LPS 2022

THE INFRA-RED SOUNDER

A NEW TOOL FOR EARLY DETECTION OF HEAVY WEATHER EVENTS AND ATMOSPHERIC GAS TRACING APPLICATIONS

25/05/2022

FRANCESC LUCAS CARBÓ, R. FECKL, G. FUSCO, K. LATTNER, R. SCHÖNFELD | OHB SYSTEM AG
S. ABDON, D. MIRAS | TAS
D. AMINOU, P. BLYTHE, J. CHAMPION, M. FALKNER, T. GUGGENMOSER, D. LAMARRE | ESA
L. DE LA TAILLE, S. GIGLI | EUMETSAT

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MTG SOUNDING MISSION OVERVIEW

- The **MTG Sounding** (MTG-S) satellite is composed by the **Infra-Red Sounder** (IRS) and the **UVN/Sentinel-4** (Ultraviolet-Visible-Near-Infrared) instruments.

- The main science goal of the MTG Sounding Mission is to provide **Atmospheric Motion Vectors** (AMVs) with higher vertical resolution (to be extracted from the tracking of three dimensional water vapour patterns) to enhance **Numerical Weather Prediction** (NWP)

- The IRS will be the first European hyperspectral sounding instrument in geostationary orbit

- An advantage of the IRS for nowcasting will be the detection of lower-level water vapor convergence preceding convection together with the retrieval of vertical temperature and wind motion profiles; thus allowing early detection of severe weather events

- Spectral resolution/calibration and radiometric performance are key elements for achieving vertical reconstruction

- Additionally, the IRS' spectral coverage allows to provide information regarding carbon monoxide, ozone, sulfur dioxide (e.g. from volcanic eruptions) and ammonia, which are very valuable for air quality forecasting and atmospheric composition monitoring (complementing UVN/Sentinel-4 observations)

CO O_3

H_2O CO_2

Clouds Aerosols

Temperature Profiles

Surface Properties
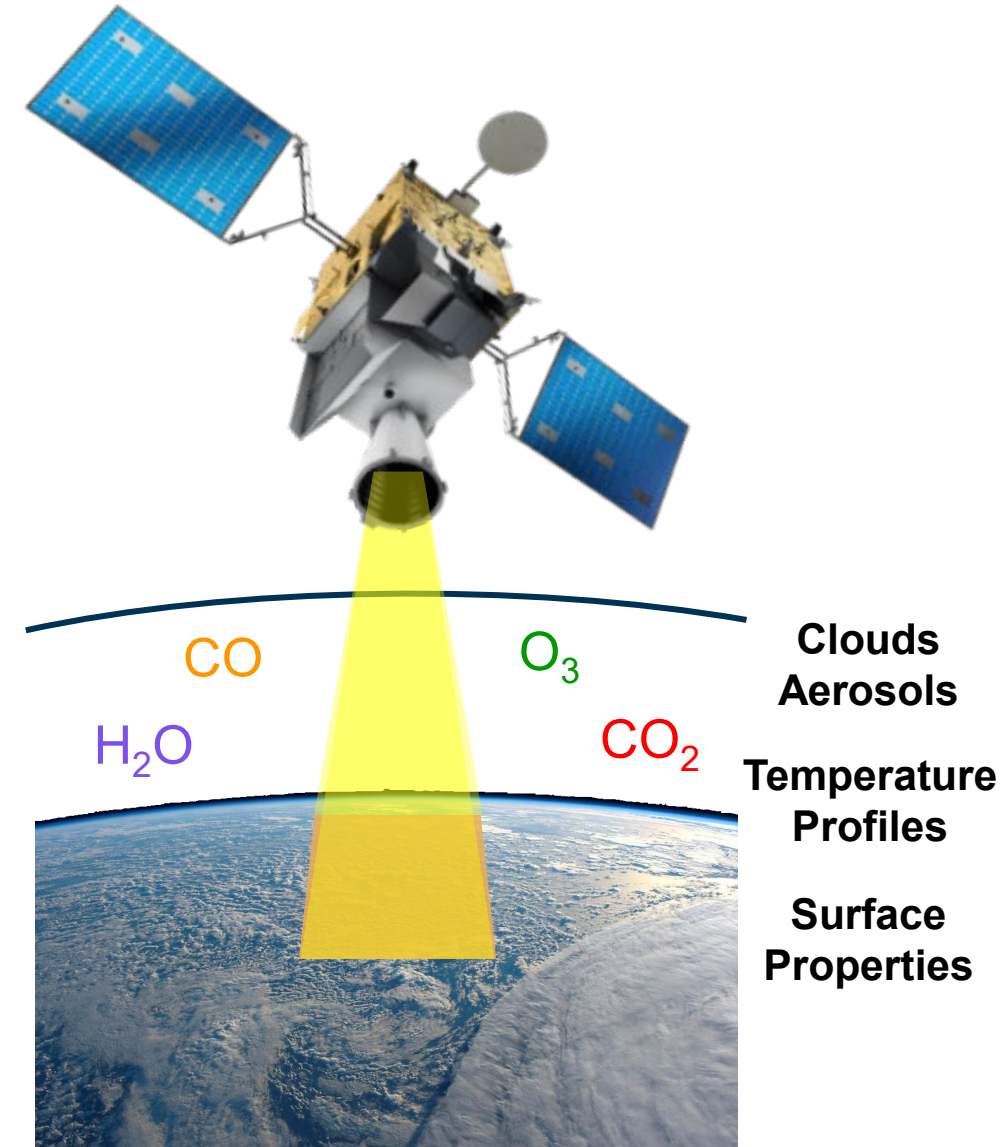
MTG-IRS INSTRUMENT OVERVIEW AND DEVELOPMENT STATUS

