MTG-IRS Instrument and Level 1 processing overview

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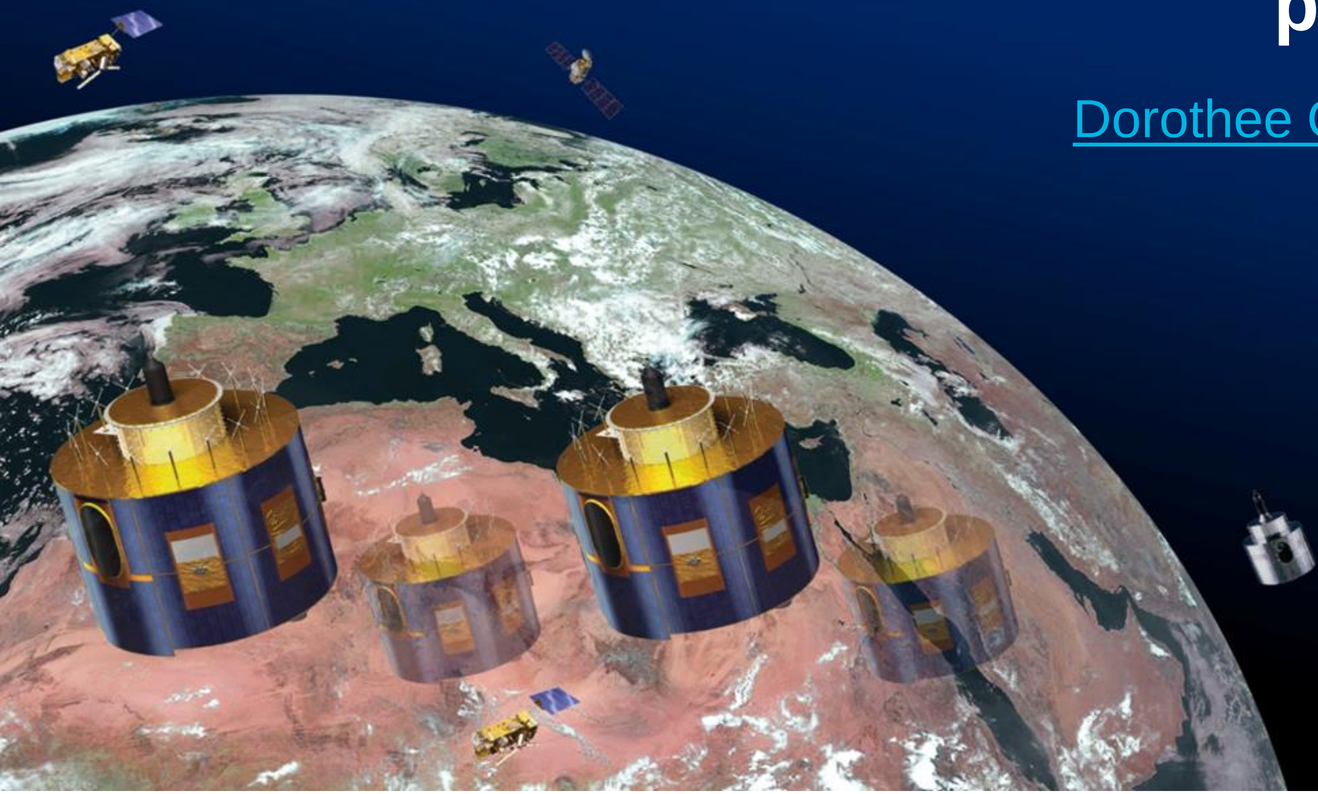


Outlines

1) Overview of IRS instrument
2) Current status of the Radiometric calibration
3) Current status of the Spectral calibration
4) Spectral Response Function Estimation
5) Performance tool available at EUMETSAT

1) MTG mission

- ✓ The Meteosat Third Generation is based on twin satellite concept, based on 3-axis platforms:
  - ✓ Four Imaging Satellites (MTG-I), expected to provide 20 years of operational services
  - ✓ Two Sounding Satellites (MTG-S), expected to provide 16 years of operational services

- ✓ MTG-I satellites:
  - ✓ Flexible Combined Imager (FCI)
  - ✓ Lightning Imager (LI)
  - ✓ Data Collection System (DCS) and Search and Rescue (GEOSAR)

