRFI sampling mode the Spatial Sampling Distance (SSD) at SSP (sampling off-nadir shall be equiangular) shall be the same for the HR-VIS and HR-NIR (Table 4-1) channels and equal to SSD$_S$ = 0.5km

and in HRFI sampling mode SSD at SSP (sampling off-nadir shall be equiangular) shall be the same for the HR-TIR (see Table 4-1) channels and equal to SSD$_T$ = 1km.

The HRFI channels’ nominal SSD shall be identical in both N/S and E/W directions.

FCI-110 – [Level 1a]

The FCI shall deliver all channels defined in Table 4-5 and grouped in Table 4-2 within the nominal FDHSI sampling mode,

Where in FDHSI sampling mode, the spatial sampling distance (SSD) at SSP (sampling off-nadir being equiangular) shall be the same for all channels within the groups of short wave channels (FD-VIS, FD-NIR) and equal to SSD$_S$ = 1km

and in FDHSI sampling mode the SSD at SSP (sampling off-nadir being equiangular) shall be the same for all channels within the groups of thermal channels (FD-TIR, FD-IR WV, FD-IR O3, FD-IR CO2) and equal to SSD$_T$ = 2km.

The FDHSI mission nominal SSD shall be identical in both N/S and E/W directions.

FCI-120 – [Level 1a]

For both the HRFI and FDHSI sampling modes, the SSD pattern shall be such that four samples of the finer SSD$_S$ grid form one sample of the coarser SSD$_T$ grid. This requirement is applicable independently for HRFI and FDHSI with respect to SSD$_S$ and SSD$_T$. 
FCI-130 – [Level 1b]

For any given spectral channel, the error in Spatial Sampling Distance (SSDE) between any two adjacent samples shall be lower than SSDS/10 including systematic and random errors. In this requirement, SSDS is defined in FCI-100.

FCI-140 – [Level 1b]

Any two samples within any imagette of 100x100 samples of an observed area on Earth shall be separated by their nominal distance, determined by the applicable SSD to within 0.5 km.

4.4.1.6.2 Spatial Resolution

FCI-150 – [Level 1b]

The system Modulation Transfer Function (MTF) of the FCI channels delivered in HRFI sampling mode shall comply with the template specified in Figure 4-3. The system MTF of the FCI channels delivered in FDHSI mode shall comply with the template specified in Figure 4-4. The requirement is applicable in both E/W and N/S directions.

FCI-160 – [Level 1b]

For the group of FCI channels identified in Table 4-1 (channels delivered in HRFI sampling mode), the instrument shall provide samples with spatial resolution ΔX (accordingly to the definition) with:

a) \(ΔX_S=1.2\times SSD_S\), identical for channels HR-VIS and HR-NIR in Table 4-1 and SSDS=0.5 km as defined in FCI-100.

b) \(ΔX_T=1.2\times SSD_T\), identical for channels HR-TIR in Table 4-1 and SSDT =1.0 km as defined in FCI-100.

FCI-170 – [Level 1b]

For all FCI channels grouped in Table 4-2 (channels at nominal FDHSI sampling mode), the instrument shall provide samples with spatial resolution ΔX [accordingly to the definition] with:

c) \(ΔX_S=1.2\times SSD_S\), identical for channels FD-VIS and FD-NIR identified in Table 4-2 and SSDS=1.0 km as defined in FCI-110.

d) \(ΔX_T=1.2\times SSD_T\), identical for channels FD-TIR, FD-IR WV, FD-IR O3 and FD-IR CO2 identified in Table 4-2 and SSDT =2.0 km as defined in FCI-110.
For all FCI channels delivered either in the HRFI or the FDHSI sampling mode, the MTF at any normalised spatial frequency between $\kappa_N = 0.0$ and $\kappa_N = 0.5$ shall not vary by more than 0.05 between S/N and the E/W directions.
FCI-190 – [Level 1b]

For the FCI channels delivered in HRFI sampling mode, the ratio of two MTFs at any normalised spatial frequency between $\kappa = 0.0$ and $\kappa = 0.5$ shall be:

- for the HR-VIS and HR-NIR channels identified in Table 4.1 equal to $1.0 \pm 0.1$
- for the HR-TIR channels identified in Table 4.1 equal to $1.0 \pm 0.1$

For all FCI channels delivered in FDHSI sampling mode, the ratio of any two MTF’s at any normalised spatial frequency between $\kappa = 0.0$ and $\kappa = 1.0$ shall be:

- for the FD-VIS, and, FD-NIR channels identified in Table 4.2 equal to $1.0 \pm 0.1$
- for the FD-TIR, FD-IR WV, FD-IR O3 and FD-IR CO2 channels identified in Table 4.2 equal to $1.0 \pm 0.1$

4.4.1.6.3 Inter-Channel Co-Registration

To define requirements on inter-channel co-registration the FCI channels are grouped as depicted in Table 4-1 and Table 4-2.

<table>
<thead>
<tr>
<th>Shortwave channels</th>
<th>HR-VIS</th>
<th>FD-VIS 0.6</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>HR-NIR</td>
<td>FD-NIR 2.2</td>
</tr>
<tr>
<td>Thermal Channels</td>
<td>HR-TIR</td>
<td>FD-IR 3.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FD-IR 10.5</td>
</tr>
</tbody>
</table>

Table 4-1 Mapping of FCI channels defined in Table 4.5 to be delivered in HRFI sampling mode.

<table>
<thead>
<tr>
<th>FD-VIS</th>
<th>FD-VIS 0.4, FD-VIS 0.5, FD-VIS 0.6, FD-VIS 0.8, FD-VIS 0.9</th>
</tr>
</thead>
<tbody>
<tr>
<td>FD-NIR</td>
<td>FD-NIR1.3, FD-NIR1.6, FD-NIR 2.2</td>
</tr>
<tr>
<td>FD-TIR</td>
<td>FD-IR 3.8, FD-IR 8.7, FD-IR 10.5, FD-IR12.3</td>
</tr>
<tr>
<td>FD-IR WV</td>
<td>FD-IR 6.3, FD-IR 7.3 µm</td>
</tr>
<tr>
<td>FD-IR O3</td>
<td>FD-IR 9.7</td>
</tr>
<tr>
<td>FD-IR CO2</td>
<td>FD-IR 13.3</td>
</tr>
</tbody>
</table>

Table 4-2 Grouping of FCI channels defined in Table 4.5 into classes of channels.
Table 4-3 Co-registration requirements between groups of channels and between channels in one group (diagonal) in units of specified spatial distance SSD.

<table>
<thead>
<tr>
<th></th>
<th>FD-VIS</th>
<th>FD-NIR</th>
<th>FD-TIR</th>
<th>FD-IR WV</th>
<th>FD-IR O₃</th>
<th>FD-IR CO₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>FD-VIS</td>
<td>0.1 SSDₛ</td>
<td>0.25 SSDₛ</td>
<td>0.5 SSDₜ</td>
<td>no requir.</td>
<td>no requir.</td>
<td>no requir.</td>
</tr>
<tr>
<td>FD-NIR</td>
<td>0.1 SSDₛ</td>
<td>0.5 SSDₜ</td>
<td>no requir.</td>
<td>no requir.</td>
<td>no requir.</td>
<td></td>
</tr>
<tr>
<td>FD-TIR</td>
<td>0.1 SSDₜ</td>
<td>0.25 SSDₜ</td>
<td>0.25 SSDₜ</td>
<td>0.25 SSDₜ</td>
<td>0.25 SSDₜ</td>
<td></td>
</tr>
<tr>
<td>FD-IR WV</td>
<td>-</td>
<td>0.1 SSDₜ</td>
<td>no requir.</td>
<td>no requir.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FD-IR O₃</td>
<td>N/A</td>
<td>0.25 SSDₜ</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FD-IR CO₂</td>
<td>N/A</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 4-4 Co-registration goal between groups of channels and between channels in one group (diagonal) in units of specified SSD.

<table>
<thead>
<tr>
<th></th>
<th>FD-VIS</th>
<th>FD-NIR</th>
<th>FD-TIR</th>
<th>FD-IR WV</th>
<th>FD-IR O₃</th>
<th>FD-IR CO₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>FD-VIS</td>
<td>0.05 SSDₛ</td>
<td>0.1 SSDₛ</td>
<td>0.25 SSDₜ</td>
<td>no requir.</td>
<td>no requir.</td>
<td>no requir.</td>
</tr>
<tr>
<td>FD-NIR</td>
<td>0.05 SSDₛ</td>
<td>0.25 SSDₜ</td>
<td>no requir.</td>
<td>no requir.</td>
<td>no requir.</td>
<td></td>
</tr>
<tr>
<td>FD-TIR</td>
<td>0.05 SSDₜ</td>
<td>0.1 SSDₜ</td>
<td>0.1 SSDₜ</td>
<td>0.1 SSDₜ</td>
<td>0.1 SSDₜ</td>
<td></td>
</tr>
<tr>
<td>FD-IR WV</td>
<td>-</td>
<td>0.05 SSDₜ</td>
<td>no requir.</td>
<td>no requir.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FD-IR O₃</td>
<td>N/A</td>
<td>0.1 SSDₜ</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FD-IR CO₂</td>
<td>N/A</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**FCI-200 – [Level 1b]**

For all FCI channels, the inter-channel co-registration accuracy (ICRA) between groups of channels and between channels within groups defined in Table 4-1 and Table 4-2 shall be better than specified in Table 4-3 in units of specified SSDₛ (SSDₛ of the short wave channels group FCI-100), with a goal as shown in Table 4-4.

**FCI-210 – [Level 1a]**

Data from all mission channels obtained for the same point of the Earth’s surface shall be coincident within 2.5 seconds.

**FCI-220 – [Level 1a]**

Any two adjacent samples in the N/S or E/W direction shall be acquired within 9s with a goal of 4.5 s.
FCI-230

For all its channels, the FCI shall be equipped (if relevant) with an on-board facility to correct registration of individual detectors of channel with respect to the other detectors. This facility shall have a quantisation step of less than SSDS/2 of the relevant channels, as per FCI-100 and FCI-110 with a goal of SSDS/3 (TBC).

The data needed for this correction shall be uplinked from ground to the satellite not more frequently than once per given repeat cycle, and they shall be loaded into memory before the start of the next repeat cycle.

4.4.1.6.4 Pixel to Pixel Registration

FCI-240 – [Level 1c]

For all FCI channels the standard deviation of the Absolute Pixel Position Error (APPE) within a 100 by 100 pixel imagette shall be smaller than 1/3 SSDS (TBC) of the relevant channel, as per FCI-100 and FCI-110. The requirement applies for all repeat cycles and in both N-S and E-W directions.

4.4.1.6.5 Absolute and Relative Geometric Accuracies

FCI-250 – [Level 1b]

For all FCI channels, the Absolute Positioning Accuracy (APA) shall be less than half the Spatial Sampling Distance (1/2*SSDs), where SSDS is the spatial sampling distance of the short wave channels, APA(k,r) ≤ 0.5 * SSDS.

The requirement applies for all repeat cycles and in both N-S and E-W directions.

FCI-255

The Absolute Geometric Accuracy (AGA) shall be less than or equal to ½ of the locally specified SSDS, where SSDS is the spatial sampling distance of the short wave channels.

AGA(k,r) ≤ 0.5 * SSDS

The relation shall be valid for all repeat cycles r, all channels k and in both E/W and N/S directions.

FCI-260 – [Level 1c]

The Relative Geometric Accuracy (RGA) between groups of channels and between channels within groups defined in Table 4-1 and Table 4-2, shall better than specified in Table 4-3 with a goal as specified in Table 4-4, where SSDS is the spatial sampling distance of the short wave channels group. This shall be valid for all repeat cycles r, all channel k and in both N-S and E-W directions.
FCI-270 – [Level 1c]

The Relative Geometric Accuracy (RGA) between two consecutive images shall be less than or equal to 0.6\[m/s]\*\Delta t_{sc}[s] (\Delta t_{sc} referring to the repeat cycle between these two images).

The requirement applies for all consecutive repeat cycles, all channels and in both N-S and E-W directions.

FCI-275

The relative Geometric Accuracy (RGA_{500}) for any sequence of 500 adjacent pixels in either N/S or E/W direction of an image shall be lower than 1*SSD_{S}, where SSD_{S} is the spatial sampling distance of the short wave channels group.

4.4.1.7 Radiometric Requirements

4.4.1.7.1 Radiometric Noise and Accuracy

The radiometric requirements are applicable for uniform scenes unless otherwise stated.

FCI-280 – [Level 1b]

For the solar channels the radiance L at TOA shall be estimated according to the following formula:

\[ L = \frac{\rho \cdot E_S \cdot \cos(\theta_s)}{\pi} \]

Where:

L is the spectral radiance TOA [W.m^{-2}.sr^{-1}.\mu^{-1}] as given in formula above
\rho is the spectral reflectance TOA (see Table 4-5)
E_S is the sun extraterrestrial spectral irradiance given in [W.m^{-2}.\mu^{-1}] in Figure 4-5
\theta_s is the sun zenith angle.
The radiometric noise of the FCI solar channels shall be determined over their full dynamic range. At the reference signal the SNR shall be better than specified in Table 4-5.

For the solar channels the minimum, maximum, and reference signal are to be derived from FCI-280 and the reference solar spectral irradiance given in Figure 4-5 (see also ftp server paragraph 2.1.1).

At signal levels $\rho$ between the minimum and maximum different from $\rho\text{ref}$, the specified SNR value shall be scaled as follows:

$$\text{SNR}(\rho) = \text{SNR}(\rho\text{ref}) \frac{\rho}{\rho\text{ref}}$$

For the TIR channels, the radiometric noise of the FCI shall be determined over their full dynamic range. The radiometric resolution shall not exceed the NEDT defined below:

- At reference temperature ($T\text{Ref}$), the channel corresponding NEdT is specified in Table 4-5.