DESIGN AND MAIN CHARACTERISTICS

- The IRS is an **Imaging Fourier Transform Spectrometer**

- The IRS is composed of five main sub-elements, which are developed and manufactured in parallel:

  - the **Front Telescope** (incl. **Scanner**) that scans the Earth and collects light from the Earth,

  - the **Calibration and Obturation** mechanism that provides reference scenes for calibration,

  - the **Michelson Interferometer** assembly that modulates the scene radiances,

  - the **Back Telescope** that collects the flux of the interferometer; and

  - the **Detection and Electronics** assembly which contains optics, the detection chain and signal processing units
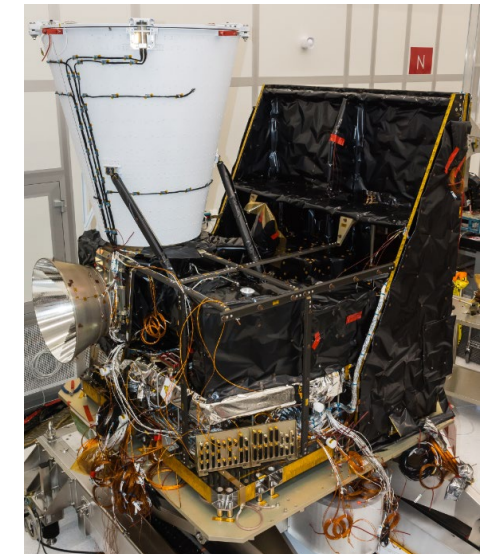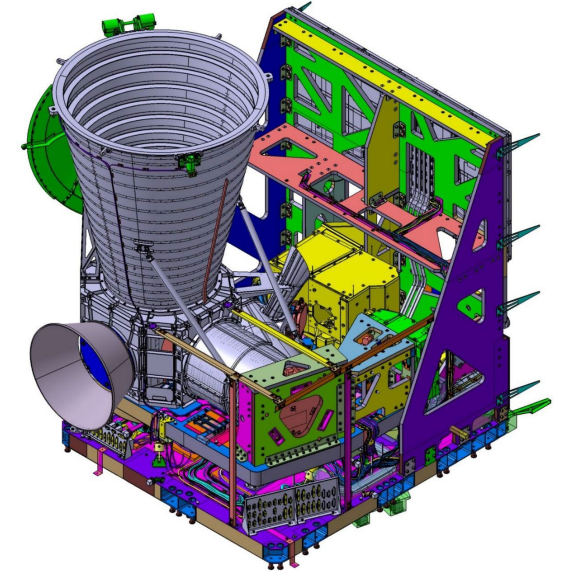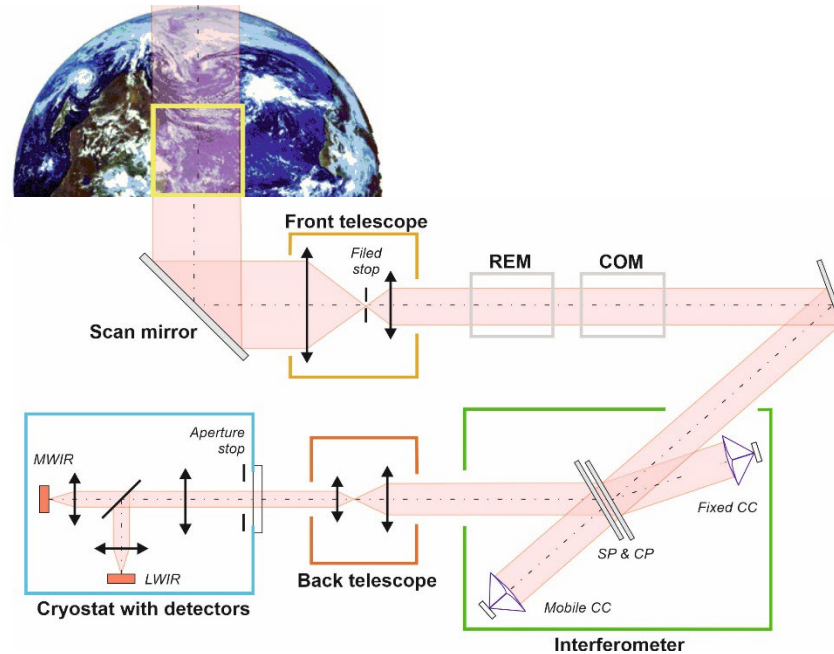

Dimensions	2021 x 1650 x 1895 mm (H x W x L)
Weight	460 kg
Radiometric Range	180 - 313 K
Spectral Range	LWIR: (680) 700 - 1210 cm^{-1} MWIR: 1600 - 2175 (2,250) cm^{-1}
Spectral Sampling	< 0.625 cm^{-1}
Ground Spatial Sampling	4 x 4 km² (at Nadir)
Detectors Size	160 x 160 pixels (90 x 90 µm/pixel)

OBSERVATIONAL SCENARIO

- The IRS observations are performed in a **step-and-stare** mode

- The stares are called dwells and contain data from 160 × 160 pixels and two spectral bands, ensuring contiguous hyperspectral imagery

- The Earth disk is divided into four Local Area Coverage (LAC) regions, which are each scanned within 15 min (full disk coverage in 60 min)

- The most northern quarter comprises **Europe** (LAC 4) and is revisited every 30 min

- LAC 4 is interleaved with other disk quarters to cover a full disk according to a fully configurable scanning pattern