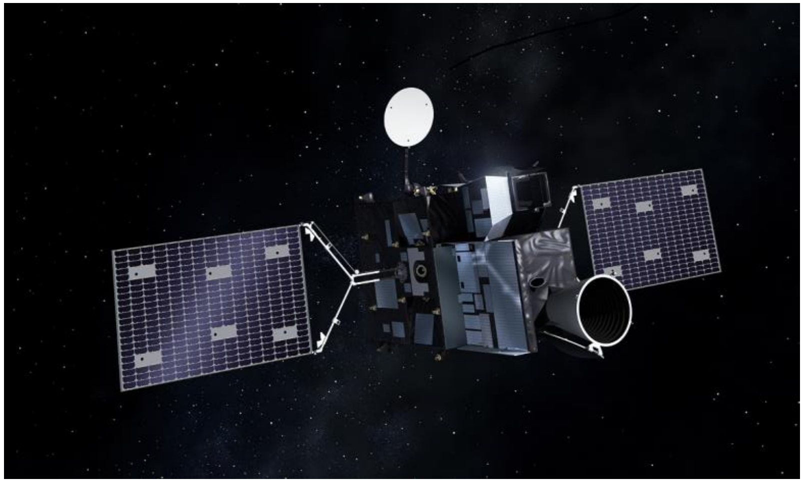
- ✓ MTG-S satellites:
  - ✓ Infrared Sounder (IRS)
  - ✓ Ultra-violet, Visible and Near-infrared Sounder (UVN)

1) IRS mission

- ✓ The IRS mission performance requirements have been established by EUMETSAT and ESA, after users consultation, and are applicable to the level 1 data
- ✓ The requirements concern all spectra covering the entire Earth disk, as seen from the geostationary orbit, when radiometrically and spectrally calibrated and geolocated
- ✓ IRS instrument is developed by OHB as a subcontractor of Thales Alenia Space under the MTG space segment contract to ESA. Whilst EUMETSAT is responsible for the overall MTG system and ground segment procurement

1) IRS mission

✓ The main performances can be summarized as follows:

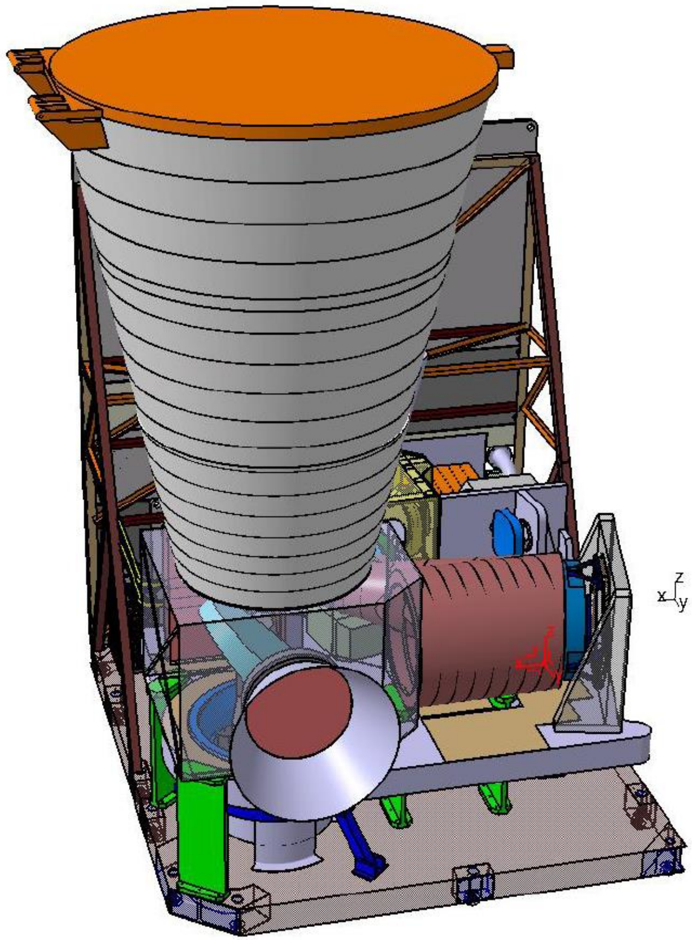


in courtesy of ESA

- Spatial sampling : 4km at Sub- Satellite Point
- Spectral sampling : 0.625 cm^{-1}
- Radiometric stability and noise : around 0.1-0.2K
- Spectral accuracy : 0.1K equivalent noise
- Repeat cycle : 60min entire Earth, 30min Europe

1) IRS instrument

- ✓ Imaging Fourier Transform Spectrometer, based on a Michelson interferometer
- ✓ 2 spectral bands: LWIR (700 to 1210 cm-1) and MWIR (1600 to 2175 cm-1)
- ✓ CCM mechanism similar to IASI
- ✓ 3 laser beams allowing monitoring the CCM speed variations as well as apex vector offset and slope
- ✓ Maximum OPD: 0,828 cm
- ✓ Detector: 160x160 pixels (a “dwell”) measured in 10 sec, with the pixel size of 4 km.