At temperatures different from $T\text{Ref}$, the specified value shall be scaled by the factor
d$$\frac{\text{dB}(\lambda_0, T\text{Ref})}{\text{dB}(\lambda_0, T)} \frac{\text{dB}(\lambda_0, T)}{\text{dT}}$$ where $B$ is the Planck's function, $\lambda_0$ is the central wavelength of the channel and $T$ is the target temperature in K.
FCI-300 – [Level 1b]

For fire applications the radiometric noise of the FD-IR3.8 and FD-IR8.7 channels shall be determined over the extended dynamic range given in Table 4-5. The NEdT shall be relaxed to the values given in Table 4-5 over this extended range.

The instrument shall be sized such that at the extended dynamic ranges, the fire channels are not saturated.

The fire application of FD-IR3.8 channel shall be at the HRFI spatial resolution whereas it applies at FDHSI spatial resolution for FD-IR8.7.

Note that the fire application has a secondary priority relative to the core application.

FCI-310 – [Level 1b]

The absolute radiometric accuracy for a uniform measured scene by solar FCI channels in HRFI sampling mode (channels identified in Table 4-1 as HR-VIS and HR-NIR) shall be over their full dynamic range better than 10%, traceable to the National Physical Laboratory (UK) radiometric standards.

The absolute radiometric accuracy for a uniform scene measured scene by all solar FCI channels in FDHSI sampling mode (channels identified in Table 4-2 under group FD-VIS and FD-NIR) shall be over their full dynamic range better than 5% with a goal of 3%, traceable to the National Physical Laboratory (UK) radiometric standards.

FCI-320 – [Level 1b]

The absolute radiometric accuracy for a uniform measured scene by the thermal FCI channels in HRFI sampling mode (channels identified in Table 4-1 as HR-TIR) shall be better than 0.1 K over their full dynamic range and traceable to the National Physical Laboratory UK radiometric standards.

FCI-330 – [Level 1b]

The absolute radiometric accuracy for a uniform scene measured by all thermal FCI channels in FDHSI sampling mode (classes of channels identified in Table 4-2 as FD-TIR, FD-IR WV, FD-IR O₃ and FD-IR CO₂) shall be better than 0.7 °K over their full dynamic range and traceable to the National Physical Laboratory UK radiometric standards.

FCI-340 – [Level 1b]

The relative radiometric accuracy (repeatability) of the solar FCI channels to be delivered in HRFI sampling mode and identified in Table 4-1 as HR-VIS and HR-NIR and those to be delivered in FDHSI sampling mode identified in Table 4-2 as FD-VIS and FD-NIR shall be better than 0.1 % over the complete mission lifetime.

FCI-350 – [Level 1b]

The relative radiometric accuracy (repeatability) of the thermal FCI channels shall be better than 0.2 K for those to be delivered in HRFI sampling mode and identified in Table 4-1 as HR-TIR and better than 0.1 K for those to be delivered in FDHSI sampling mode and identified in Table 4-1 as FD-TIR, FD-IR WV, FD-IR O₃ and FD-IR CO₂ over the complete mission lifetime.
Table 4-5 FCI Channels radiometric requirements.

<table>
<thead>
<tr>
<th>Channels</th>
<th>Central wavelength (µm)</th>
<th>Width (µm)</th>
<th>Minimum Signal (reflectance)</th>
<th>Maximum Signal (reflectance)</th>
<th>Reference Signal (reflectance)</th>
<th>SNR</th>
</tr>
</thead>
<tbody>
<tr>
<td>FD-VIS 0.4</td>
<td>0.444</td>
<td>0.06</td>
<td>0.01</td>
<td>1.20</td>
<td>0.01</td>
<td>25</td>
</tr>
<tr>
<td>FD-VIS 0.5</td>
<td>0.510</td>
<td>0.05</td>
<td>0.01</td>
<td>1.20</td>
<td>0.01</td>
<td>25</td>
</tr>
<tr>
<td>FD-VIS 0.6 #1</td>
<td>0.645</td>
<td>0.08</td>
<td>0.01</td>
<td>1.20</td>
<td>0.01</td>
<td>30</td>
</tr>
<tr>
<td>FD-VIS 0.8</td>
<td>0.860</td>
<td>0.07</td>
<td>0.01</td>
<td>1.20</td>
<td>0.01</td>
<td>30</td>
</tr>
<tr>
<td>FD-VIS 0.9</td>
<td>0.96</td>
<td>0.06</td>
<td>0.01</td>
<td>0.80</td>
<td>0.01</td>
<td>12</td>
</tr>
<tr>
<td>FD-NIR 1.3</td>
<td>1.375</td>
<td>0.03</td>
<td>0.01</td>
<td>0.80</td>
<td>0.01</td>
<td>40</td>
</tr>
<tr>
<td>FD-NIR 1.6</td>
<td>1.61</td>
<td>0.06</td>
<td>0.01</td>
<td>1.00</td>
<td>0.01</td>
<td>30</td>
</tr>
<tr>
<td>FD-NIR 2.2 #1</td>
<td>2.26</td>
<td>0.05</td>
<td>1%</td>
<td>100%</td>
<td>1%</td>
<td>25</td>
</tr>
<tr>
<td>FD-IR 3.8 #1,#2</td>
<td>3.8</td>
<td>0.40</td>
<td>200 350#2</td>
<td>350 450#2</td>
<td>300 350-450#2</td>
<td>0.1 0.2#1 1#2</td>
</tr>
<tr>
<td>FD-IR 6.3</td>
<td>6.3</td>
<td>0.40</td>
<td>165</td>
<td>270</td>
<td>250</td>
<td>0.3</td>
</tr>
<tr>
<td>FD-IR 7.3</td>
<td>7.35</td>
<td>0.50</td>
<td>165</td>
<td>285</td>
<td>250</td>
<td>0.3</td>
</tr>
<tr>
<td>FD-IR 8.7 #2</td>
<td>8.7</td>
<td>0.30</td>
<td>165 330#2</td>
<td>330 400#2</td>
<td>300 330-400#2</td>
<td>0.1 0.5#2</td>
</tr>
<tr>
<td>FD-IR 9.7</td>
<td>9.66</td>
<td>0.30</td>
<td>165</td>
<td>310</td>
<td>250</td>
<td>0.3</td>
</tr>
<tr>
<td>FD-IR 10.5 #1</td>
<td>10.5</td>
<td>0.7</td>
<td>165</td>
<td>340</td>
<td>300</td>
<td>0.1 0.2#1</td>
</tr>
<tr>
<td>FD-IR 12.3</td>
<td>12.3</td>
<td>0.5</td>
<td>165</td>
<td>340</td>
<td>300</td>
<td>0.1</td>
</tr>
<tr>
<td>FD-IR 13.3</td>
<td>13.3</td>
<td>0.60</td>
<td>165</td>
<td>300</td>
<td>270</td>
<td>0.2</td>
</tr>
</tbody>
</table>

#1 identifies the FCI channels to be delivered in both the HRFI and FDHSI sampling modes together with the SNR/NEdT figures applicable for the HRFI sampling mode.

#2 represents the fire application channels with extended dynamic ranges, reference temperature and relaxed noise requirements applicable for the application. The noise requirement is applicable to the complete extended range, i.e. the reference signal is the complete extended range.

FCI-360 – [Level 1b]

The FCI imaging solar channels (λ<3µm) shall have less than 2% polarisation sensitivity to the incoming light at all Earth-viewing angles. For the IR channels sensitivity to polarisation shall be minimised by design and performance characterisation shall be performed in order to assess the sensitivity to incoming polarised radiance.

The difference in sensitivity to polarisation between channels with wavelengths less than 3µm shall be less than 1% at all Earth-viewing angles.
FCI-370 – [Level 1a]  
The Channel to channel cross talk shall be less than the radiometric noise specification of the lowest signal channel. This requirement applies for channel grouping as depicted in Table 4-1 and Table 4-2.

FCI-380 – [Level 1b]  
Whenever the imager acquires samples (in either E/W or N/S direction) from a bright scene greater than the maximum of the dynamic range (e.g. worst case the sun for the VIS/NIR channels and a fire beyond 800 K for the TIR channels), the instrument shall be able to recover full performances after acquiring samples from targets within the dynamic range without damage to any detector element.

FCI-390 – [Level 1a]  
The scanning mirror reflectivity variation versus the angle of incidence in both E/W and S/N direction shall not change by more than 1% (TBC) for each FCI channel. In case of any observable variation, the contractor shall deliver characterisation data and means allowing the correction of such variations affecting the image (if relevant).

FCI-400 – [Level 1b]  
The inter-channel temperature differences between all channels within the FD-TIR, FD-IR WV, FD-IR O₃, FD-IR CO₂ classes identified in Table 4-2, looking at the same black body scene, shall be less than 0.1 °K. The temperature difference is the RMS of the difference between the average temperature corresponding to the measured radiances on channels k₁ and k₂ when observing the same reference scene over a number of images N_image allowing to state that the requirement is met with a confidence level of 90%.

4.4.1.7.2 Radiometric Stability

FCI-410 – [Level 1a]  
The long-term radiometric stability of the FCI VIS/NIR channels over the complete lifetime of the instrument shall be better than 2 %, with a goal of 1 %

FCI-420 – [Level 1a]  
The long-term radiometric stability of the IR channels over the complete lifetime of the instrument shall be better than 0.3 K

FCI-430 – [Level 1a]  
All raw data acquired during on-board calibration shall be transmitted to ground
4.4.1.8 Restricted Mission Operations

FCI-440

The FCI shall be capable of continuous operation through eclipse periods. For all samples taken in the Thermal channels during the eclipsed sun, the FCI shall meet all requirements, except for the NEdT, radiometric accuracy, and geometric accuracy requirements.

For these samples, the relaxed NEdT, radiometric accuracy, and geometric accuracy requirements shall be:
- NEdT < 2 x nominal specification.
- Radiometric accuracies (absolute and relative) < 2 x nominal specification.
- Geometric accuracies (absolute and relative) < 2 x nominal specification

For all samples taken in the shortwave channels during the eclipsed sun, there are no requirements on the radiometric and geometric accuracies and the images taken during this period are not to be included in the downtime (DT) from an availability perspective (see chapter 4.12, PQA-105 and also FCI-530). However, the data shall still be taken and transmitted to ground.

FCI-450

For samples within the outer limits shown in the restricted zone bound in Table 4-6, the SNR, NEdT, radiometric accuracy and geometric accuracy requirements shall be:
- SNR > 0.5 x nominal specification
- NEdT < 2 x nominal specification
- Radiometric Accuracy (absolute and relative) < 2 x nominal specification
- Geometric accuracies (absolute and relative) < 2 x nominal specification

Any images not meeting the operationally available definition of FCI-530 due to stray light, when taking into account the restricted zones requirements, shall be included in the downtime (DT) from and availability perspective, as specified in chapter 4.12, PQA-105. Such outages due to stray light contamination shall be minimised and as a maximum only samples lying within the inner limits of the restricted zones (Table 4-6) shall be allowed to exceed the restricted zone relaxed requirements and thus contributed to the downtime. All stray light contaminated soundings shall be transmitted to the ground.

FCI-460

For all samples whose distance from the centre of the uneclipsed portion of the sun lays within outer limits shown in the Restricted Zone bound in Table 4-6, the FCI shall meet all requirements, except for the SNR, NEdT, and radiometric accuracy requirements.
### Table 4-6 FCI Restricted Zones

<table>
<thead>
<tr>
<th>FCI Channels</th>
<th>Inner Limit Radius [Degree]</th>
<th>Outer Limit Radius [Degree]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Channels with central wavelengths below 4.0µm</td>
<td>5</td>
<td>7.5</td>
</tr>
<tr>
<td>Channels with central wavelengths above 4.0µm</td>
<td>3</td>
<td>7.5</td>
</tr>
</tbody>
</table>

### 4.4.1.9 Level 0, 1b and 1c Data and Timeliness

**FCI-470**

The contractor shall design the instrument with a decontamination system to prevent the cooled parts of the imager from degradation by particulate or chemical contamination. However, the decontamination shall be approached with a minimum number and duration of outages of the imaging mission.

**FCI-480 – [Level 1b]**

In all FCI imaging modes, Level 0 data shall be available to EUMETSAT for analysis, storage and further processing if deemed necessary, within $T_o + 1/5 T_{image}$ (TBC) where:

- $T_o = \text{Time at which the last image sample is acquired}$;
- $T_{image} = \text{Time required to acquire all the samples constituting the image}$.

**FCI-490 – [Level 1c]**

FCI Level 1c mission data shall be registered to a reference grid and projection defined according to the CGMS HRIT/LRIT Global Specification (AD [3]) and to the grid steps specified in the relevant definition.

**FCI-500– [Level 1b]**

Level 1b mission data shall include, but not necessarily be restricted to, the following:

- Geometrically and radiometrically corrected, calibrated and geolocated radiances (measured site);
- Information on mission planning and events (e.g. ephemeris, manoeuvres);
- Satellite localisation;
- Instrument auxiliary data housekeeping information;
- Calibration coefficients;
- Time registration.
FCI-510 – [Level 1c]

<table>
<thead>
<tr>
<th>Level 1c mission data shall include, but not necessarily be restricted to, the following:</th>
</tr>
</thead>
<tbody>
<tr>
<td>o Geometrically and radiometrically corrected, calibrated and geolocated radiances, resampled to the specified reference grid;</td>
</tr>
<tr>
<td>o Information on mission planning and events (e.g. ephemeris, manoeuvres)</td>
</tr>
<tr>
<td>o Satellite localisation;</td>
</tr>
<tr>
<td>o Instrument auxiliary data housekeeping information;</td>
</tr>
<tr>
<td>o Landmarks,</td>
</tr>
<tr>
<td>o Calibration coefficients;</td>
</tr>
<tr>
<td>o Time registration</td>
</tr>
</tbody>
</table>

FCI-520 – [Level 1b]

FCI Level 1b data shall be time stamped with respect to UTC to accuracy better than 10 msec.

FCI-530 – [Level 1c]

The Imagery mission shall be declared operationally available–operable- when the Level 1c images are of “nominal” quality, that requiring more than 95% of the pixels of the full image meeting with the specified geometric and radiometric requirements and less than three contiguous (in either direction) pixels missing.

A pixel shall be declared as “missing” if its corresponding SNR is less than ½ the specified value or its NEDT is larger than twice the specified value.