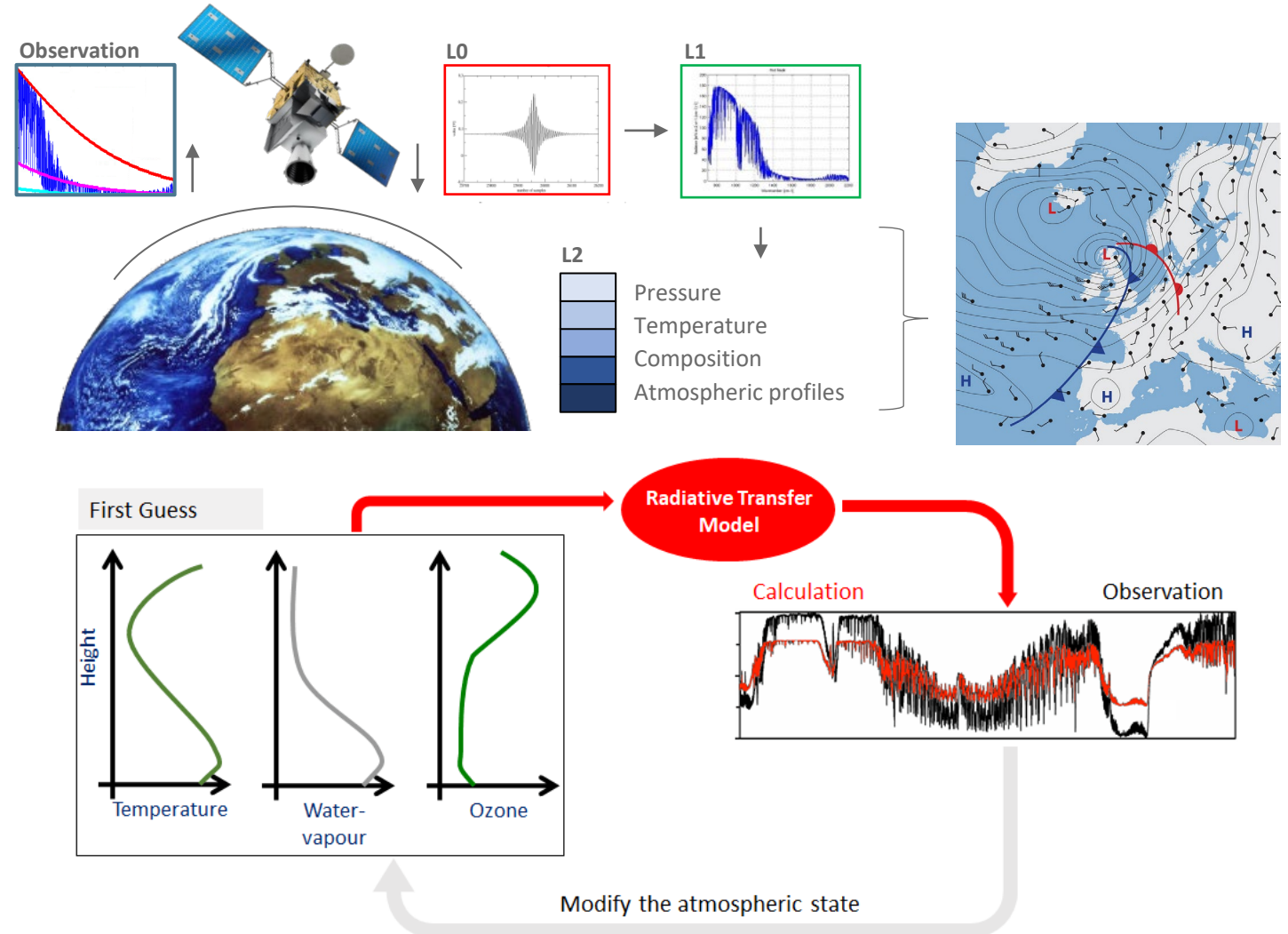- The scanning pattern is an optimized arrangement of Earth, Cold-Space and Blackbody views
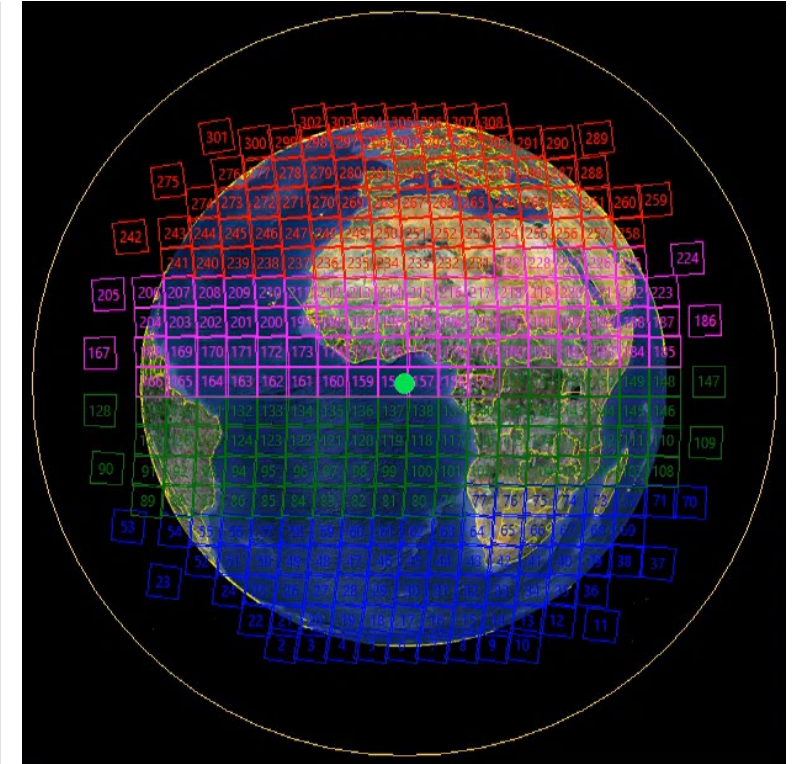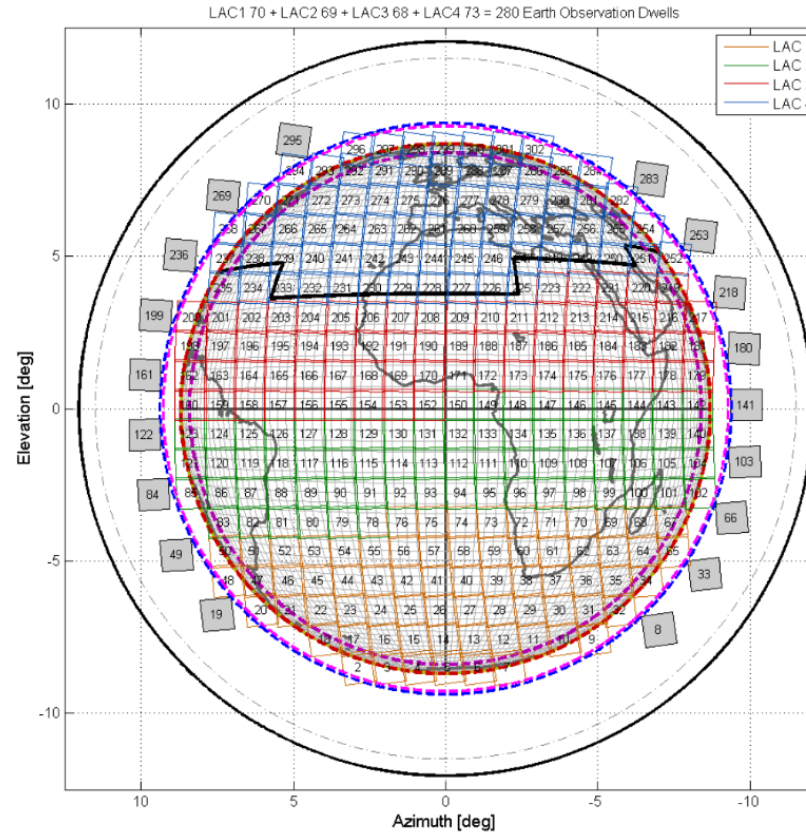
"The IRS delivers 25,600 infrared soundings covering 640 x 640 km² (410,000 km²)on Earth every 10 seconds"