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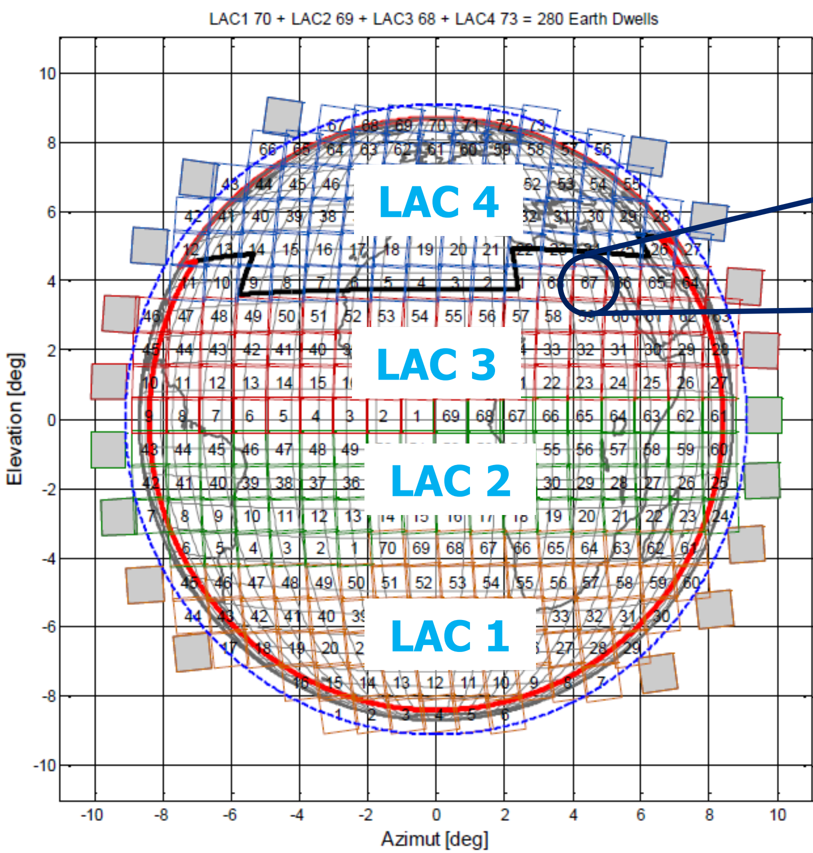
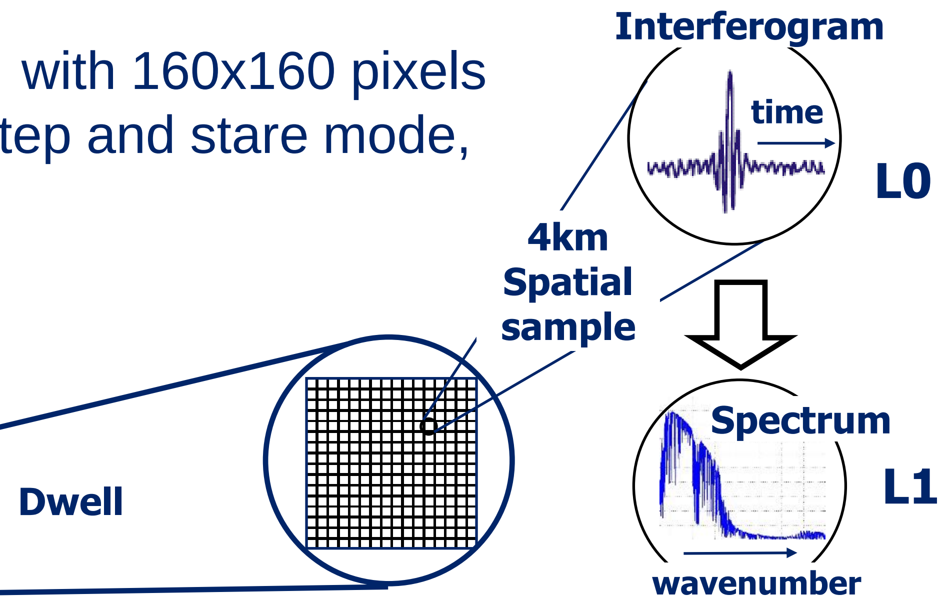
1) IRS spatial coverage

- ✓ A single detector array covers 640x640km^2 with 160x160 pixels → a two-axis scanning mirror, actuated in step and stare mode, ensures the Earth coverage in 280 steps