This requirement imposes to minimise the number of defective detection chain.

4.4.1.10 On-ground Characterisation

The FCI instrument shall be subject to a comprehensive characterisation programme before launch in order to provide data that will be used in the on-ground processing of the flight data. The characterisation shall be performed at instrument level and at satellite level. The requirements established here for this phase A are only for programmatic assessments (schedule and ROM cost establishment).

The characterisation data may be obtained from direct measurements at instrument and satellite levels or through analyses and computations based on partial instrument measurements and/or on lower level measurements.

The characterisation data shall be delivered to the Agency after each test campaign.

All the characterisations shall be performed at the operating temperature of the focal plane and at the nominal, cold and hot case of the instrument environmental temperatures (if relevant).
FCI-540 – [Level 1b]

The instrument spectral response functions of all channels shall be characterised over twice the spectral bandwidth and centred on the central wavelength, as given in Table 4-5 and Figure 4-2, to an accuracy of better than 5%, with a goal of 2%. The spectral response functions shall be characterised for at least 100 points equally spaced in frequency over the characterisation range.

The full width half maximum positions of the instrument spectral response functions of all channels shall be characterised to better than 1%.

FCI-550 - [Level 1b]

The MTF of all channels shall be characterised to better than 5%, with a goal of 2%. The MTF shall be characterised for at least 100 points equally spaced in normalised spatial frequency over the range $0 \leq \kappa_N \leq 1$.

FCI-560 - [Level 1b]

The PSF of all channels shall be characterised to better than 5%, with a goal of 2%. The PSF shall be measured for at least 100 points equally spaced in space over the range $-5^*\Delta X \leq \kappa_N \leq +5^*\Delta X$.

FCI-570 – [Level 1a]

For all FCI channels, the radiance response characteristics of each detection chain shall be measured. The measurements shall be taken over the full dynamic range at intervals of 10% of the dynamic range in terms of radiance, with absolute errors less than 3% for the VIS/NIR channels and less than 0.5 K for the TIR channels.

Non-linearities of the detection chains shall be characterised at this level and means for correction shall be determined and established.

FCI-580 – [Level 1a]

Both the E/W and N/S scanning directions shall be characterised/measured (TBC). Measurements shall be performed over the full range of motion of the scan mechanism at intervals of each scan step. If relevant, a scan law shall be established and fully characterised. The accuracy of the measurements shall be less than the following distances measured at SSP in worst case:

- between all scan lines that are adjacent due to the scan motion: $SSD_S/10$ (TBD) where $SSD_S$ relates to the HRFI VIS/NIR channels.

- over all the swaths in one image: $SSD_S/10$ (TBD) where $SSD_S$ relates to the HR-VIS/NIR channels.
FCI-590 – [Level 1a, 1b]

Other characterisation to be performed if deemed relevant:
- Within-channel (accuracy SSDs/3) and inter-channel spatial registration (accuracy SSD/10)
- Response to polarisation as specified in FCI-360
- On-board calibration system as specified in FCI-310 to 350
- Optical transmission (1% accuracy) and emissivity (0.5% accuracy)
- Scan mirror reflectivity versus scan angles in both directions with accuracy better than 1% for all applicable wavelengths.
- System LOS assessment
- Image quality assessment (simulations)
- Etc...

FCI-600

The FCI instrument operation modes shall be determined including its commandability and observability (TM/TC).
Operations modes such as:
Off, Standby, Diagnostic, Configuration or safe, Nominal modes shall be described

FCI-610

The instrument shall have a test port through which it can be tested with its high data rate ON during integration and test.

4.4.1.11 In-flight Characterisation Tool

It is assumed that the In-Flight Characterisation (IFC) will be addressed with a specific in-flight verification plan. However, the feasibility of an Image Quality Tool (IQT) shall be considered already in phase A to allow establishing its impact on the MTG overall programmatic and ROM cost estimate. The latter part shall be assessed for all instruments and satellite system.
### FCI-620

An Image Quality Tool (IQT) operating independently from the EUMETSAT ground System with the purpose of:
- Performing a “geometric image quality assessment at satellite level (on-ground satellite system performance simulations)”;
- Determining “in orbit performances” for geometric Image quality and for radiometric aspects (e.g. Image Quality, Noise and Calibration Efficiency);
- Supporting in-orbit commissioning;
- Allowing for the optimisation of system performances;
- Helping in resolving in-flight anomalies impacting the satellite system performances;

shall be analysed (at concept level) as part of the MTG phase A study.

The IQT will be a non-operational system and will be only used by the satellite prime contractor (under ESA coordination) as a test and verification tool.

### FCI-630 – [Level 1c]

The image rectification tool shall be able to perform image deformation correction in real-time, when connected directly to the EUMETSAT Ground System.
4.4.2 Lightning Imaging Mission

4.4.2.1 Introduction

The Lightning Imaging (LI) mission is specified in terms of its targeted real time data output, and involves all MTG system functions required to generate this basic output, excluding the functions required to make it available to users. However, in the case of the LI mission, users are expected to use only level 2 products, or a selection of pixels containing useful information. The design of the LI shall consider the assumptions accepted by the Agency and EUMETSAT during the pre-phase A (refer to RD [3], RD [4]) concept studies.

4.4.2.2 Applicability of Requirements

Unless otherwise stated, the LI observational requirements shall be met for:
- the full dynamic range
- level 1c
- the specified mission lifetime
- all pixels acquired within an image.

4.4.2.3 Mission Requirements

LI-010

*The Lightning Imagery (LI) mission shall monitor continuously lightning over both land and water during day and night over an area of the Earth disk within a circle of 16° in diameter, shifted northward to cover high latitude regions, by taking measurements of the strongest lightning emission features within the cloud top optical spectra produced by the neutral oxygen lines in the near infrared (e.g., the OI(1) line at 777.4 nm made of three lines of nearly equal intensity with a total separation of 0.34 nm)*

LI-020

*The LI mission Instantaneous Field of View (IFOV) shall be optimised to provide the lightning information over Europe, at 45°N, with a spatial resolution better than or equal to the lightning flash spatial signature of 10 km when viewed from above.*

LI-030

*The LI mission shall identify and discriminate lightning flashes from noise with a Detection Efficiency (DE) better than 90% for any individual flash of a minimum detectable energy of 7.0 µJm^-2sr^-1 and a DE better than 40% for any individual event of a minimum detectable energy of 4.0 µJm^-2sr^-1.*

LI-040

*The False Alarm Rate (FAR) averaged over the Earth coverage area shall be lower than 1s^-1, assuming a 50% cloud cover of the Earth and an average cloud albedo of 80%.*
LI-050

The background radiance generated by the clouds shall be estimated according to the formula:

\[ L = \frac{\rho E_s \cos(\theta_s)}{\pi} \]

Where:
- \( L \) is the spectral radiance TOA [W.m\(^{-2}\).sr\(^{-1}\).\(\mu\)m\(^{-1}\)]
- \( \rho \) is the cloud spectral reflectance = 0.8
- \( E_s \) is the sun extraterrestrial spectral irradiance = 1164.3 W.m\(^{-2}\).\(\mu\)m\(^{-1}\) at 777.4 nm
- \( \theta_s \) is the sun zenith angle.

LI-060

The LI mission integration time, \( \Delta t_{\text{int}} \) specifying the time how long a particular IFOV accumulates charges between readout, shall be optimised to meet the DE and FAR requirements taking into consideration a median optical lightning pulse width of 0.5 ms when observed from above.

LI-070

The LI mission shall provide ‘continuously’, determined by the integration time \( \Delta t_{\text{int}} \) in LI-050, the lightning flash location, time, and its intensity.

LI-080

The LI mission shall provide the lightning flash intensity over the full dynamical range from 4.0 to 400 \( \mu \)J.m\(^{-2}\).sr\(^{-1}\) with accuracy better than 50%, with a goal of 20%.

LI-090

The lightning data shall be processed for quality control checks in near real time and available for redistribution with a maximum timeliness of 2 minutes.

LI-110

The LI mission shall provide the Earth location for each detection element in the detection array with an absolute pixel position error (ASPE) of less than 1.5 km (40 \( \mu \)rad) at SSP.

LI-120

As for the FCI, it is assumed that the In-Flight Characterisation (IFC) will be addressed with a specific in-flight verification plan. However, the feasibility of a verification tool shall be considered from phase A to allow establishing its impact on the MTG overall programmatic and ROM cost estimate. The latter part shall be assessed for the LI and satellite system.
Infra-Red Sounding Mission

4.4.2.4 Introduction

It is anticipated that the instrument concept meeting the Infra-Red Sounder (IRS) mission needs shall be of an interferometric Fourier Transform Spectrometer (FTS) type.

Certain requirements can be derived under the assumption that the Earth scenes are spatially homogeneous. However, it is well known that the real scenes are not homogeneous and will thus lead to a decrease of the quality of level 1b data, in particular in case of partly cloudy scenes. In addition, dynamic scenes will be used as priorities for wind products (Water Vapour tracking). For that, the system stability during any observation becomes crucial.

It is supposed that the spectral calibration is carried out in Earth observation mode and is based on the correlation of typical absorption line pattern between reference spectra and measured spectra. The spectral calibration period is derived by noise optimisation (decrease of instrument noise with increasing number of spectra vs. increase of instability noise with increasing length of calibration period). The consolidation of the allocation hypothesis and the related instrument requirements is a trade-off process between instrument concept/design and spectral calibration design.

4.4.2.5 Applicability of the requirements

Unless otherwise stated, the observational requirements shall be met for:

- the full signal dynamic range considering uniform scenes;
- each spectral channel;
- the level defined within the specification;
- the specified mission lifetime excluding outage periods;
- for all the samples acquired within an image (as specified) for spectral and radiometric requirements (TBC);
- for all the pixels acquired within an image for geometric requirements. For off-nadir pixels the spatial requirements shall be extrapolated with distance scaled after projection on the earth and assuming constant SSA (TBC).
4.4.2.6 Spectral Requirements

4.4.2.6.1 Spectral Coverage

IRS-010

The InfraRed Sounding Mission shall cover the spectral domain from 700 to 2175 cm\(^{-1}\). This shall be done in two spectral bands namely a longwave (LWIR) and a midwave (MWIR) bands according to the boundaries provided in Table 4-7.

<table>
<thead>
<tr>
<th>Mission Band</th>
<th>Frequency range [cm(^{-1})]</th>
<th>Threshold Task</th>
<th>Main Contribution by</th>
</tr>
</thead>
<tbody>
<tr>
<td>LWIR</td>
<td>700-1210</td>
<td>Temperature profile, Window observation, Tracer profile/Chemistry</td>
<td>H(_2)O, O(_3), CO(_2) Surface, Clouds, Aerosols</td>
</tr>
<tr>
<td>MWIR</td>
<td>1600-2175</td>
<td>Humidity/tracer profile, Chemistry</td>
<td>H(_2)O CO, N(_2)O, and NO</td>
</tr>
</tbody>
</table>

Table 4-7 IRS Reference Spectral Bands.

4.4.2.6.2 Spectral Channels and Resolution

IRS-015

The IRS instrument shall be based on an interferometer concept (Fourier Transform Spectrometer or FTS type) that converts input spectral radiances into interferograms.

IRS-020 – [Level 0]

The spectral sampling (\(\Delta \nu\)) for both IRS bands LWIR and MWIR shall be better or equal to 0.625 cm\(^{-1}\)

\[0.625 \text{ cm}^{-1} \geq \Delta \nu = \frac{1}{2*\text{MOPD}}.\]

IRS-030 - [Level 1a]

All spectral channels, determined by the achieved spectral sampling and forming a set of contiguous unapodised channels in both the MWIR and the LWIR bands, shall be delivered.

4.4.2.6.3 Spectral Calibration

IRS-050 – [Level 1b]

The ISRF centroid wave number shall be determined by the spectral calibration algorithm such that the radiometric uncertainty associated to the shift determination will not exceed 0.05 K (NEdT@280K, 1\(\sigma\) in the LWIR and MWIR bands (1\(\sigma\)) over all spectral channels \(j\) in each band) and for each spatial sample in case of a spatially homogeneous scene.
IRS-060 – [Level 1b]

The position of the ISRF centroid of each spatial sample \( i \) in both the LWIR and MWIR bands (over all spectral channels \( j \) in each band) shall be stable over the spectral calibration period such that the associated radiometric uncertainty is equal to or less than 0.066K \((\text{NEdT}@280K, 1\sigma)\) for a spatially homogeneous scene. This corresponds to the relative centroid position instability \( \delta v/\nu = 1.6 \times 10^{-6} \) \((1 \sigma \text{ over all spectral channels } j \text{ in each band})\).

IRS-070 – [Level 1b]

The ISRF shape error index \( \int_{-\infty}^{+\infty} ISRF_{\text{mod}}(v,v_0) - ISRF(v,v_0) \, dv \) averaged over the spectral calibration period shall not exceed a value corresponding to a radiometric uncertainty of 0.05K \((\text{NEdT}@280K, 1\sigma)\) in both the LWIR and MWIR bands over all spectral channels \( j \) in each band) for each spatial sample in case of a spatially homogeneous scene. \( ISRF_{\text{mod}} \) is computed through the instrument Estimation Model (ISRF-EM).

IRS-080 – [Level 1b]

The remaining associated radiometric uncertainty introduced into the spectral calibration through unknowns in the ISRF-EM (e.g. due to mis-alignment of detector arrays, micro vibrations and others) shall not exceed 0.025K \((\text{NEdT}@280K, 1\sigma)\) in both the LWIR and MWIR bands over all spectral channels \( j \) in each band) for each spatial sample in case of a spatially homogeneous scene.

Notes 4:

The random component of errors in the spectral calibration contributes to the radiometric noise budget at level 1b. Currently, the following system hypotheses are made:

The ISRF centroid frequencies and the ISRF shape are evaluated in-flight by an ISRF Estimation Model. This model consists of an instrument model, the spectral calibration algorithm and auxiliary data.