MTG-IRS INSTRUMENT OVERVIEW AND DEVELOPMENT STATUS

DATA PROCESSING AND PRODUCTS

- The main purpose of IRS on-board data processing is to **reduce the amount of data to be transmitted to ground** (L0 Product). Before running the data reduction algorithms, some **pre-corrections** shall be applied in order maintain the performance of the data.

- All interferograms from the IRS are downlinked to ground, where they are **transformed into spectra** via fast Fourier Transformation, **radiometrically/spectrally calibrated**, and **geo-located** (L1 Product)

- The main geophysical products (L2 Products) at the start of operations will be **profiles of atmospheric temperature**, **specific humidity**, and **ozone**. In addition, total column water vapor, total column ozone, land/sea surface temperature, and land surface emissivity will be provided. The cloud products include cloud mask, cloud effective coverage, cloud-top pressure, and a dust indicator.


Observation

L0

L1

L2
- Pressure
- Temperature
- Composition
- Atmospheric profiles

First Guess

Height

Temperature | Water-vapour | Ozone

Radiative Transfer Model

Calculation | Observation

Modify the atmospheric state

MTG-IRS INSTRUMENT OVERVIEW AND DEVELOPMENT STATUS

EXPECTED RADIOMETRIC PERFORMANCE

- **Radiometric Noise**: standard deviation of the radiometric error associated with a spectral channel

- **Radiometric Accuracy**: mean radiometric error associated with a spectral channel