- ✓ **The GEO disk is split in 4 Local Area Coverage (LAC) zones, covered in 15 min each**
- ✓ Every staring view produces a dwell
- ✓ A dwell contains 25600 samples, each one is an interferogram (per detector)
- ✓ All interferograms are sent to ground for the level 1 processing

1) Situation of the IRS processing vs. IASI

- On board Interferogram pre-processing are nearly identical
  - Non linearity correction
  - Spike detection + correction
  - NZPD knowledge by fringe counting
  - Metrology (3 lasers beam): first terms of the Apex vector estimation
    - Speed variation correction
    - Interferogram OPD correction (at center of the field)
- On board compression:
  - Interferogram decimation (using OPD correction)
  - Data quality check
- On ground
  - Interferogram apodisation (still open)
  - Interferogram Fourier transform (on-ground)
  - Radiometric calibration equation (on-ground)
  - Instrument spectral state estimation (ISRF-EM)
  - Spectral shift removal
  - Spectral resampling (Level 1b)
  - Spectral shape removal (still open)
  - Data quality check

Relatively similar
IRS specific
Different approach

Taking inputs from Tournier & Jacquette

1) MTG-IRS situation compared to IASI

✓ Dwell of 160x160 pixels (IRS) <-> 2x2 pixel (IASI)

Wn (in m^{-1})	70000	121000	159000	225000
IRS centre	0.0053	0.0091	0.0119	0.0169
IRS corner	88.34	152.7	200.0	284.0
IASI	9.24	15.84	21.12	29.70

Factor 10

-> Corner pixel is much further, the spectral shift is **10 times larger**

✓ Pixel size of 4km (IRS) <-> 12 km (IASI)

FWhm (in m^{-1})	70000	121000	159000	225000
IRS centre	72.87	72.87	72.87	72.87
IRS corner	72.874	72.883	72.893	72.917
IASI	30.64	31.63	32.94	36.70

Increase of

0.04%

19.8 %

-> Instrument Line shape **varies less** for IRS

-> Spectral responsivity has **more impact** on the Spectral Response Function

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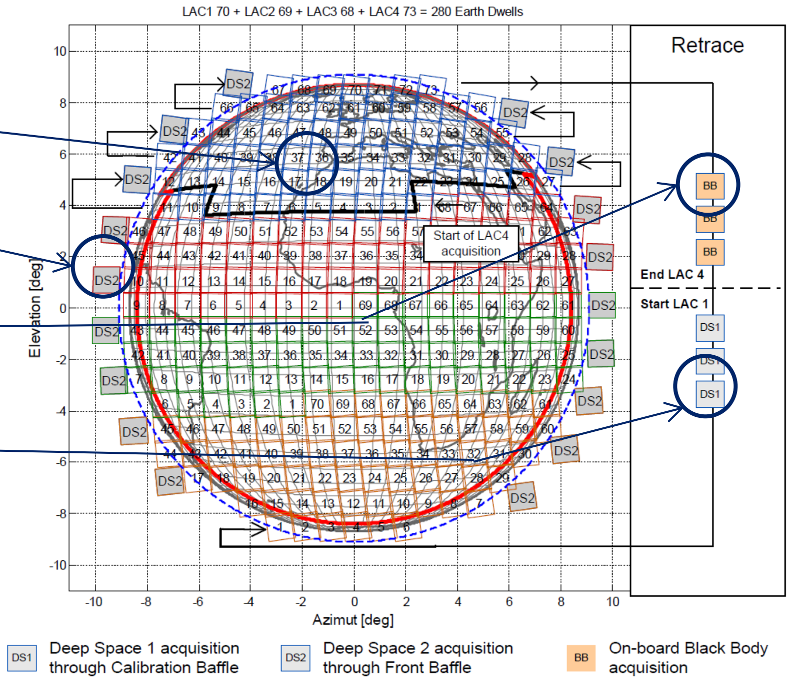
1) IRS measurements

✓ L0 data (interferograms, images and auxiliary data) from the instrument, collected and packed by the L0 pre-processor

✓ Each dataset represents a dwell (split into 2 bands)

✓ 4 different kinds of measurements within an L0 dataset, one Earth View and three radiometric Calibration Views:

- Earth View (EV): actual Earth scene
- Deep Space 2 (DS2): a deep space observation at the beginning of a row
- Blackbody (BB): direct observation of the internal blackbody
- Deep Space 1 (DS1): a deep space observation through the BB path



2) Radiometric calibration: Earth Views Processing

For each dwell two types of data is acquired:

✓ Interferograms returned at 4 km spatial sampling, allowing the spectra for each of the 2 bands to be reconstructed (called spectro mode)