The knowledge of the ISRF centroid wave number and of the ISRF shape together with the applied spectral calibration procedure shall be such that the associated radiometric uncertainty will not exceed 0.1 K \((\text{NEdT}@280K, 1\sigma)\) in the LWIR and MWIR bands \((1 \sigma \text{ over all spectral channels in band})\) and for each spatial sample in case of a spatially homogeneous scene.

The ISRF Estimation Model controls numerous instrument parameters, in particular those that have high frequency variability and that are not retrievable from analysis of the measurements. In particular, the ISRF-EM controls the following instrument specifications:

- the stability of the ISRF centroid wave number during the spectral calibration period,
- the ISRF shape knowledge and its variability during the spectral calibration period.

These specifications depend on the final instrument design and a defined spectral calibration algorithm.
IRS-090 – [Level 1a]

The ISRF centroid position knowledge ($\delta \nu_0$) of each channel $j$ shall be as a goal within $\delta \nu_0/\nu_0 = \pm 3.5 \times 10^{-4}$, expressed as a relative shift.

Notes 5:

- The qualitative requirement supports the spectral shift determination within the spectral calibration process in the spectral domain by constraining the range of possible spectral shifts.
- The quantitative requirement, if met, enables to use regular CO\textsubscript{2} absorption line patterns (at about 2050 cm\textsuperscript{-1}) for spectral shift determination in Fourier space (much more fast).

IRS-100 – [Level b]

For any channel $j$ the relative position of the ISRF centroid frequency shall not vary by more than $4 \times 10^{-5}$ if a point source is placed at any position within a spatial sample $i$.

4.4.2.7 Geometric Requirements

4.4.2.7.1 Coverage

IRS-110

The IRS shall be capable of providing Full Disk (FDC) and Local Area (LAC) coverage with a repeat cycle of 30 min and 10 min (goals), respectively as depicted in Table 4-8. Thereby the LAC shall be selectable anywhere within the full Earth disk. The flexibility to change the scan area is essential but the speed to effect the change has a lower priority.

The FDC and LAC repeat cycles shall not be a system driver, however both baseline repeat cycles shall not exceed the thresholds specified in Table 4-8.

IRS.120

The Limited Area Coverage (LAC) and the Full Earth Disk Coverage (FDC) shall be selectable, with sufficient flexibility to allow interleaved scenarios and change in the selected LAC area over the complete lifetime.

The IRS shall be capable of performing continuous FDC operation followed by a 'rapid scan' operations, e.g. a continuous LAC operation over a selected area within the FD over the complete lifetime.

Note 6:

Extended scanning, covering and area up 22° x 22° centred on the SSP, can be accepted to ease image navigation.
4.4.2.7.2 Spatial sampling

IRS-130 – [Level 1a]

The Spatial Sampling Distance (SSD) at SSP shall be equal to or less than 4 km for all spectral channels in both the LWIR and MWIR bands. The spatial sampling off-Nadir shall be equiangular.

IRS-140 – [Level 1b]

In both E/W and N/S IRS scanning, the difference between the actual E/W SSD (respectively N/S SSD) and the ideal E/W SSD (respectively N/S SSD) is the error in Sampling Distance. For any given spectral channel, the error in sampling distance between any two adjacent samples (E/W, N/S and diagonal) shall be lower than SSD/10 (TBC) including systematic and random errors.

IRS-150 – [Level 1b]

Any two samples within any 100 by 100 sample imagette of an observed area on Earth shall be separated by their nominal distance, determined by the applicable SSD, to within 0.5 km. The requirement applies for all repeat cycles and in both N-S and E-W directions.

4.4.2.7.3 Integrated Energy

IRS-160 – [Level 1b]

For all IRS samples the Integrated Energy (IE) over a square 4x4 km² shall be equal to or larger than 67%. This requirement shall be met at least for all spectral channels from 2175 cm⁻¹ down to 900 cm⁻¹. For channels with wavenumbers below 900 cm⁻¹ a non compliance should be acceptable.

<table>
<thead>
<tr>
<th>Observation Area Name</th>
<th>Coverage of Earth disk (degrees)</th>
<th>Repeat Cycle (min) threshold/goal</th>
</tr>
</thead>
<tbody>
<tr>
<td>LAC</td>
<td>6°N/S x 18°E/W</td>
<td>20/10</td>
</tr>
<tr>
<td>FDC</td>
<td>Φ18°</td>
<td>60/30</td>
</tr>
</tbody>
</table>

Table 4-8 IRS Coverage versus repeat cycle
4.4.2.7.4 Registration Requirements

IRS-170 – [Level 1c]

The Relative Geometric Accuracy (RGA) between two consecutive L1c images derived from any pair of consecutive L1b repeat cycle (FDC or LAC), shall be less than or equal to 0.6[m/s]* Δtsc[s], where 0.6[m/s] is the largest acceptable wind speed error that can be tolerated by image registration and Δtsc referring to the repeat cycles as defined in IRS-110 and IRS-120.

The requirement applies for all repeat cycles and in both N-S and E-W directions.

In case a FDC repeat cycle of 30 min is achieved, a non compliance should be acceptable in case of the shorter repeat cycle Δt for the LAC areas. In case only the threshold repeat cycles area achieved a full compliance also for the LAC coverage and repeat cycle is mandatory.

IRS-180 – [Level 1a]

Any two adjacent spatial samples in the N/S or E/W directions shall be acquired within 15s with a goal of 10s.

4.4.2.7.5 Intra-band Channel to Channel Spatial Co-Registration

IRS-190 – [Level 1b]

The channel to channel co-registration within LWIR and MWIR bands shall be equal or better than 1/10 of the specified SSD of 4 km.

4.4.2.7.6 Inter-band spatial co-registration

IRS-200 – [Level 1b]

The band to band co-registration between the LWIR and MWIR bands shall be equal or better than 1/10 of the required SSD of 4 km.
4.4.2.7.7 Navigation Requirements

Mission-level Image Navigation and Registration requirements apply to spatial samples and encompass the combined system performance of the IRS, spacecraft and ground processing system.

IRS-210 – [Level 1b]

The absolute knowledge of the Line Of Sight (LOS) of any spatial sample within an image shall be less than or equal to 22 µrad (1σ) at nadir (or 800 m at nadir) over the corresponding repeat cycle.

IRS-220 – [Level 1a]

The Line Of Sight (LOS) pointing accuracy stability shall be less than or equal to 8.5 µrad (1σ) (300 m at nadir) over the dwell time.

4.4.2.8 Temporal Requirements

4.4.2.8.1 Spectral Sounding Acquisition Duration

IRS-230

The maximum duration for acquiring a complete Spectral Sounding shall not exceed 10 seconds, corresponding to the maximum dwell time.

4.4.2.8.2 Inter-channel Temporal Co-registration

IRS-240

The inter-channel temporal co-registration shall not exceed 5 seconds with a goal of 3 seconds.

4.4.2.9 Radiometric Requirements

4.4.2.9.1 Dynamic Range

The dynamic range of the IRS shall be designed to cover the spectral radiances derived from nadir measurement over a clear sky hot desert target with a 334 K surface temperature and a 4 km thick cirrus cloud placed at the tropopause of a tropical atmosphere, as presented in figure 4-6. A complete data set of the spectral radiances will be available to the contractor through the allocated ftp server defined in paragraph 2.1.1.
IRS.250

The dynamic range of the IR-Sounder shall be optimised to cover the spectral radiances provided in Annex 2 and illustrated in Figure 4-6. The specifications apply only within the spectral range depicted in IRS-010.

IRS-260

The IR-sounder shall be able to measure, without saturation, radiances as provided in IRS-250 including a 10% margin on the warm side (Figure 4-6) and a 20% margin on the cold side.

Figure 4-6 Spectral radiances for a hot desert (334 K surface temperature and a 4 km cold thick cirrus cloud placed at the tropopause of a tropical atmosphere).

4.4.2.9.2 Radiometric Noise

IRS-270 – [Level 1a]

The radiometric noise of each channel in the LWIR and MWIR bands over their full dynamic range shall be less than or equal to the NEdT at (T_ref=280 K) value specified in Table 4-9 and Table 4-10 (the selected wavenumbers are points of support).

At temperatures T different from 280 K, the here above specified limits shall be scaled by the factor \( \frac{\frac{dB(v_0,280K)}{dT}}{\frac{dB(v_0,T)}{dT}} \), where B is the Planck’s function, \( v_0 \) is the frequency of the channel and T is the target temperature in K. This implies a constant accuracy in terms of radiances. The performances shall be computed over the full dynamic range.

The contribution of the spectral calibration is excluded from the NEdT specified.

IRS-280 - [Level 1b]

After calibration the absolute radiometric accuracy shall allow the determination of equivalent temperature with accuracy better than 0.5 K over the full dynamic range.

IRS-290 - [Level 1b]

Assuming a homogeneous scene, the retrieved temperature of a blackbody scene between any spatial sample of the same channel shall be equal within 0.05 K over the full dynamic range.
<table>
<thead>
<tr>
<th>Wavenumber (cm⁻¹)</th>
<th>Channel @ requested spectral sampling</th>
<th>NEdT @ T_ref=280 K</th>
</tr>
</thead>
<tbody>
<tr>
<td>700</td>
<td>0.625</td>
<td>&lt; 0.5</td>
</tr>
<tr>
<td>714</td>
<td>0.625</td>
<td>&lt; 0.5</td>
</tr>
<tr>
<td>715</td>
<td>0.625</td>
<td>&lt; 0.4</td>
</tr>
<tr>
<td>729</td>
<td>0.625</td>
<td>&lt; 0.4</td>
</tr>
<tr>
<td>730</td>
<td>0.625</td>
<td>&lt; 0.3</td>
</tr>
<tr>
<td>769</td>
<td>0.625</td>
<td>&lt; 0.3</td>
</tr>
<tr>
<td>770</td>
<td>0.625</td>
<td>&lt; 0.2</td>
</tr>
<tr>
<td>1100</td>
<td>0.625</td>
<td>&lt; 0.2</td>
</tr>
<tr>
<td>1210</td>
<td>0.625</td>
<td>&lt; 0.35</td>
</tr>
</tbody>
</table>

Table 4-9 LWIR band Noise Requirements

<table>
<thead>
<tr>
<th>Wavenumber (cm⁻¹)</th>
<th>Channel @ requested spectral sampling</th>
<th>NEdT @ T_ref=280 K</th>
</tr>
</thead>
<tbody>
<tr>
<td>1600</td>
<td>0.625</td>
<td>&lt; 0.2</td>
</tr>
<tr>
<td>1810</td>
<td>0.625</td>
<td>&lt; 0.2</td>
</tr>
<tr>
<td>1980</td>
<td>0.625</td>
<td>&lt; 0.4</td>
</tr>
<tr>
<td>2175</td>
<td>0.625</td>
<td>&lt; 0.85</td>
</tr>
</tbody>
</table>

Table 4-10 MWIR band Noise Requirements

IRS-310 - [Level 1b]

The relative radiometric accuracy of the IRS channels (repeatability) shall be better than 0.1 K (3σ) over a 24 hour time period.

IRS-320 - [Level 1b]

The relative radiometric accuracy of the IRS channels (repeatability) shall be better than 0.3 K over the complete mission lifetime.

IRS-330 - [Level 1a]

All raw data acquired during on-board calibration shall be transmitted to ground.
4.4.2.10 Level 0 and level 1b Data and Timeliness

**IRS-350** [Level 1b]

*For a given coverage, the IRS mission Level 1b data shall be available at the user end within To + 1/2 Timage (TBC) where:*

- To = Time at which the last image sample is acquired
- Timage = Time required to acquire all the samples constituting the image.

4.4.2.11 Operability

**IRS-360**

*A spectral channel shall be declared ‘non-operable’ if NeDT(achieved) ≥ 2*NeDT(required).*

**IRS-370**

*A spectral sounding in the LWIR or MWIR band shall be declared as “non-operable” if more than or equal to 10% (TBC) of the spectral channels within the LWIR of MWIR bands are non-operable channels.*
IRS-380

A spatial cluster of spectral soundings with $N_{\text{cluster}} = 3$ (TBC) shall be declared non-operable if it consists only of non-operable spectral soundings.

IRS-390

The IR sounding mission shall be declared operationally available/operable when within the area coverage over a repeat cycle:
- Less than 15% (TBC) of the spectral soundings in the LWIR band and less than 5% of the spectral soundings in the MWIR band are non-operable spectral soundings;
- Less than 3 (TBC) spatial clusters of spectral soundings are non-operable clusters of spectral soundings.

4.4.2.12 Restricted Mission Operations

IRS-400

The IRS shall be capable of continuous operation through eclipse periods.
For all samples taken in the LWIR and MWIR channels during the eclipsed sun, the IRS shall meet all requirements, except for the NEdT, radiometric accuracy, and geometric accuracy requirements.
For these samples the relaxed NEdT, radiometric accuracy, and geometric accuracy requirements shall be:
- $\text{NEdT} < 2 \times \text{nominal specification}$;
- Radiometric accuracies (absolute and relative) $< 2 \times \text{nominal specification}$;
- Geometric accuracies (absolute and relative) $< 2 \times \text{nominal specification}$.

IRS-410

For all samples whose distance from the centre of the uneclipsed portion of the sun lays within the outer limits shown in the Restricted Zone bound in Table 4-11, the IRS shall meet all requirements, except for the NEdT, radiometric accuracy, and pointing accuracy requirements.

IRS-430

For samples within the outer limits of the restricted zone (Table 4-11) the NEdT, radiometric accuracy, and geometric accuracy requirements shall be:
- $\text{NEdT} < 2 \times \text{nominal specification}$;
- Radiometric accuracies (absolute and relative) $< 2 \times \text{nominal specification}$;
- Geometric accuracies (absolute and relative) $< 2 \times \text{nominal specification}$.
Direct solar exposure to the instrument interferometer and photo-optical components shall be prevented as much as possible.
When the instrument is operated within the solar restricted zone, the instrument shall recover to full performance within 120 seconds of returning to normal operational zone.
See also note 7.
Table 4-11 IRS Restricted Zones

<table>
<thead>
<tr>
<th>IRS Bands</th>
<th>Inner Limit Radius [Degree]</th>
<th>Outer Limit Radius [Degree]</th>
</tr>
</thead>
<tbody>
<tr>
<td>LWIR and MWIR</td>
<td>3</td>
<td>7.5</td>
</tr>
</tbody>
</table>

**Note 7:**
Any soundings not meeting the operationally available definition of IRS-390 due to stray light, when taking into account the restricted zones requirements, shall be included in the downtime (DT) from and availability perspective, as specified in chapter 4.12, PQA-105. Such outages due to stray light contamination shall be minimised and as a maximum only samples lying within the inner limits of the restricted zones shall be allowed to exceed the restricted zone relaxed requirements and thus contributed to the downtime. All stray light contaminated soundings shall be transmitted to the ground.