- **Mid-Term Stability:** radiometric stability over one day

- **Long-Term Stability:** radiometric stability over instrument lifetime
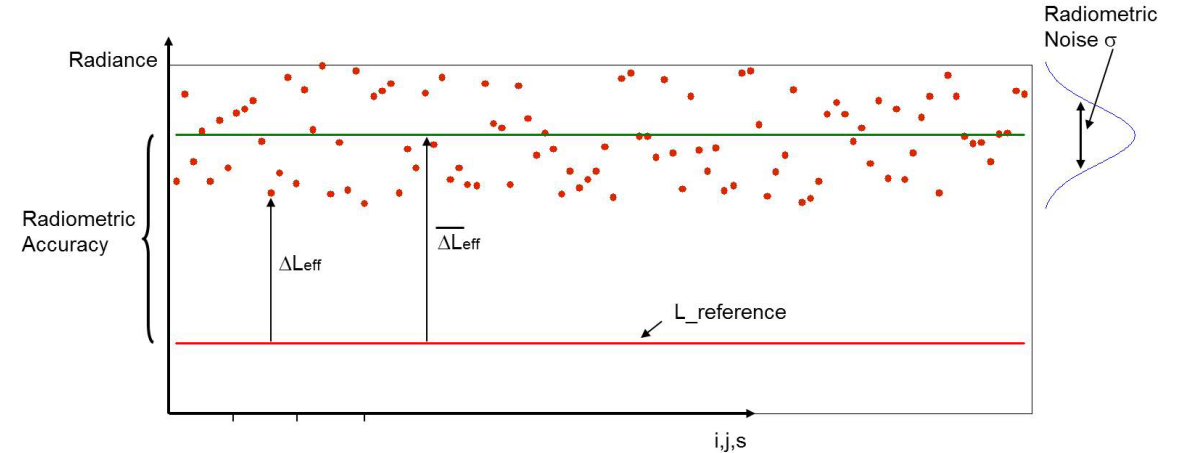
|	
Radiometric Accuracy	< 0.5 K (< 0.6 near 700 cm-1)
Medium Term Stability	< 0.1 K (< 0.2 near 700 cm-1)
Long-Term Stability	< 0.3 K (< 0.5 near 700 cm-1)
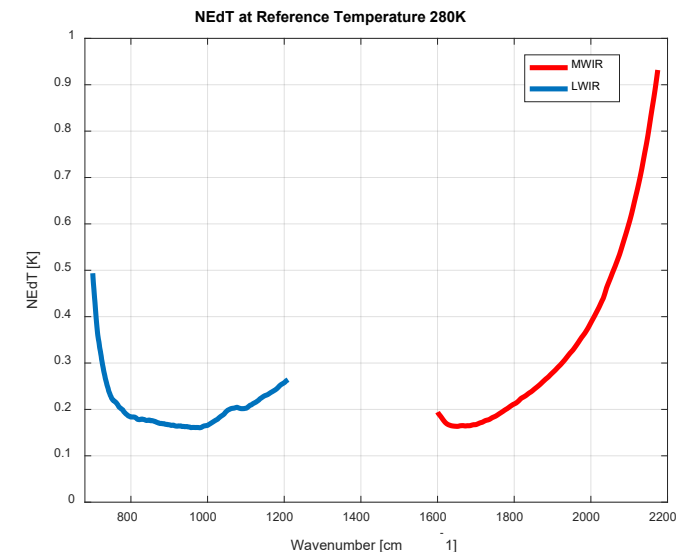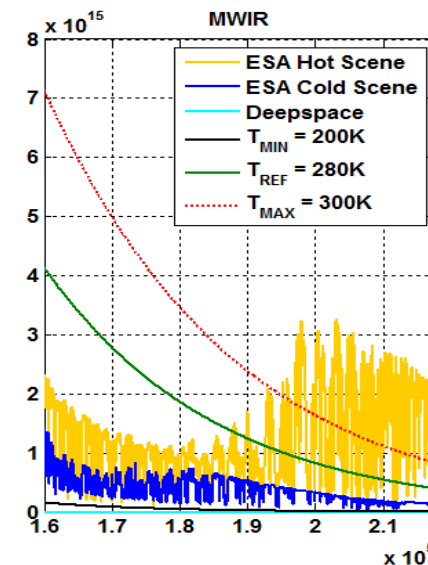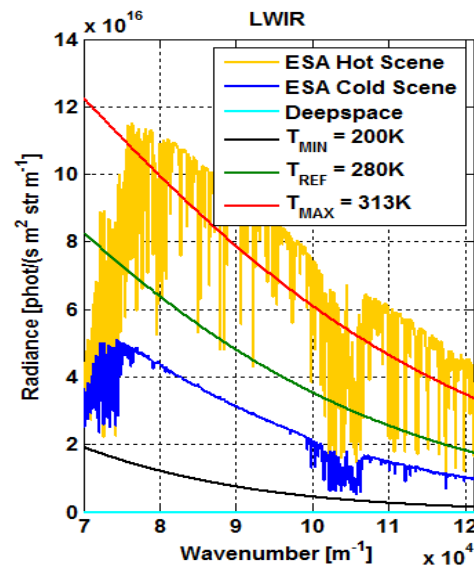
MTG-IRS INSTRUMENT OVERVIEW AND DEVELOPMENT STATUS

EXPECTED SPECTRAL PERFORMANCE

- **Spectral Response Function Knowledge:** spectral shape knowledge of the instrument

- **Spectral Resolution:** full-width half maximum of the SRF

- **Spectral Accuracy:** mean spectral scale error of the Spectral Response Function's centroid


Predicted and Measured ILS
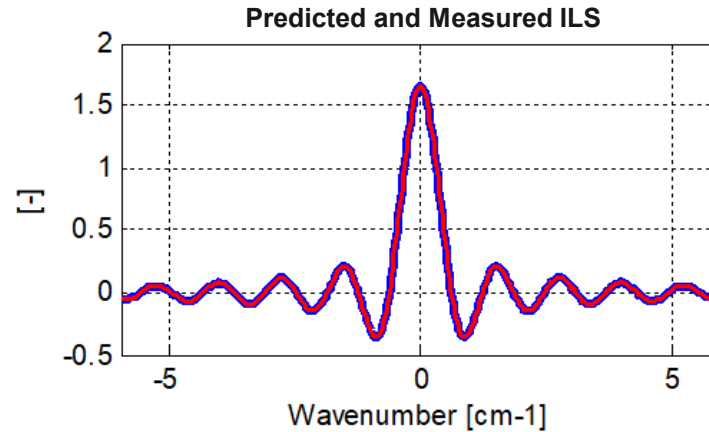
MOPD	0.828 cm
Spectral Sampling	< 0.625 cm^{-1}
SRF FWHM	< 0.747 cm^{-1}
Spectral Accuracy	~1.6 ppm (LWIR) and ~1.1 ppm (MWIR)
SRF Shape Knowledge	~20 mK (daily average) and ~30 mK (variation from dwell to dwell)