✓ Image data returned at 1.3 km spatial sampling, consisting of the band integrated signal separately for each of the 2 bands (called imager mode)

✓ The background is determined online from the timeseries of DS2 for the two modes

✓ Specific to the spectro mode: Sun straylight correction is applied

2) Radiometric calibration: Calibration Views Processing

- 2 same branches are also considered:

Spectro mode and the Imager mode

Spectro mode

✓ The DS1 and the BB are used for the characterization of the radiometric response (every 15 minutes) as well as the uniformity

✓ The DS2 are stored for the determination of the instrumental background from the timeseries

✓ The characterization of the mirrors is performed off-line from a set of dedicated DS2 and DS1 views

Imager mode

✓ The DS1 and the BB are used for the characterization of the uniformity (every 15 minutes)

✓ The DS2 are stored for the determination of the instrumental background from the timeseries

✓ The characterization of the mirrors is performed off-line from a set of dedicated DS2 and DS1 views

2) Radiometric Accuracy

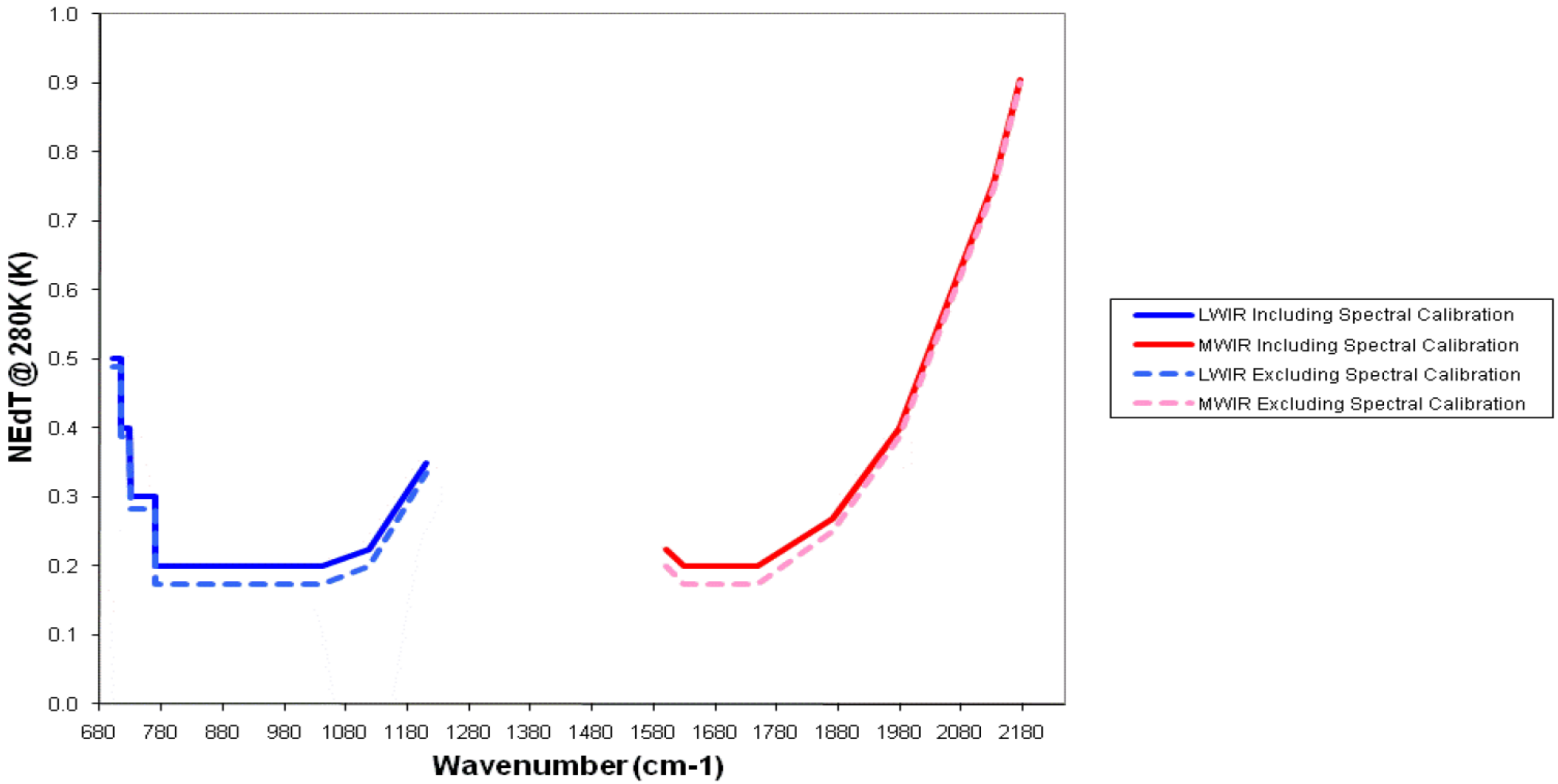
- ✓ Combining the expected accuracy of the various terms of the radiometric calibration equation, it is possible to estimate the radiometric accuracy