4.4.2.13 Characterisation before Launch

IRS-430

*The IRS instrument shall be subject to a comprehensive characterisation programme before launch to provide data that will be used for the on-ground image data processing.*

All the characterisations shall be performed at the operating temperature of the focal plane and at the nominal, cold and hot case of the instrument environmental temperatures.

The characterisation data may be obtained from direct measurements at instrument and satellite levels or through analyses and computations based on partial instrument measurements and/or on lower level characterisation. The characterisation data shall be delivered to the Agency after each test campaign.

Though the characterisation before launch is not expected to be analysed in details in the course of the Phase A system study, it is anticipated that the characterisation programme shall include as a minimum:
- Spectral Response (ISRF)
- Radiance response, calibration characterisation, determination of non-linear terms and corrective means
- Spatial Sampling, resolution and coverage
- Co-registration between channels/bands
- Instrument/system PSF
- Scan law
- System LOS instability (simulations)
At least the same level of characterisation as for the FCI shall be considered for the ROM cost and programmatic assessments.

Note 8:
For calibration purposes, auxiliary data that is necessary for a full calibration shall be delivered to ground. In general, auxiliary data is needed to characterise and calibrate measured radiances and determine IFOV locations through ground processing. It will be used to support instrument measured data processing.

IRS-440
The IRS instrument operation modes shall be determined including its commandability and observability (TM/TC).
Operations modes such as:
Off, Standby, Diagnostic, Configuration or safe, Nominal modes shall be described as for the FCI.

IRS-450
The instrument shall have a test port through which it can be tested with its high data rate ON during integration and test.

4.4.2.14 In-Flight Characterisation Tool

IRS-460
As for the FCI, it is assumed that the In-Flight Characterisation (IFC) will be addressed with a specific in-flight verification plan. However, the feasibility of an Image Quality Tool (IQT) shall be considered from phase A to allow establishing its impact on the MTG overall programmatic and ROM cost estimate. The latter part shall be assessed for the IRS and satellite system.

4.4.2.15 Priority of Mission Requirements associated to primary and secondary objectives
Considering that it may not be practicable to meet all the requirements simultaneously, a priority ranking is given below:

- 1st Radiometric accuracy – (low priority however assigned for channels within the CO₂ band at frequencies lower than 720 cm⁻¹)
- 2nd spectral resolution defined by the unapodised FTS spectral sampling \( \Delta \nu = 1 / (2 * \text{MOPD}) \)
- 3rd spatial resolution defined by the SSD and the IE(d) requirements
- 4th temporal resolution.
4.5 Other Missions Requirements

4.5.1 Data Collection System

DCS-010
The MTG Data Collection Mission shall provide continuity to the services currently provided by the MSG System subject to the characteristics described in AD [1].

DCS-020
The MTG system shall be able to support at least 223 regional DCPs and 200 contingency channels (in addition to the 33 IDCS channels). The bandwidth of regional DCPs is 1.5 kHz. Transmission times can be flexible; Guard times are up to ½ minute (TBC).

DCS-030
Within the present band allocation it shall be possible to expand the MTG DCS up to 403 MHz. This would allow more than 500 regional DCP channels in the sub-band 402.1 – 403 MHz.

DCS-035
The space segment component of the MTG DCS system shall support the relay of DCP signals transmitted by ground-based platforms operated within the band from 401.701 to 403 MHz.

DCS-040
The MTG DCS Mission shall comply with the interface constraints set for the International and Regional channels according to AD[1], AD[2].

DCS-050
The future DCS mission shall support the acquisition and distribution of messages from collection platforms set-up with channels of 1.5 kHz and 3 kHz bandwidth.

DCS-060
The MTG DCS mission shall support the acquisition and distribution of messages transmitted by platforms using a combination of 1.5 kHz channels.

DCS-070
The mission shall be able to support the relay, acquisition, and transmission of messages transmitted by enhanced platforms operating at a data rate of up to 3000 bps (TBC).

DCS-080
The MTG DCS mission shall support reception and distribution of DCP messages from any platform for which the elevation to the nominal satellite (at 0° latitude) is equal to or higher than 5°.
DCS-090

The threshold DCP link performance shall allow for a bit error rate better than $1.0 \times 10^{-6}$\[1\] at 99% availability.

DCS-100

The threshold DCP link performance shall allow for a bit error rate better than $1.0 \times 10^{-8}$\[2\] at 99% availability.

4.5.2 Support to the COSPAS-SARSAT System

SAR-010

The MTG Space Segment shall have the capability to accommodate a GEOSAR Terminal with the characteristics specified in AD[5], in support to the Search and Rescue mission operated under the aegis of COSPAS-SARSAT.

4.6 Satellite System Requirements

4.6.1 Configuration

SAC-010

The satellite configuration shall be designed to be compatible with the launcher constraints.

SAC-020

The number of deployable items shall be minimised.

SAC-030

The satellite configuration shall provide unobstructed fields of view to optical sensors and antennas.

SAC-040

The satellite configuration design shall take into account Radio Frequency and Electromagnetic Compatibility (RFC/EMC) effects.

SAC-050

The satellite configuration shall facilitate the attitude control tasks by minimizing moments of inertia and structural flexibility.

SAC-060

The satellite configuration shall provide adequate antenna environment such that the power of any multipath signal shall be at least 20 dB below that of the direct signal received within the antenna field of view.

[1] This applies to the conventional 100 bps as identified in AD[1] and AD[2].

[2] This applies to the future 3000 bps DCP link.
SAC-070

The spacecraft shall provide any necessary means to minimise and control the level of contamination during the entire mission (i.e. during ground test, on-ground storage, launch and in-orbit operations).

SAC-080

The platform shall provide the necessary footprint area and volume for the instruments and the platform elements. Simple load paths shall be used.

SAC-090

The requirements/constraints resulting from the selected model philosophy and from the AIV approach shall be taken into account for the definition of the configuration.

SAC-100

A separation between platform and payload, e.g. providing separate carriers in the form of service and payload modules, shall be made only where this would result in programmatic savings.

SAC-110

The separation between the platform and the payload module, when relevant, shall be clearly defined for all system engineering and Assembly, Integration and Verification (AIV) activities.

SAC-120

Constraints affecting the electromagnetic and radio frequency compatibility (EMC and RFC) in terms of structural blockage, shielding and path length shall be derived from the functional requirements of the payload and the platform.

SAC-130

The satellite coordinate frame shall be a right-handed orthogonal system with its origin in the centre of the launch vehicle separation plane. The axes shall be aligned with the principal axes of the satellite. Coordinate sub-frames may be defined for satellite elements and functions as necessary.

SAC-140

All drawings, specifications and engineering data shall use the International System of Units (SI).
4.6.2 Budgets

SAB-010

A sound margin policy shall be defined and documented early in the course of the study. The satellite(s) budgets shall clearly identify the levels of margins.

SAB-020

Pointing, geo-location and co-registration budgets shall be established in accordance with the methodology defined in the ESA Pointing Error Handbook [ND30]. Error propagation should be based on statistical methods with due consideration of the nature of these errors and the resulting probability density functions (PDF). The Contractor shall provide in the proposal a detailed description of the methodology that he intends to use for the establishment of pointing, geo-location and co-registration budgets.

SAB-030

All resource requirements and engineering parameters shall be documented and controlled in the form of Budgets.

SAB-040

The Budgets shall include (but not necessarily be limited to):

- Mass and Mass Properties
- Alignment and Stability
- Electrical Power and Energy
- Heat Generation and Dissipation
- Telemetry and Telecommand
- Frequency Plan
- Radio Frequency Links (TT&C, Mission Data)
- Software and Memory Usage
- Computer(s) Load
- Propellant & propellant gauging
- Observation data (are these outages?), if not, outages should be added
- Torque and Momentum
- Attitude Pointing Accuracy, Stability and Knowledge
- Geo-location and co-registration of observation data
- Radiometric budget of observation data
- Contamination.
SAB-050

The total satellite mass including margins shall be compatible with the launcher performance.

SAB-060

The mass budget shall take into account the following margins at unit level:

- for completely new developments: 20 %
- for new developments derived from existing hardware: 15 %
- for existing units requiring minor/medium modification: 10 %
- for existing units: 5 %

A 10 % system margin shall be added to the above.

SAB-060

Whenever engineering data from other projects are used, these shall be identified to allow traceability.

4.7 Satellite Subsystems Requirements

4.7.1 Structure

The requirements below are applicable not only to a conventional structure subsystem but rather to “Engineering Domains”, as defined in ND[1]. Therefore structural requirements apply to all elements that fulfil a structural function whether or not part of a structure subsystem formally defined as such.

STR-010

The structure shall meet the requirements of ND[13]

STR-020

The structure shall carry and support all spacecraft equipment, ensure their alignments and sustain the environment conditions on ground (i.e., during manufacturing, integration, transport and testing, storage), during launch and during in-orbit operation, without degradation of performance.

STR-030

The structure shall be designed to cope with the whole satellite operational life including ground testing.
STR-040

The structure shall be able to withstand the yield load levels (limit load multiplied by the yield safety factor) without showing elastic or local plastic deformation that will adversely affect the system performance.

STR-050

The structure shall be able to withstand the ultimate load levels (limit load multiplied by ultimate safety factor) without rupture, collapse or permanent deformations that impact the integrity of other parts or the system performance.

STR-060

The structure shall be designed to withstand the static and dynamic loads induced by the launch vehicle, including the mechanical environment as deduced from the coupled analysis with the launch vehicle.

STR-070

For design purposes the quasi-static design loads will be as derived from the following Figure 4-8.

![Figure 4-8: Quasi-static acceleration.](image)

STR-080

For the elements heavier than 100 kg, the quasi-static acceleration that shall be considered in the design is 15 g. The quasi-static loads shall be applied at the centre of mass of the element concerned, acting along the worst spatial direction with respect to the resulting reactions and with the loads in the different axes not acting simultaneously.
STR-090

The structure safety margins will be as per ND[13]. Positive margins shall be demonstrated by strength analysis after application of the relevant safety factors (yield and ultimate) for all worst-case loads.

STR-100

The minimum main mode frequencies of the satellite hard-mounted at the launcher interface shall be higher than the required frequencies as defined by the launch vehicle authority. The analytically predicted first resonance frequency shall be at least 15% higher than the launcher minimum requirement before any modal survey test results are available.

STR-110

The eigen-frequencies of compact equipment and boxes in hard mounted conditions shall be sufficiently above those of the structure on which they are mounted and in any case above 100 Hz (TBC).

STR-120

The structure shall guarantee the necessary alignments between sensors and instrument, as derived from the spacecraft design and the observation requirements. In particular the structure shall ensure alignments between spacecraft references, sensors and instruments as required for attitude determination, pointing and observation localisation, including co-registration between the instruments themselves.

STR-130

The alignments shall be achieved taking into account the effects of passage from ground to orbit and the orbital effects including eclipse-sunlight transitions and temporary transitions to non-nominal modes.

STR-140

Mounting interfaces shall allow for easy maintenance, mounting and demounting.

STR-150

The layout of the structure shall provide sufficient accessibility to allow for easy integration, removal and maintenance activities.

STR-160

The accommodation and locking of deployable items shall be such that stowage is reliable and deployment easy.
4.7.2  Mechanisms and Pyrotechnics

MPY-010

The mechanisms shall fulfil the requirements of ND[14].

MPY-020

The mechanisms shall provide the movement and mechanical reconfiguration functions (e.g. latching, hold down, release, deployment, scanning and position control) as required by the satellite(s).

MPY-030

The utilisation of mechanisms shall be minimised.

MPY-040

The mechanisms shall provide sufficient data to monitor their status and operation condition. These data shall be transmitted as part of the housekeeping telemetry.

MPY-050

It shall be possible to command all mechanisms from ground.

MPY-060

Failure of mechanisms at instrument level shall not affect other instruments or the rest of the satellite.

MPY-070

Whenever possible the failure of a mechanism shall not cause the total loss of the mission. Continuation should be possible albeit at reduced performance. These cases shall be identified and submitted to the Agency for approval.

MPY-080

Redundancy provisions shall be as simple as possible and shall be preserved at the interfaces so that further reconfiguration is not imposed.

MPY-090

Mechanisms shall be simple, self-locking and not capable of being driven in anomalous and non-recoverable configurations.

MPY-100

Mechanism lifetime shall be demonstrated by test using the sum of predicted nominal ground test cycles (other than lifetime test), cycles during on-ground storage and the in orbit operation cycles. The number of predicted cycles shall be multiplied by the factors specified in ND[14].

MPY-110

The mechanisms shall be designed to allow for representative testing on ground.
MPY-120

*The mechanisms shall be secured to withstand transportation and launch loads.*

MPY-130

*The use of pyrotechnics in the design shall be justified by the Contractor and approved by ESA.*

MPY-140

*The pyrotechnics shall fulfil the requirements of ND[16].*

MPY-150

*All mechanism pyrotechnic releases shall be redundant. Redundancy shall be provided by duplication up to and including the initiators and to the mechanism interface as required.*

MPY-160

*High reliability and safety shall be provided for pyrotechnic devices by using approved practices including the screening of all leads and electronics.*

MPY-170

*All pyrotechnics shall be initiated via a spacecraft unit incorporating the required safety inhibits.*

MPY-180

*The use of pyrotechnic devices shall be compatible with the cleanliness requirements of the spacecraft.*

4.7.3 Thermal Control

TCR-010

*The Thermal Control shall fulfil the requirements of ND[12].*

TCR-020

*The Thermal Control shall provide the thermal environment (temperature ranges, temperature gradients, temperature stability) required to ensure the full performance for each mission phase and operational mode and for the complete duration of the mission.*

TCR-030

*The Thermal Control shall ensure survival thermal environment under the worst-case satellite anomaly conditions.*

TCR-040

*The Thermal Control design shall be compatible with the in-orbit environment expected for all nominal variations of the solar aspect angle, Earth albedo and infrared radiation. Worst-case hot and cold conditions shall be identified and analysed.*
TCR-050

The Thermal Control shall include sufficient sensors to allow for temperature monitoring in-orbit and on-ground.