SRF Representation

Spectral Coverage

~2,000 IRS Channels
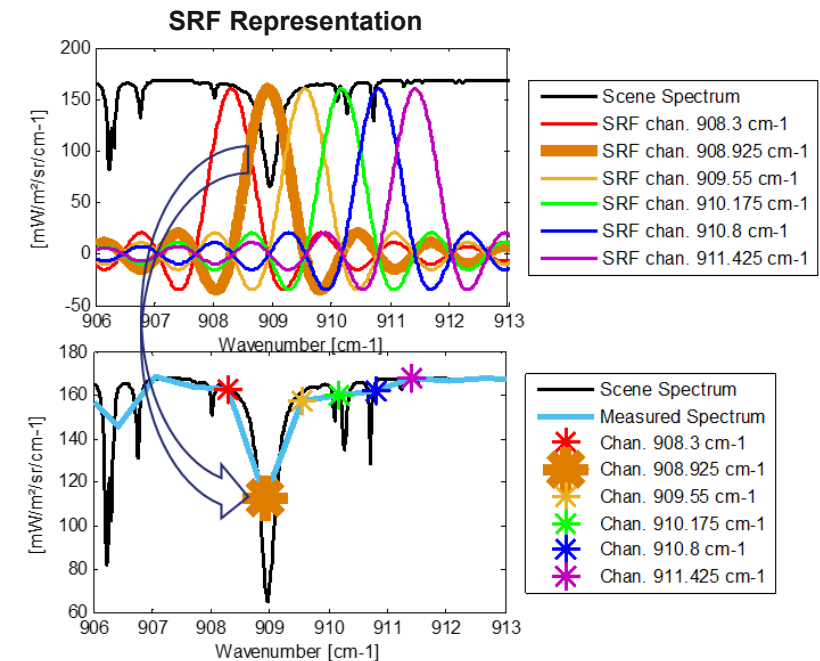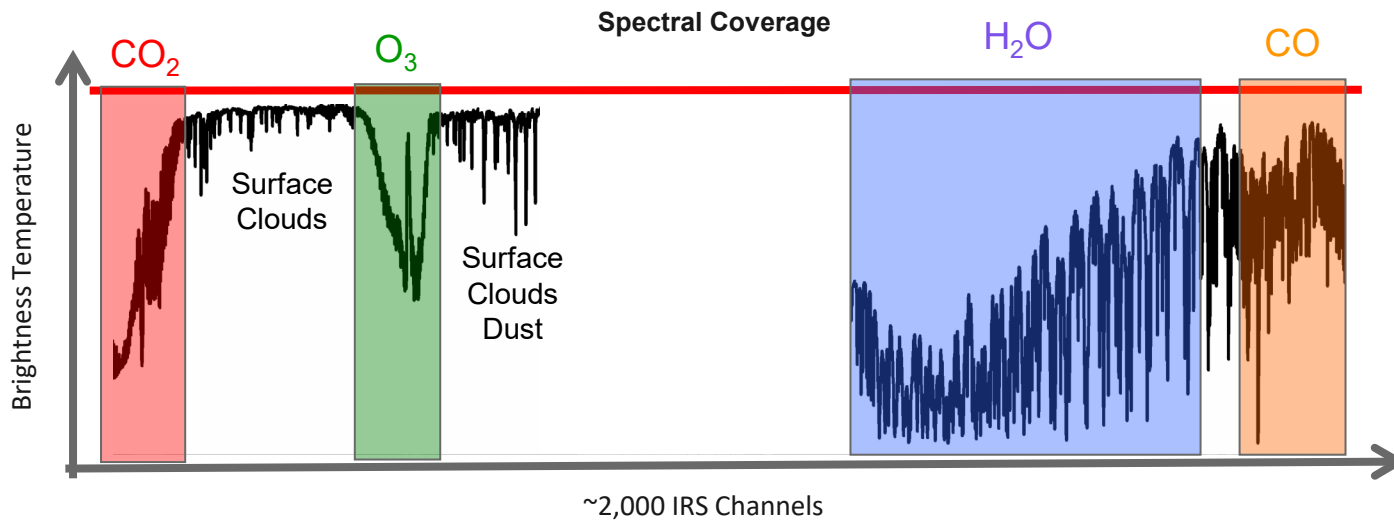
MTG-IRS INSTRUMENT OVERVIEW AND DEVELOPMENT STATUS

EXPECTED SPATIAL PERFORMANCE

- **Integrated Energy:** spatial integral of the Point Spread Function (PSF) of a spatial sample and a spectral channel over a square area centered around the PSF centroid

- **Spatial Sampling Distance:** spatial sample spacing on-ground

- **Spatial Sampling Error:** flight variation of spatial sample distance

- **Co-Registration:** relative difference of spatial sample position between different spectral channels on one detector (Intraband) or between detectors (Interband)

- **Pointing Performance:** line of sight knowledge and stability
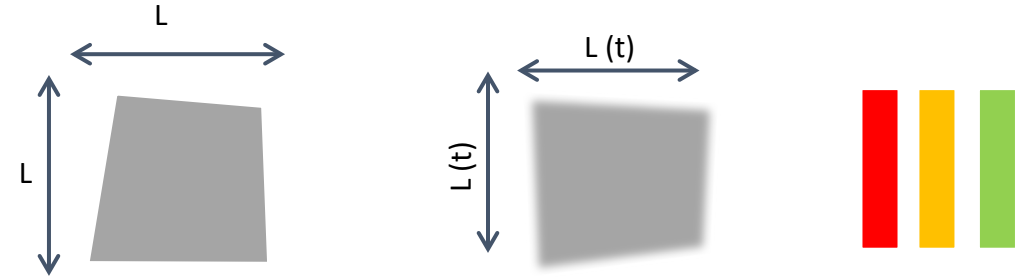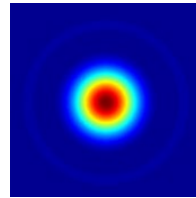