- ✓ It is of the order of 0.25 K

- ✓ It is dominated by:
  - ✓ The Front Section transmission
  - ✓ The radiometric response
  - ✓ Polarization effect

- ✓ Large temperature variations of the front telescope (+/- 15 K) may play a significant role as it is open to space and to direct sun heating

2) IRS Radiometric Noise at 280K



Requirements essentially met by Industry

3) Spectral calibration

- ✓ Main aspects
  - ✓ Operates on each pixel independently
  - ✓ Based on spectral invariant (weighted average of Spectral Features (SF))
  - ✓ Direct spectra averaging to increase performance
  - ✓ Scale extrapolation to reduce instrument temporal instabilities
  - ✓ Assumption: spectral changes are continuous and slow varying (hour level)

- ✓ Outline
  - ✓ Spectral calibration area (ZOI)
  - ✓ Representative set of spectra/s
  - ✓ Specific apodization developed (Sinc and instrument gain)
  - ✓ Spectral invariant determinatio

- The chosen ZOI is the North Atlantic Ocean for a viewing angle smaller than 8 degrees
- Known surface emissivity (water)
- Low spatial and temporal variability of the surface temperature
- Reasonable atmospheric variability demonstrated with a full

- Based on statistical analysis over full year of ECMWF over ZOI (zone between 51W and 18W and between 22.5N and 42.75N)

- Find combination of SFs positions (discrete weighted average) that show very low sensitivity to atmospheric variability (therefore spectral invariant) while maintaining a good resistance to noise
- SF pre-selection based on low sensitivity level to atmospheric variability and noise
- Determination of the optimal SF combination

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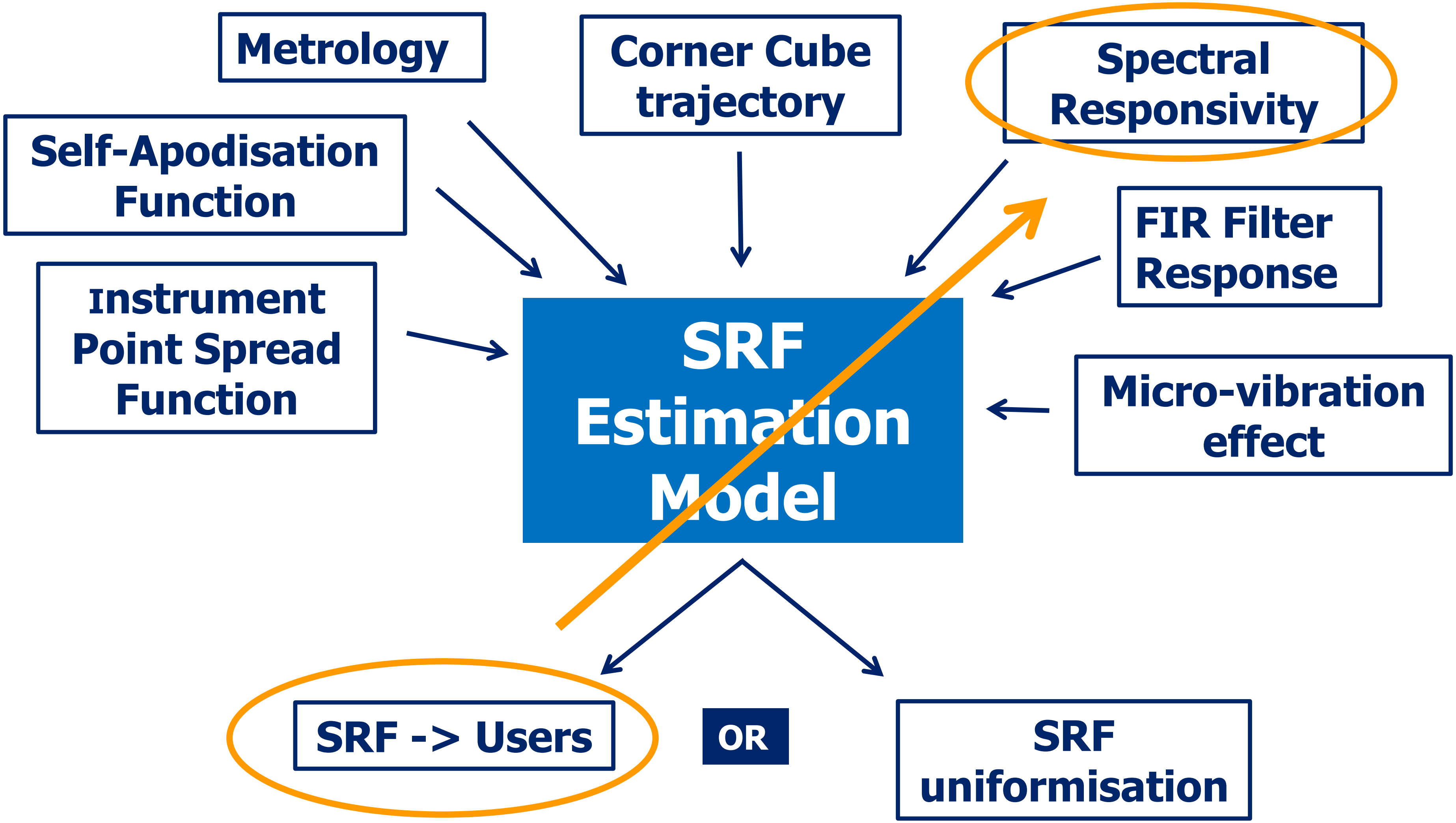
4) SRF-EM (Estimation Model)