TCR-060

The Thermal Control design shall include flexibility to accommodate reasonable changes in layout, power dissipation, mission requirements (e.g., orbit) and required temperature ranges.

TCR-070

The design of the Thermal Control shall be such that the instruments and the platform(s) can be developed integrated and tested separately with minimum interactions.

TCR-080

The Thermal Control design shall allow for easy integration of instrument thermal models in the overall satellite model(s).

TCR-090

The Thermal Control shall guarantee that the contributions of thermally induced effects to the observation error budget, including thermo-elastic deformation effects, remain below the allocations.

TCR-100

The design of the Thermal Control shall be such that the thermal model of the satellite is kept simple can be verified and used with confidence for cases for which testing on ground is not representative or affordable.

TCR-110

The Thermal Control design shall minimise the need for ground operational testing and subsystem-level thermal vacuum tests.

TCR-120

The Thermal Control design shall take into account the degradation of surface properties (alpha, epsilon) during the mission lifetime.

TCR-130

The Thermal Control shall be designed to provide adequate margins between the predicted extreme temperature ranges of units (based on worst case steady state and transient conditions) and the required design limits, in order to minimise costly satellite verification and qualification effort in subsequent phases of the project.

TCR-140

The design limits of a unit are defined as the extreme temperatures, temperature gradients and transients that the unit is required to tolerate during its specified lifetime and for the various operational modes.
TCR-150

*For temperature, the qualification limits of a unit are equal to the design limits extended at both extremes by a margin of at least 10 K.*

TCR-160

*The Thermal Control design shall not impose unacceptable constraints on other satellite systems or on satellite operations.*

TCR-170

*The actual design limits of units and parts, affected by the qualification margins, shall be taken into account in their procurement.*

TCR-180

*Permanent operations shall be assumed for the design of the thermal control of the instruments (nominal hot case).*

4.7.4 Electrical Power

EPS-010

*The Electrical Power Subsystem (EPS) shall provide electrical power to satisfy all power supply load requirements during all mission phases and for all operation modes including ground testing, pre-launch operations and contingencies.*

EPS-020

*The topology of the EPS shall be such that the satellite architecture is optimised, considering not only power generation/distribution and energy storage, but also satellite resources like mass, volume and propellant supply.*

EPS-030

*The EPS design shall fulfil the requirements of ND[11].*

EPS-040

*Electrical power generation shall be provided by a solar generator, with electrical configuration defined on the basis of the topology selected for the electrical power subsystem.*

EPS-050

*The degradation factors of the solar generator shall cater for efficiency changes of the energy conversion process due to the space environment, variations in solar illumination including the ensuing thermal effects and design uncertainties.*

EPS-060

*The electrical energy storage shall be provided by batteries. The configuration shall be derived from the definition of the EPS topology in terms of number of batteries and battery cells.*
EPS-070

The battery type maximum depth of discharge shall be based on the qualification status, the number of expected charge/discharge cycles and the temperature environment.

EPS-080

EPS operations shall be fully autonomous, including mode transitions, operation of protections and energy storage management.

EPS-090

The worst-case power margin at end-of-life (EOL) including battery charge shall not be less than 10%.

EPS-100

The following additional maturity power margin factors shall be applied for each satellite unit to account for the hardware development status.

- Completely new developments: 30 %
- New developments derived from existing hardware: 20 %
- Existing units requiring minor / medium modification: 10 %
- Existing units: 5 %

EPS-110

The margin for energy recharge shall be no less than 10%, for all nominal mission phases.

EPS-120

Electrical power shall be distributed in accordance with the load interface requirements, both static and dynamic, as well as the characteristics of the power/energy sources. Failure propagation between equipment shall be avoided.

EPS-130

The EPS topology and harness shall be optimised for power and energy transfer between sources and loads and for a suitable EMC environment. This shall include the choice of a suitable power bus concept and the resulting range of bus voltages.

EPS-140

The electrical architecture shall be based on the Distributed Single Point Grounding Concept, which requires primary power leads to be referenced to the structure at one point only, preferably the regulation point. Secondary power lines shall be referenced to the structure locally with isolation as high as possible between primary and secondary, for both DC and AC, in order to minimise common mode currents.

EPS-150

The structure shall not be used as DC or AC current path and only serve as a ground reference and to provide shielding against emitted electromagnetic fields and from such fields externally generated. Ground loops shall be avoided.
EPS-160

Batteries shall be protected against overcharge, undervoltage and adverse temperature conditions.

EPS-170

The EPS shall accept modification of operation parameters by ground commands.

EPS-170

The EPS shall accept ground commands to over-ride and disable all automatic protections.

EPS-180

The EPS shall provide sufficient housekeeping information to support monitoring and potential commanding during in-flight operation and ground testing.

EPS-190

The EPS shall accept power supply from external sources during ground operations.

EPS-200

The EPS shall provide the possibility to switch off the satellite with batteries being integrated, fully loaded and connected during ground operations.

4.7.5 Attitude and Orbit Control

AOC-010

The attitude and orbit control subsystem (AOCS) shall provide the satellite pointing control and pointing estimation functions, both real-time in-orbit and on-ground a posteriori.

AOC-020

The AOCS, supported by the GNSS tracking system (TBC) and the satellite propulsion, shall provide the satellite orbit estimation and control functionalities required for the satellite operations.

AOC-030

The accuracy of the estimation and control of attitude, position, velocity and angular rates shall be derived from the observational, geo-location and co-registration requirements and from the needs of the satellite operations.

AOC-040

The AOCS shall provide day/night flags in support of on-board operations.
AOC-050

The AOCS operation modes shall be defined in accordance with the satellite functional requirements including contingency modes. Mode transitions shall be autonomous, with provisions for back up and inhibit by ground command. This applies in particular to recovery from contingency modes. The reference signals necessary for transition to and maintenance of these contingency modes shall be independent of those used for nominal modes.

AOC-060

The AOCS shall provide all data for orbit, attitude and angular rate determination for transmission to ground. The update frequency shall be sufficient to satisfy the accuracy requirements of the payload observations.

AOC-070

The AOCS shall provide sufficient housekeeping data for monitoring its configuration, health and operation at all times, including contingency modes.

AOC-080

It shall be possible to update on-board AOCS laws and parameters by ground commands.

AOC-090

The AOCS shall include a safe mode of operation to permit satellite survival in case of anomalies not resolved in real-time by redundancy or back-up actions.

AOC-100

The nominal operations of the AOCS shall be fully automatic and autonomous from ground.

AOC-110

It shall be possible to perform any slew manoeuvres to acquire the nominal pointing attitude and prior/after orbit correction manoeuvres both autonomously and upon ground command.

AOC-120

The parameters of the orbit shall be controlled to the level of accuracy required by the observation requirements with due allowance for error contributions from on-board and ground sources.

AOC-130

Satellite position, velocity and time shall be determined by a GNSS tracking system (TBC). In case of outage of this system, it shall be possible to propagate on-board the orbit information from the last state provided by the GNSS tracking system or as up-linked from the ground.

AOC-140

The elaboration of pointing budgets shall follow the guidelines of ND[23].
AOC-150

The AOCS design shall follow the requirements of ND[27].

AOC-160

The attitude determination shall be based on concepts providing robust performance and cost-effectiveness.

4.7.6 Propulsion

PRO-010

The satellite propulsion shall provide the actuation functionalities necessary to fulfil the orbit control requirements.

PRO-020

The propulsion sub-system shall be sized in order to correct the launcher injection errors, to perform the transfer from GTO to GEO (with a margin of 50 m/s), to maintain the orbit parameters within the required conditions, to perform in-orbit repositioning/attitude manoeuvre as required, to perform reaction/momentum wheel off-loading, to perform a minimum of 10 emergency sun acquisition/recovery and to perform the final transfer into graveyard orbit at EOL.

PRO-030

The implementation of orbit control manoeuvres shall minimize the mission outages and shall be compatible with the overall availability requirement.

PRO-050

The propulsion subsystem shall fulfil the requirements of ND[15].

4.7.7 Data Handling

DHS-010

The data handling subsystem (DHS) shall provide all data acquisition, storage and commanding functions required for the operations of the spacecraft and the recovery by the ground segment of observation data.

DHS-020

The DHS shall operate fully autonomously, including initialization.

DHS-030

The DHS shall rely on the GNSS Tracking Instrument to generate the on-board time reference (TBC). In case of outage of this instrument, the DHS shall continue to generate the on-board time reference, albeit at degraded performance.
DHS-040

The DHS design shall provide a 50% margin for data storage and processor load for all functions supported, except for payload data storage, for which a margin of 25% shall apply.

DHS-050

The DHS shall allow for simultaneous data acquisition and data downlink.

DHS-060

The DHS shall provide for the acquisition, processing, storage and transmission to ground of all data generated by the payload and the platform. This shall include ancillary data necessary for instrument and other sensor calibrations, operations and monitoring as well as the supporting timing, orbit and attitude data.

DHS-070

On-board data handling and storage shall be reconfigurable by ground command. It shall be possible to acquire, process and transmit to ground any selected sub-sets of on-board data. This shall include over- and under-sampling of data channels from one or more instruments or platform subsystems.

DHS-080

Acquisition of housekeeping data shall be performed for all instruments and platform subsystems, such that their state of health can be assessed at any time. Housekeeping data shall be unambiguous, with update frequencies compatible with the characteristics of the signal sources.

DHS-090

Telecommands generated by the ground segment shall be validated and transferred to the relevant on-board users. Both time and event triggering shall be provided.

DHS-100

Timelines, consisting of several telecommands, shall be handled according to the specified conditions. Handling of nested timelines shall be possible.

DHS-110

Mode changes by telecommand shall be possible including the definition of new modes.

DHS-120

The DHS shall support on-board failure detection, isolation and recovery functions.

DHS-130

The DHS shall allow for simultaneous reception of telecommands and downlink of data.

DHS-140

The DHS design shall avoid the need for utilisation of non-standard data links, e.g. dedicated connections, and shall minimise the number of standards.
DHS-150

The architecture of the DHS shall follow the recommendations of ND[20].

DHS-160

The design of the DHS shall fulfil the requirements of ND[11].

4.7.8

4.7.8 Communications

Considering the constraints imposed by the ITU and the ECSS and CCSDS standards, contractors should have enough information and margin to define the interface, according to their concepts and analysis. A draft space to ground segment interface shall be proposed taking into account AD[4].

COM-010

The communications system shall provide the capabilities to transmit the global data stream to and receive data and commands from the ground segment.

COM-020

The system shall provide communications for housekeeping telemetry and telecommand for any satellite attitude.

COM-030

The housekeeping telemetry shall be downlinked in S-band.

COM-040

The telecommands shall be uplinked in S-band.

COM-050

The global data stream shall be downlinked in TBD band to the Ground Station. The selection of suitable frequency bands will take AD[4] into account.

COM-060

The communication subsystem shall follow the guidelines of ND[25], ND[26], ND[21], ND[28], ND[30], ND[31], ND[33] and ND[58].

COM-070

Communications to and from ground shall be packet-based. The telecommand and telemetry protocols, the authentication of telecommands shall be as defined in the ECSS standards and specifically ND[25], ND[26] and ND[28].

COM-080

The observation data rate shall be derived from the observation requirements, the payload design and shall take into account the relevant operational constraints.
The data rate for the housekeeping telemetry shall be derived from the satellite monitoring requirements.

The data rate for telecommand shall be derived from the satellite command and operation requirements, including provisions for potential software updates.

The space segment shall support Range and Doppler measurements, as a backup to nominal GNSS-based orbit determination.

The following data quality requirements apply for the global data stream:

TBD

The following data quality requirements apply for the S-band uplink:

TBD

The up and downlinks margins shall be defined as specified in ND[22].

4.7.9 On Board Software

Onboard software for the execution of vital operational procedures, including boot procedures, shall be stored in a non-volatile memory such that a default configuration is always available in the event of anomalies. This default configuration shall be transferred automatically into a working memory upon switch on of the onboard computer.

It shall be possible to replace this default configuration totally or partially with software uplinked from ground.

It shall be possible to copy to ground the contents of the default configuration and working memories.

The onboard software shall be designed in a layered structure so that software maintenance (before and during flight) is confined to the upper application layer.

The onboard software shall be structured in a modular way using high level language(s) to be agreed with the Agency.
OSW-060

Safety critical software (e.g. safe mode, bootstrap, etc.) shall be designed, integrated, tested and validated independently from the rest of the software.

OSW-070

Any embedded software shall be justified.

OSW-080

In-orbit modification of embedded software shall be possible.

OSW-090

If software is reused from previous programmes, it shall be possible to test it when integrated in its new environment.

OSW-100

All software shall be designed and validated in accordance with ND [19].

OSW-110

Preliminary software metrics shall be established and suitable margins shall be identified.

OSW-120

The software elements shall fulfil the requirements of ND[19].

4.8 Space To Ground Interface Requirements

See statement in paragraph 4.7.8, and refer to AD [4] for a preliminary ground to space interface requirements document.