Spatial Sampling Distance Distribution
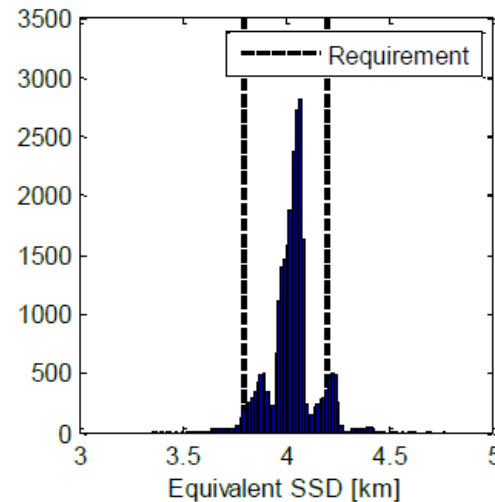
Integrated Energy (4 x 4 km²)	> 58.1 % (LWIR) and > 64.7 % (MWIR)
Integrated Energy (12 x 12 km²)	> 92.5 % (LWIR) and > 94.9 % (MWIR)
Spatial Sampling Distance	90% Spatial Samples within 200 m of Nominal (4 km)
Spatial Sampling Error	< 186 m
Co-Registration	< 350 m (Intraband), < 980 m (Interband) and < 100 m (Knowledge)
Absolute Spatial Knowledge	1.0 km
Inter-Dwell Navigation Error	~ 0.25 km
Inter-Image Relative Position Knowledge	~ 0.7 km
LOS Stability over dwell	392 m (RMS)

PERFORMANCE TESTING CAMPAIGNS

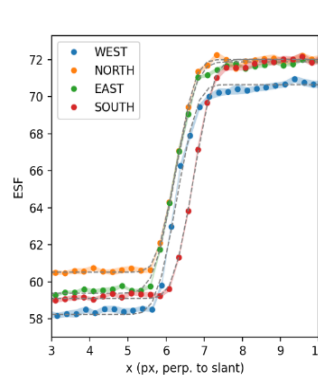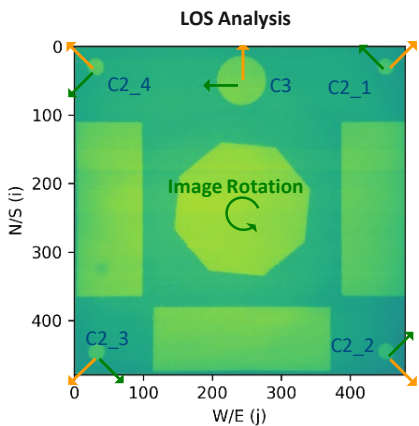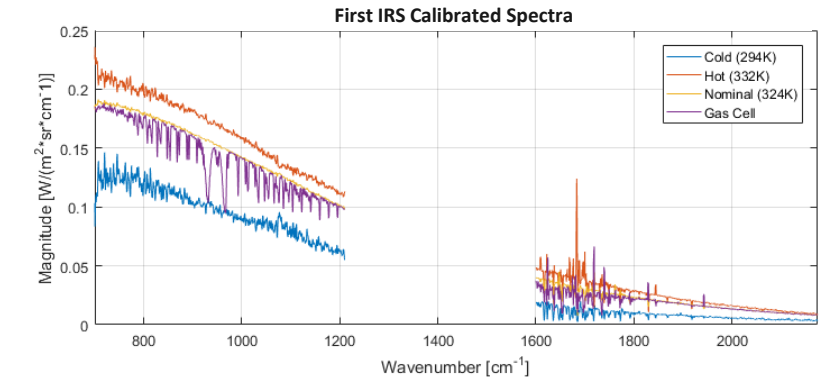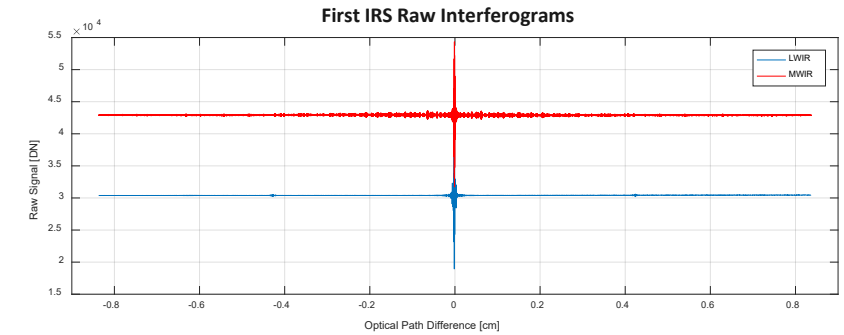**Core Spectrometer Campaign** (IRS EM Spectrometer) in <u>TVAC</u>:

– Correlation of Radiometric/Spectral Mathematical Models with performance-representative IRS spectrometer

– „Debugging" of MTG-IRS hardware

– Test successfully completed in 2019

IRS PFM Optical Reference Measurements in <u>Ambient</u>:

– Confirm the integration of the IRS PFM and to obtain a reference to allow performance monitoring throughout AIT phase (e.g. after mechanical testing or transportation)

– 1st test successfully completed in January 2022 and 2nd test starting next week

IRS PFM Optical Performance Test in <u>TVAC</u>:

– Full characterization of IRS performances with Blackbodies, Gas Cell and Laser sources and moving Target Plate