4) Case of the Spectral Responsivity

The Spectral Responsivity is:

- ✓ Pixel dependant ⟶ 25600 functions ⟶ To reduce that number in grouping spatially
- ✓ Spectral dependant ⟶ 2000 functions ⟶ Since the spectral variation is small, we can reduce to 20 functions
- ✓ Instrument dependant ⟶ N Regular update — Every year ? Every month ? Every day ?

⟶ **This is being currently studied to make sure that the users community won't be affected by the amount of SRF to take into account in their Radiative Transfer models**

5) EUMETSAT Performance tool

EUMETSAT has initiated the development by Noveltis of a simulator of the IRS instrument+level 1 processing called IRASS IRS Radiometric And Spectral Simulator

IRASS is/will be used to:

- ✓ To test the instrument design and IDPF functionalities
- ✓ To test the sensitivity of some specific parameters/noise
- ✓ To help EUMETSAT to produce the specification of the processing
- ✓ To produce test data for the IRS L2PF
- ✓ To give an additional performance tool for the definition of the level 1 processing, the commissioning and the future monitoring of the IRS products

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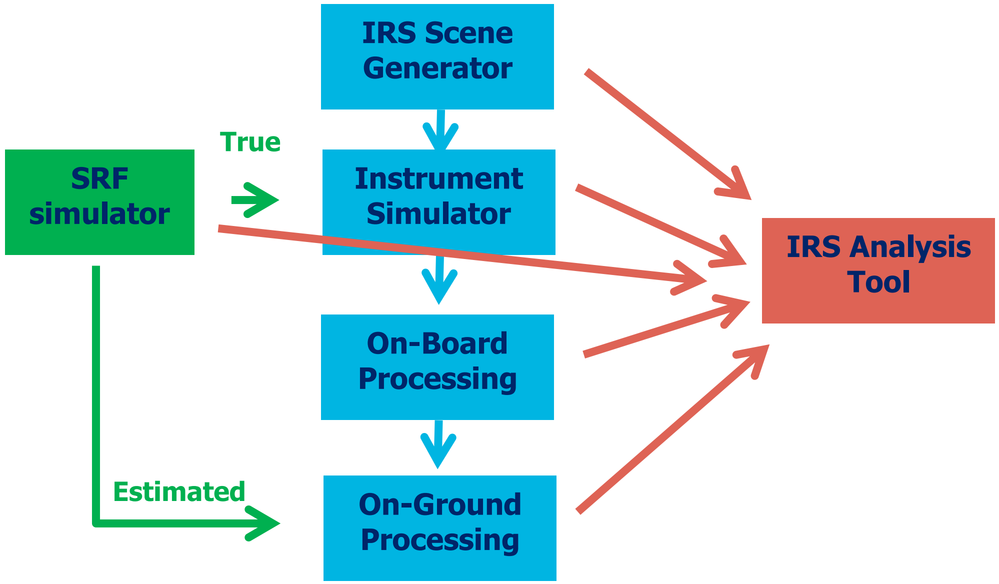
5) EUMETSAT Performance tool

It contains 5 main modules:

- IRS Scene Generator (called ISG)
- IRS Instrument Simulator (called IIS)
- IRS On-Board Processor (called OBP)
- IRS Reference L1 Processor (called RLP)
- IRS SRF simulator (called SRF)