4.9 Operability Requirements

4.9.1 General Operability Requirements

OPE-010

The Space Segment shall fulfil the operability requirements of ND[62], with the following tailoring specific to MTG mission:

1. Mission Constants
   
   <ANOM_RESP_TIME>: 3 minutes
   <ANT_SWITCH_TIME>: 3 minutes
   <AUT_DUR_EXEC>: minimum 1 hour
   <AUT_DUR_DATA>: not required
   <AUT_DUR_FAIL>: 72 hours
   <BATT_CHARGE_ACC>: 1%
   <DIAG_MIN_INTERV>: 1 ms
   <GRND_RESP_TIME>: 2 hours
<PARAM_ABS_SAMPL_TIME>: 1 ms
<PARAM_REL_SAMPL_TIME>: 100 microsec
<PAYLOAD_INT>: 1 hour
<PKT_RETR_DELAY>: 1 minute
<PKTS_NUM_STORED>: 100
<POW_CONS_THRESH>: 100 mW
<RESOURCE_MARGIN>: 50%
<TC_VERIF_DELAY>: 10s
<TIME_CORREL_ACCUR>: half of the time it takes to sample one pixel of the highest resolution image

2. Other tailored clauses
The following clauses of ND[62] are not required:
Clause 5.7.2.3 - There is no need to store mission products onboard.
Clause 5.7.5.7 - There is no need to autonomously establish a fully operational configuration after a failure.
Clause 5.8.2.1 to 5.8.2.6 - There is no need for statistical data reporting.
Clause 5.8.9.1 - MTG will have continuous ground coverage during on-station operation therefore there is no need to store all packets generated on-board.

3. Modified/added clause
The following clauses of ND[62] are modified/added for the MTG mission:
Clause 5.9.4.8 - Assuming a worst case satellite dry mass of the MTG (imaging or sounding) satellite of 1800 kg, a yearly propellant consumption for station keeping is assumed to be 30 kg. It is required to determine the need date for a replacement satellite with an accuracy of 1 months during the final 36 months of nominal lifetime. Therefore it is required to be able to determine the remaining amount of the propellant mass to an accuracy of 2 kg for the last 100 kg of propellant.

Clause 5.9.3.3 - The text needs to be modified to: ’The combined coverage of all on-board TT&C antennas shall be such that telemetry and telecommand contact can be provided under all foreseeable attitude and orbit conditions. This explicitly includes contingency cases during which the satellite attitude could be uncontrolled. This implies the implementation of a TTC antenna system with omnidirectional coverage.’

New Clause 4.5.7 (more specific than Clause 5.9.7.1 and not restricted to the payload) - ‘The design of the MTG satellite shall be such that no on-board equipment can be damaged or degraded in its performance by the incident of direct sunlight. As there are contingency cases during which the satellite attitude is uncontrolled, all equipment which is susceptible to direct sunlight shall be protected by means of retractable covers or similar measures. This
protection shall be automatically engaged when the satellite attitude becomes uncontrolled or when direct sunlight would enter the equipment. This applies in particular to imaging equipment, telescopes and sensors.”

Note 9:
For costing and planning purposes, it should be anticipated that all data related to the MTG satellite operation on-ground and in-orbit are developed, maintained and configuration controlled electronically using data structures and tools that are compatible between the development (including design and AIT) and operations entities. This data includes the mission database (refer to ND[60]), operational procedures/sequences (refer to ND[61]) and maintainable on-board software (refer to ND[62]). The data should be available to the operations entities incrementally and in a time frame compatible with the operations preparation schedule for the satellite launches.

4.9.2 Specific Operability Requirements

The following requirements identify the “what and when” of key operational data that should be considered, as a minimum, for costing and planning purposes.

**OPE-020**

_The Space Segment development shall fulfil the requirements of ND[59], particularly regarding the document structure of the Space Segment User Manual._

**OPE-030**

_The operations defined in the Space Segment User Manual shall be fully validated by the Satellite Manufacturer, as far as possible through use during the AIV programme._

**OPE-040**

_The satellite operations procedures shall be compliant with the requirements of ND[61]._

**OPE-050**

_It shall be possible to bring the Hot Backup satellite into full operational service within 2 (TBC) hours of detection of an anomaly on the Prime satellite, i.e. including all necessary satellite reconfiguration and thermal stabilisation._

**OPE-060**

_The satellite shall operate in nominal mode throughout the eclipses, in accordance to the requirements of the restricted zones {FCI-440, 450 & 460 and IRS-400, 410 & 430, for LI (TBD)} and the constraints of FCI-380._

**OPE-070**

_A standby satellite configuration shall be defined that can be used for prolonged periods of time and from which it is possible to reconfigure to a nominal mission configuration within 3 hours. In this standby configuration there shall be the need for minimal ground intervention._
4.10 Launcher

LAU-010

The Space Segment shall be compatible with the launch vehicle provided GTO elements defined in the User Manual for both primary and back-up launchers. In case one of the two launchers use a launch site at a non-equatorial latitude, the benefits of a supersynchronous transfer orbit shall be considered in the Mission Analysis. This implies also that the Space Segment design shall be able to cope with supersynchronous orbit altitudes.

LAU-020

The satellite shall be able to withstand without performance degradation the environment generated by the launcher. This shall be verified by methods approved by the Agency against the requirements as published in the relevant launch vehicle documentation.

LAU-030

The Space Segment shall be compatible with at least one launcher from an European Supplier.

4.11 Satellite Environment

4.11.1 Ground Handling, Transportation and Testing

GHT-010

The Mechanical ground support equipment shall ensure that the ground environment does not become a design driver for any flight element.

GHT-020

Integration and handling shall take place in a controlled environment. Mechanical and thermal loads induced by the environment shall not establish the dimensioning case for any element of the satellite. This shall be ensured by the use of adequate means of transportation and protective ground support equipment.

GHT-030

The satellite and the GSE shall be designed to withstand without any performance degradation the tests to be performed on ground.

GHT-040

The tests, their definition, the applicable environmental levels, as well as the underlying rationale shall be derived from the predicted conditions during launch and in-orbit suitably factored for qualification and acceptance.
4.11.2 Space Environment

4.11.2.1 General

SEN-010

*The MTG in-orbit elements shall be compatible with the in-orbit environment as defined in ND[7]. The Space Environment defined by the ECSS Standard shall be used with respect to the definitions of:*

- Atomic oxygen environment (as relevant to GTO and transfer to GEO)
- Charged Particle Radiation
  - Magnetospheric Particles
  - Cosmic Rays
- Atmosphere (as relevant to GTO and transfer to GEO)
  - Atmospheric Density
  - Plasma
- Solar Activity
- Gravity field
- Magnetic Field
- Thermal Environment

*where applicable.*

4.11.2.2 Electromagnetic Compatibility

SEN-020

*All electric circuits shall be protected against the effects of Electrostatic Discharges.*

SEN-030

*Electromagnetic, including radio frequency, compatibility of the satellite and its constituent parts shall be ensured by design and verified by one of the defined methods as per AIV-150 or a combination thereof. This shall include conducted as well as radiated interference.*

SEN-040

*Compatibility with the test facilities and particularly the launch environment, as specified in the relevant launch vehicle documentation shall be ensured.*

SEN-050

*The system, subsystem and unit design and test programme shall be adequate to ensure that the combined conducted and radiated emissions from all sources shall not adversely affect the correct operation of the payload.*
SEN-060

Suitable margins shall be established for susceptibility to and emission of interference. As a guideline, a margin of at least 6 dB shall be demonstrated, except for pyrotechnic devices where a minimum margin of 20 dB shall be demonstrated.

SEN-070

Design rules shall be defined for all design, manufacturing and verification activities to achieve a high level of compatibility already by design. This shall include, but not be limited to grounding, shielding as well as the distribution of power and data. The constraints of the ground and space environments shall be duly accounted for.

SEN-080

As a guideline, power and signal lines and returns shall be separated, a distributed single point grounding concept shall be adopted, housing of electronic boxes shall be isolated from electrical signals, filters shall be used to reduce conducted emission and susceptibility, electronic boxes shall be bonded to the mounting structure and power converter frequencies shall be selected outside the operating bandwidths of instruments.

SEN-090

All external surfaces of the satellite shall be conductive to a level compatible with the in-orbit particle environment. They shall be connected to the satellite structure to avoid the effects of differential charging.
4.11.2.3 Radiation

SEN-100

Energetic particles, resulting from solar radiation or trapped in the Earth’s radiation belts as well as cosmic rays are likely to inflict damage to parts exposed on the outside of the satellite or to sensitive parts located inside. Their effects shall be analysed by means of suitable simulation tools as described in ND [7]. Potentially sensitive electronics shall preferably be designed to minimise the effects resulting from the radiation environment.

SEN-110

Cosmic Rays can produce intense ionisation that could induce single event upsets and latch up of the on-board digital circuitry. All electronics shall be free of or protected from single event latch-up.

SEN-120

The design of the satellite shall be robust against Single Event Upset (SEU) effects. This implies the use of EEE parts with low SEU sensitivity and/or the mitigation of SEU effects by appropriate electronic design measures (e.g. filters in signal lines where necessary). It shall be possible to recover from the effects of SEU’s.

SEN-130

Charging of the external surfaces may result from severe solar or auroral events giving rise to electrostatic discharge and thus high current pulses in the satellite structure. Likewise, interactions with the geomagnetic field could generate disturbance torques. These effects shall be duly analysed and suitable countermeasures included in the design.
4.12 Product Assurance Requirements

4.12.1 General

PQA-010

The PA activities shall ensure the traceability of requirements across the various levels of specifications with verification methods, with identification of Customer agreed waivers whenever requirements cannot be met.

4.12.2 Reliability

PQA-020

The reliability of the MTG Space Segment elements shall be compatible with the system availability requirements.

PQA-030

Reliability considerations shall be used as criteria for trading-off candidate concepts on a quantitative basis.

PQA-040

Failure avoidance, if possible, shall be preferred to failure tolerance.

PQA-050

Reduction of stresses shall be preferred to over-design to increase margins.

PQA-060

Single point failures (SPF) in the categories “catastrophic” and “critical” shall be avoided for satellite vital functions. Exceptions, if any and if unavoidable, shall be justified and their impacts shall be identified. Any SPF shall be submitted to the Agency for approval. SPF's shall result from Failure Mode Effects and Criticality Analysis (FMECA).

PQA-070

No single satellite failure in combination with an operator error shall result in the loss of the mission.

PQA-075

For the MTG missions (HRFI and FDHSI), the reliability of the satellite(s) shall be better than 0.95 over any 18 months period (TBC).

For the DCS mission, the reliability of the satellite(s) shall be better than 0.99 over any 18 months period (TBC).

For the IRS mission, the reliability of the satellite(s) shall be better than 0.8 for 7 years.
**PQA-080**

*Failure propagation shall be avoided by design.*

**4.12.3 Availability**

**PQA-090**

*Nominal satellite performance including all instruments shall be ensured for the nominal mission duration. Availability requirements for mission elements shall be derived from the space segment system level availability and observation requirements.*

**PQA-095**

*The MTG satellite(s) shall ensure that the communication between the Spacecraft and the Ground control is 99.9% available.*

*The outage budget (see outage definition) for each of the MTG missions (HRFI, FDHSI and IRS) shall be better than 4% (TBC).*

**PQA-100**

* Interruption of observation due to orbit operations, e.g. orbit correction, calibration, shall be minimised.*

**PQA-105**

*The following addresses the limits that shall be applied for certain planned and predictable outages (not exhaustive list):*

- Outage resulting from sun stray light entering into the instruments field of view shall follow OPE-060;
- There shall be no outage resulting from instrument calibration (TBC);
- Outage resulting from manoeuvres shall be minimised;
- Outage resulting from instrument decontamination shall be less than 24 hours per year for IR channels and less than 1 hour for Visible channels (if relevant).
- It shall be possible for the Imaging satellite to be configured from High Resolution imaging mode to Normal Imaging mode (and vice versa) with no outage;
- It shall be possible for the Imaging satellite to be configured from Full Earth Coverage mode to Limited Area Coverage mode (and vice versa) with no outage.*
4.12.4 Maintainability

**PQA-110**

Provisions shall be made in the design to ease the maintainability of the satellite elements, including both hardware and software components.

**PQA-120**

The satellite shall support a TBD years storage period (starting after completion of the FAR) on ground in a suitable environment to be specified by the Contractor requiring only minimum of maintenance activities.

**PQA-130**

It shall be possible to remove and replace failed and critical units and consumables with minimum de-integration of the satellite.

**PQA-140**

The design shall allow for late and fast integration of units and consumables that could require removal for prolonged storage.

**PQA-150**

The possibilities offered by the launcher authority for late integration and on-site maintainability shall be taken into account.

**PQA-160**

Software shall be maintainable while in orbit.

### 4.12.5 Safety

**PQA-170**

All elements of the system shall be designed to minimise hazards to personnel and property.

**PQA-180**

The relevant requirements of the launcher authority shall be complied with in full as well as the requirements in force for facilities to be used in the execution of the AIV programme.

**PQA-190**

The design shall avoid materials, operations and any feature likely to create safety concern unless the derived performance and cost benefits justify such choices.

**PQA-200**

Design choices likely to create safety concerns shall be identified and submitted to the Agency for approval.
### 4.12.6 Parts, Materials, and Processes (PMP)

**PQA-210**

*Parts, materials and processes (PMP) activities including cleanliness considerations shall be initiated during the Phase A Study to the extent needed to perform the required tasks.*

**PQA-220**

*Parts, materials and processes (PMP) that are either defined as critical for the achievement of the mission objectives, or to be developed, or, if already available, which would be operated outside the limits of previous applications or existing specifications, shall be identified and subjected to qualification programme for the MTG mission environment.*

**PQA-230**

*The design should ensure that the non-availability of PMPs does not imply in later stages of the project major redesign or delays.*

**PQA-240**

*New development and/or qualification of PMPs should be avoided.*

**PQA-250**

*The need for the production of elements in configurations different from already available standards should be avoided.*

**PQA-260**

*The procurement from non-European/Canadian sources should be avoided. If retained, it shall be done in consultation with the Agency.*

**PQA-270**

*Off-the-Shelf (OTS) parts, equipment or software may be used for the MTG Programme. This includes OTS items developed, built and qualified for other space projects with requirements at least equivalent to the ones in force for the MTG Programme or items categorised as commercial, aviation and military (CAM). The applicable quality requirements shall be covered by the PA plan.*
4.12.7 Electrical, Electronic and Electromechanical (EEE) Parts

**PQA-290**

EEE parts shall be selected among candidates able to withstand the expected environmental conditions, providing the performance expected under these conditions, as opposed to classical approaches of selecting components with the widest operational and survival range.