– Main input to IRS V&V

– Planned in Q4 2022
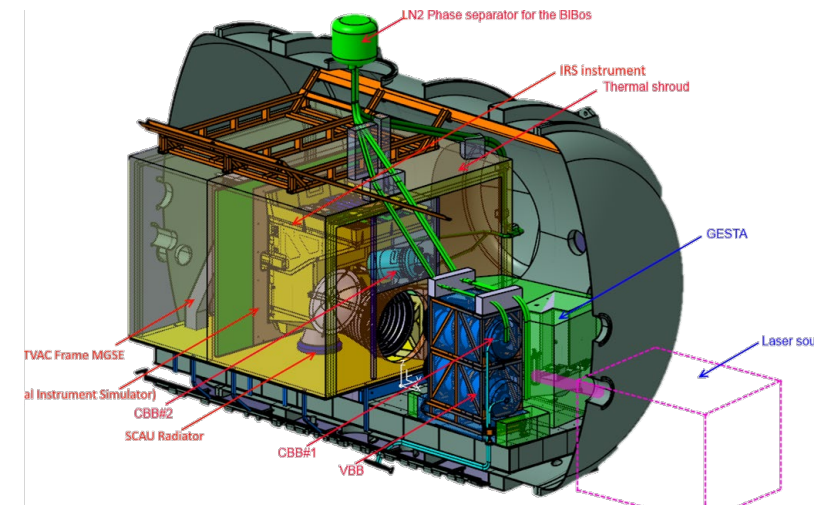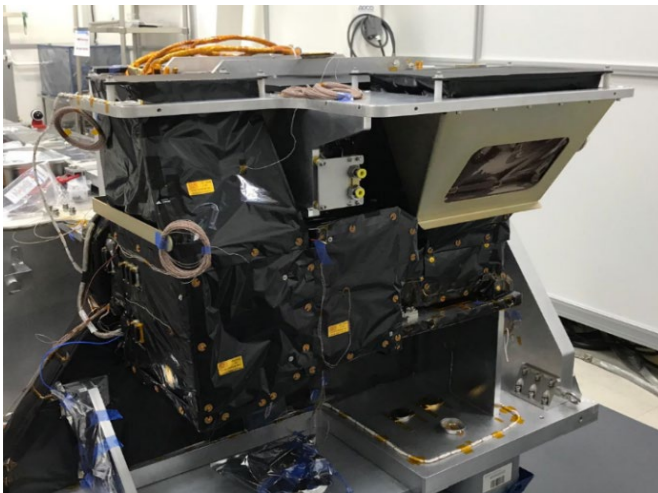
MTG-IRS INSTRUMENT OVERVIEW AND DEVELOPMENT STATUS

OPTICAL REFERENCE MEASUREMENTS (IRS PFM)

- OGSE consists of a **Blackbody** and **Gas Cell Sources** behind a **Target Plate**

- IRS first light obtained and instrument's main functionality as spectrometer confirmed

- First data shows promising performance within expectations and allows to set a reference for monitoring performance evolution

  - LOS and MTF retrieved with very good repeatability

  - NH3 (LWIR) and H2O (MWIR) lines are well resolved by the instrument

  - Signal-to-Noise ratio is higher than expected in ambient conditions

First IRS Raw Interferograms

First IRS Calibrated Spectra

LOS Analysis

MTF Analysis

Spectral Analysis (with Ammonia)

SUMMARY
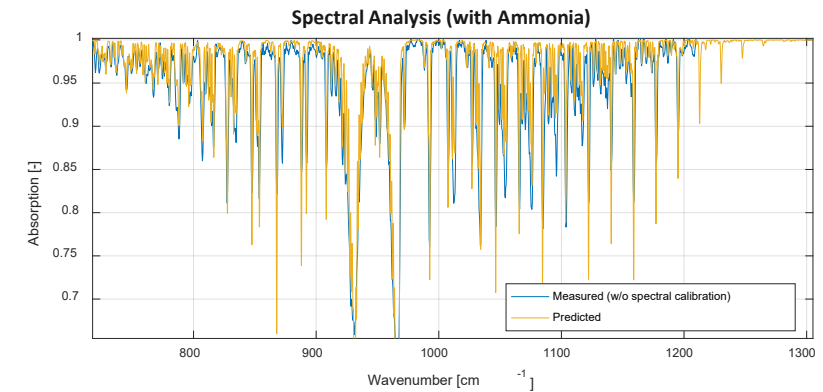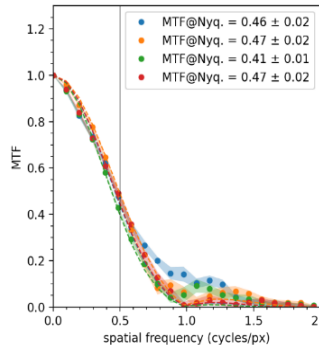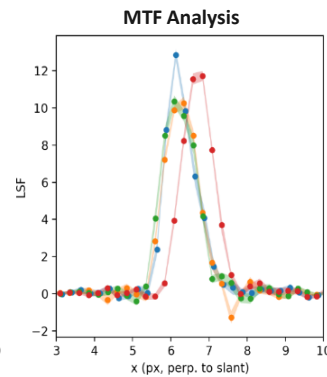
- The first flight model of the IRS is currently in its final AIT phase that will culminate in Q4 2022 with an **Optical Performance Verification and Calibration Campaign in Thermal Vacuum**

- The testing campaigns carried out so far are showing very promising performance

- The first MTG-S satellite launch is currently planned in 2024

- The benefits and applications of the IRS data for the meteorological and scientific community will be manifold:

  - **Nowcasting, very short-range and global numerical weather predictions**

    - IRS will support the monitoring of severe whether events from the pre-convective (clear environment) until mature convection phases

    - IRS will provide more frequent, better resolved and more contiguous observations compared to polar sounders, which will offer unprecedented hyperspectral imaging capabilities of the atmospheric thermodynamics that will allow to depict vertically-resolved atmospheric motion

  - **Monitoring climate, hazards, atmospheric composition and air quality**

    - The IRS spectral coverage and spatiotemporal sampling will be particularly suited to study the diurnal cycle of ammonia and other trace gases, hence contributing to climate, air quality, and fire monitoring

    - IRS data will provide additional capabilities to estimate the volcanic ash cloud height and concentration