+ IRS Analysis Tool (called IAT)



5) EUMETSAT Performance tool

- ✓It can simulate the sounder pixel of 4 km, but also a complete dwell

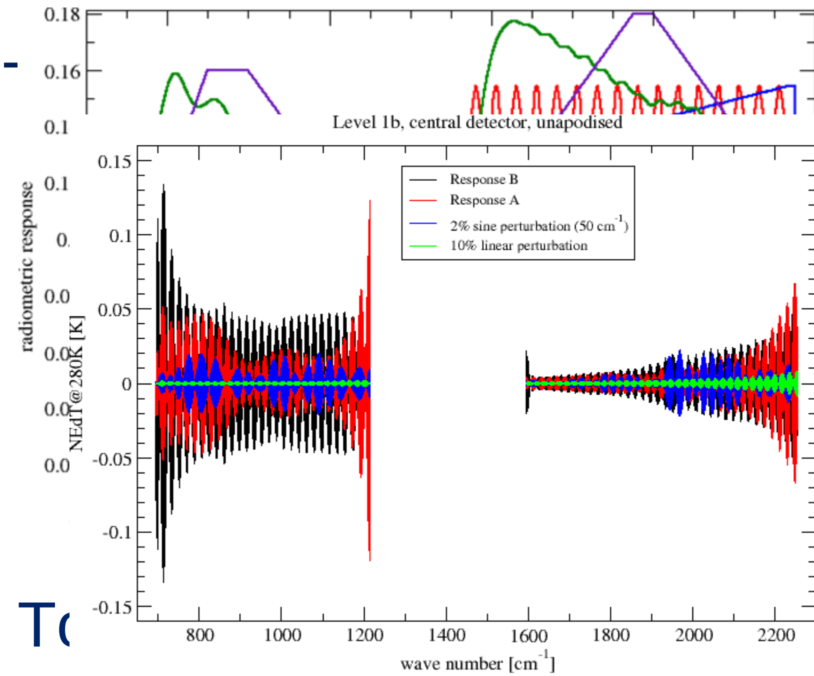
- ✓ It can simulate all necessary calibration targets

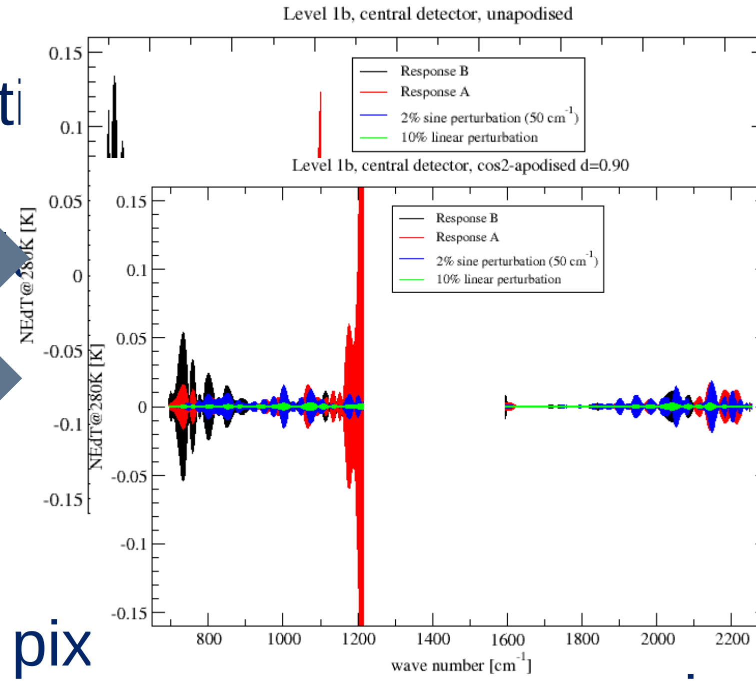
- ✓It can simulate the IRS imager mode of 3x3 pixels of 1.3 km spatial resolution

- ✓ It can looks at different perturbation: simulated and later real perturbations, its impact and test the more suitable correction.

5) IRASS – Examples of analysis

- ✓ To see the radiometric differences at level 1b for two different spectral responsivity/radiometric response (vs. a flat one)





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- ✓ To corner pix el, in terms of spectral response, instrument line shape, and radiometric differences
- ✓ To compute noise statistics

Main numbers

MTG-IRS will:

✓ provide a 25600 (640x640 km2) of high spectral resolution spectra every 10 seconds in PCs

✓ With a 30 minutes re-visit over Europe, 60 minutes re-visit over the whole globe

✓ and that will happen from 2022 on, when MTG-S1 with the sounding instruments will be launched and commissioning activities will be starting