### 4.13 Assembly, Integration and Verification (AIV) Requirements

#### 4.13.1 General

**AIV-010**

Assembly, integration and verification (AIV) are defined as the processes in the life cycle of a mission leading from assembly of components to the verification of system performance at mission level. It thus covers all levels of hardware and software. This must include the end-to-end verification of all mission elements, preferably by operating them in a configuration, which is fully representative for the intended functions.

**AIV-020**

Verification methods based on simulations rather than testing shall be applied only when significant cost savings can be demonstrated. In other cases, testing shall be the baseline verification method.

**AIV-030**

Approaches based on early utilisation of system performance test benches, which are progressively upgraded to the system performance bench, including hardware and software in the loop, ground segment interfaces and operational procedures are encouraged.

**AIV-040**

Commonality of Mission Development Verification Environment (MDVE) elements across MTG Satellites shall be exploited if resulting in cost reduction and increased confidence in the verification.

#### 4.13.2 Assembly and Integration

**AIV-050**

Assembly and integration shall be planned to ensure accomplishment of the schedule and efficient use of resources along the development.

**AIV-060**

Integration interfaces shall be simple and with clear allocation of responsibilities.
AIV-070

The integration flow shall minimise the number of models and test drivers compatible with the overall development plan.

AIV-080

The design shall allow for easy access to onboard units during AIV. Skin test connectors and test points shall be provided.

AIV-090

The integrity of all interfaces, which are mated/demated during AIV for integration or replacement of units or for tests, shall be verified by test.

4.13.3 Verification

AIV-100

The verification programme shall cover the performance of all the elements of the MTG Space Segment.

AIV-110

The verification programme shall cover the interface requirements on elements external to MTG Space Segment.

AIV-120

The verification programme shall provide confidence in the mission objectives by demonstrating that the complete system meets the performance requirements under the specified environments.

AIV-130

The verification programme shall cover all performance parameters in a hierarchical structure such that all mission objectives, broken-down to lower levels, can be fully traced.

AIV-140

Verification shall be performed hierarchically and exhaustively at each level of specification, without omissions, and therefore without assuming that the next upper level of verification can properly address not verified lower level requirements. This will improve early detection and correction of non conformance, avoiding impacts to the programme at later stage when the way to resolve the problem will be much more complex and costly.

AIV-150

All satellite functions shall be verifiable by review-of-design, similarity, analysis, simulation or test or combinations thereof. These methods are listed by increasing order of priority.

AIV-160

All prime and redundant functions shall be verified during the AIT programme.
AIV-170

End-to-end verification shall be performed to ensure that all system elements contributing to mission success are covered. In particular, all mission representative operational scenarios will be run to demonstrate overall system operability and performance prior to the launch.

AIV-180

The verification programme shall include verification of the interfaces with the launcher.

AIV-190

Standard verification procedures and configurations shall be used at all levels of integration to ensure repeatability and reproducibility.

AIV-200

The design shall provide for in-orbit verification and calibration as required.

AIV-210

MTG Satellites and all their elements shall be designed to allow long-term Validation and Calibration of the payload data.

4.13.4 Satellite Models

AIV-220

A model concept shall be developed for the various development stages according to the following principles:
- minimum number of models,
- maximum utilisation of each model,
- as far as possible, decoupling of payload and platform development activities.

AIV-230

Hardware models and testing shall be replaced by analysis and simulation when the latter can provide sufficient confidence in combination with adequate design margins. The analytical tools and simulators shall be validated for the intended purpose.

AIV-240

Instrument models shall be defined with the objective to be integrated in the system models.

AIV-250

The concept for spare and replacement models shall cover all levels of hardware. This concept shall minimise the impact of hardware failures on the AIV programme. The model standards shall be commensurate with that of the articles replaced. In particular, they shall not introduce undue stresses on other flight hardware or invalidate verification results. A balance shall be made between the reduction of risk to the AIV programme and economic constraints.
AIV-260

In establishing the policy for spares, the needs across MTG Satellites shall be considered.

4.13.5 Ground Support Equipment

AIV -270

The ground support equipment (GSE) shall include all hardware and software necessary to support the AIV activities at all levels of integration up to and including preparation and testing at the launch site.

AIV-280

The GSE shall permit functional testing to demonstrate flight readiness of the integrated system.

AIV-290

The GSE shall be compatible with the satellite and shall not cause failure or damage to it.

AIV-300

The GSE shall be compatible with the launch site facilities and the ground facilities as required.

AIV-310

The Mechanical GSE (MGSE) shall also include the equipment needed for transport, handling and storage.

AIV-320

The MGSE and the associated handling procedures shall ensure that no item is subjected to environments more demanding than equipment flight acceptance level.

AIV-330

The Electrical GSE (EGSE) shall support the integration and testing of on-board hardware and software.

AIV-340

The EGSE shall be capable of loading, dumping and modifying the flight software.

AIV-350

The EGSE shall support the development and testing of operational procedures.

AIV-360

The EGSE shall support end to end system tests as SVT, SSVT, listen in and instrument data recording.

AIV-370

The GSE design shall take into account the requirements of the AIV facilities as appropriate.
AIV380

The RF suitcase model shall comprise flight-representative hardware sufficient to test all up- and downlinks for functional and performance characteristics.

AIV-390

The commonality of GSE across MTG Satellites shall be exploited when resulting in cost savings and more robust AIV.

4.13.6 Facilities

AIV-400

Instrument end-to-end verification during payload thermal vacuum testing shall be performed to the extent feasible within the given constraints of European Test Facilities.

AIV-410

Special facilities, if needed shall be early identified.

AIV-420

The use of a particular facility shall in no way result in unacceptable degradation of the test article or invalidation of the verification results.

AIV-430

The GSE design shall take into account the requirements of the facilities as appropriate.

5 Acronyms and Abbreviations

AD : Applicable Document
AEG : Application Expert Group
AMDR : Aircraft Meteorological Data Relay
AOT : Aerosol Optical Thickness
ASAP : Automated Shipboard Aerological Programme
AVHRR : Advanced Very High Resolution Radiometer
CAL : Calibration
CAPE : Convective Available Potential Energy
CBA : Cost Benefit Analysis
CCSDS : Consultative Committee for Space Data Systems
CEOS : Committee on Earth Observation Satellites
CGMS : Coordination Group for Meteorological Satellites
CMV : Cloud Motion Vectors
DCAPE : Downdraught Convective Available Potential Energy
DCS : Data Collection System
DCP : Data Collection Platforms
DCPC : WMO Information System: Data Collection or Product Centre
<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>DE</td>
<td>Detection Efficiency</td>
</tr>
<tr>
<td>ECMWF</td>
<td>European Centre for Medium Range Weather Forecasting</td>
</tr>
<tr>
<td>ECSS</td>
<td>European Cooperation for Space Standardization</td>
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<tr>
<td>EMC</td>
<td>Electromagnetic Compatibility</td>
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<td>ESA</td>
<td>European Space Agency</td>
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<td>EUMETSAT</td>
<td>European Organisation for the Exploitation of Meteorological Satellites</td>
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<tr>
<td>EURD</td>
<td>End Users Requirements Document</td>
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<td>E/W</td>
<td>East/West</td>
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<td>FAR</td>
<td>False Alarm Rate</td>
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<tr>
<td>FDHSI</td>
<td>Full Disk High Spectral resolution Imagery mission</td>
</tr>
<tr>
<td>FD</td>
<td>Full Disc</td>
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<tr>
<td>FDC</td>
<td>Full Disk Coverage</td>
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<tr>
<td>FOR</td>
<td>Field of Regard</td>
</tr>
<tr>
<td>FT</td>
<td>Free Troposphere</td>
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<tr>
<td>FWHM</td>
<td>Full-Width at Half-Maximum</td>
</tr>
<tr>
<td>FWIS</td>
<td>Future WMO Information System</td>
</tr>
<tr>
<td>GCOS</td>
<td>Global Climate Observing System</td>
</tr>
<tr>
<td>GERB</td>
<td>Geostationary Earth Radiation Budget instrument</td>
</tr>
<tr>
<td>GISC</td>
<td><em>WMO Information System</em>: Global Information System Centre</td>
</tr>
<tr>
<td>GMES</td>
<td>Global Monitoring for Environment and Security</td>
</tr>
<tr>
<td>GMS</td>
<td><em>Japanese</em> Geostationary Meteorological Satellite</td>
</tr>
<tr>
<td>GOES</td>
<td><em>American</em> Geostationary Environmental Operational Satellite</td>
</tr>
<tr>
<td>GOMS</td>
<td><em>Russian Federation</em> Geostationary Operational Meteorological Satellite</td>
</tr>
<tr>
<td>GOOS</td>
<td>Global Ocean Observing System</td>
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<td>GOS</td>
<td>Global Observing System</td>
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<tr>
<td>GTOS</td>
<td>Global Terrestrial Observing Systems</td>
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<tr>
<td>GTS</td>
<td>Global Telecommunication System</td>
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<tr>
<td>HIRLAM</td>
<td>High Resolution Local Area Model</td>
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<tr>
<td>HR</td>
<td>Hit Rate</td>
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<tr>
<td>HRFI</td>
<td>High Resolution Fast Imagery mission</td>
</tr>
<tr>
<td>HRV</td>
<td>High Resolution Visible</td>
</tr>
<tr>
<td>IDCS</td>
<td>International Data Collection System</td>
</tr>
<tr>
<td>IE</td>
<td>Integrated Energy</td>
</tr>
<tr>
<td>IFOV</td>
<td>Instantaneous Field of View</td>
</tr>
<tr>
<td>IGOS</td>
<td>Integrated Global Observing Strategy</td>
</tr>
<tr>
<td>INR</td>
<td>Image Navigation and Registration</td>
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<tr>
<td>IOC</td>
<td>Intergovernmental Oceanographic Commission (UNESCO)</td>
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<tr>
<td>IR</td>
<td>Infrared</td>
</tr>
<tr>
<td>IRS</td>
<td>Infrared Sounding Mission</td>
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</table>
ISRF : Instrument Spectral Response Function
ITU : International Telecommunications Union
LAC : Limited Area Coverage
LI : Lightning Imagery mission
LOS : Line Of Sight
LS : Lower Stratosphere
LST : Land Surface Temperature
LT : Lower Troposphere
MAR : Mesoscale Area Region
MATER : Mission Assumption and Technical Requirements
MDR : Mission Definition Review
MDT : Mean Down Time
MFV : Meteosat Field of View
MODIS : Moderate Resolution Imaging Spectro-radiometer
MSG : Meteosat Second Generation
MRD : Mission Requirements Document
MTBDE : Mean Time Between Downing Events
MTG : Meteosat Third Generation
NC : WMO Information System: National Centre
NEDN : Noise Equivalent Differential Radiance
NEDT : Noise Equivalent Differential Temperature
NIR : Near-Infrared
NMS : National Meteorological Services
NPOESS : National Polar-orbiting Operational Satellite System
NPP : NPOESS Preparatory Programme
NR : Normative Document
NWC : Nowcasting
NWP : Numerical Weather Prediction
N/A : Not Applicable
N/S : North/South
OAIS : Open Archival Information System (CCSDS Std)
OPD : Optical Path Difference
PAN : Peroxyacetyl nitrate
PARD : Programmatic Assumptions and Requirements Document
PBL : Planetary Boundary Layer
PCR : Preliminary Concept Review
PRR : Preliminary Requirements Review
PSF : Point Spread Function
QOS : Quality of Service
<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>RAMS</td>
<td>Reliability, Availability, Maintainability &amp; Safety</td>
</tr>
<tr>
<td>RD</td>
<td>Reference Document</td>
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<tr>
<td>RDCS</td>
<td>Regional Data Collection System</td>
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<tr>
<td>RMS</td>
<td>Root Mean Square</td>
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<tr>
<td>RMDCN</td>
<td>Regional Meteorological Data Communication Network</td>
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<tr>
<td>ROI</td>
<td>Region of Interest</td>
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<tr>
<td>RSE</td>
<td>Remote Sensing Expert</td>
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<tr>
<td>RTM</td>
<td>Radiative Transfer Model</td>
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<tr>
<td>SAF</td>
<td>Satellite Application Facilities</td>
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<tr>
<td>SEU</td>
<td>Single Event Upset</td>
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<tr>
<td>SEVIRI</td>
<td>Spinning Enhanced Visible and Infrared Imager</td>
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<tr>
<td>SOG</td>
<td>Statement of Guidance</td>
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<tr>
<td>SRD</td>
<td>System Requirements Document</td>
</tr>
<tr>
<td>SSA</td>
<td>Aerosol Single Scattering Albedo</td>
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<tr>
<td>SSA</td>
<td>Spatial Sampling Angle</td>
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<tr>
<td>SSD</td>
<td>Spatial Sampling Distance</td>
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<tr>
<td>SST</td>
<td>Sea Surface Temperature</td>
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<tr>
<td>STD</td>
<td>Standard</td>
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<tr>
<td>SWIR</td>
<td>Short Wave Infrared</td>
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<tr>
<td>TBC</td>
<td>To Be Confirmed</td>
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<td>TBS</td>
<td>To Be Specified</td>
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<tr>
<td>TDI</td>
<td>Time Delay Integration</td>
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<tr>
<td>TIR</td>
<td>Thermal Infrared</td>
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<tr>
<td>TN</td>
<td>Technical Note</td>
</tr>
<tr>
<td>TOA</td>
<td>Top of the Atmosphere</td>
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<tr>
<td>UTC</td>
<td>Universal Time Coordinated</td>
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<tr>
<td>UV</td>
<td>Ultra-violet</td>
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<td>UVS</td>
<td>UV-VIS Hyperspectral Imager</td>
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<td>VIS</td>
<td>Visible</td>
</tr>
<tr>
<td>VSRF</td>
<td>Very Short Range Forecast</td>
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<tr>
<td>WMO</td>
<td>World Meteorological Organisation</td>
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<td>WWW</td>
<td>World Weather Watch</td>
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End of Document