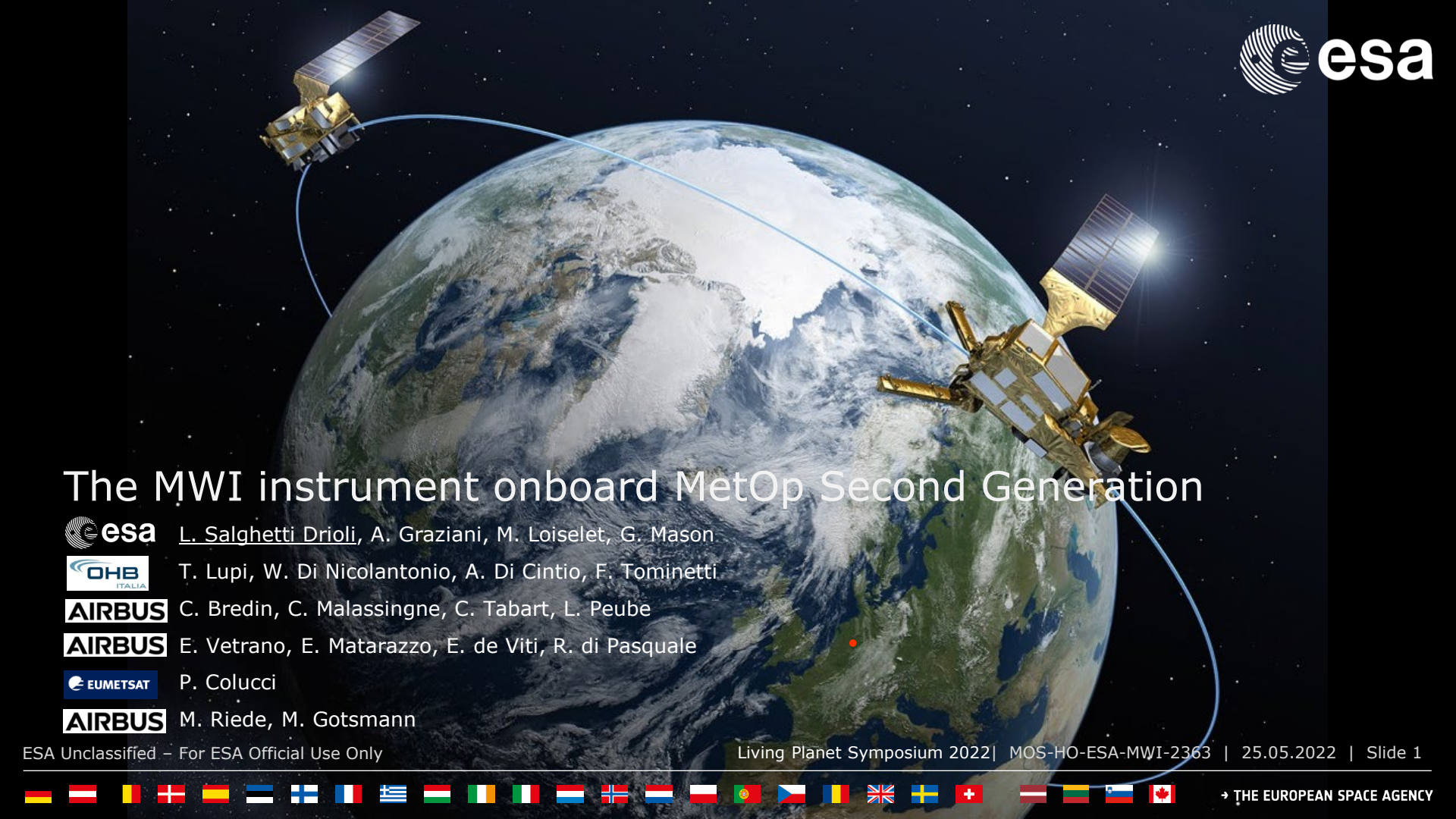

The MWI instrument onboard MetOp Second Generation

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T. Lupi, W. Di Nicolantonio, A. Di Cintio, F. Tominetti

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Outline

- Introduction to MWI science;
- MWI Instrument design overview;
- MWI development status;
- Achieved performances;
- Conclusions;

End User Products

MWI high level Products:

- Cloud liquid water content (total column and gross profile)
- Cloud-ice content (total column and gross profile)
- Precipitation detection
- Precipitation content (liquid and frozen; total column and gross profile)
- Precipitation rate near the surface
- Total column water vapour;
- Sea surface wind speed
- Snow variables (e.g. Snow water equivalent, Snow status (wet/dry), Snow detection, Snow cover)
- Sea ice variables (e.g. Sea ice concentration, Sea ice type, Sea ice motion)
- Sea ice variables for climate monitoring

Level 1b Product:

- Calibrated and geo-located scene brightness temperature

Channel name	Frequency [GHz]	Utilisation
MWI-1	18.7	Precipitation over sea
MWI-2	23.8	Total column water vapour over sea
MWI-3	31.4	Precipitation over sea and (marginally) land
MWI-4	50.3	Precipitation over sea and land including drizzle, snowfall, height and depth of the melting layer
MWI-5	52.70	
MWI-6	53.24	
MWI-7	53.75	
MWI-8	89	Precipitation (sea & land) & snowfall
MWI-9	118.7503±3.2	Precipitation over sea and land including light precipitation and snowfall, height and depth of the melting layer
MWI-10	118.7503±2.1	
MWI-11	118.7503±1.4	
MWI-12	118.7503±1.2	
MWI-13	165.5±0.725	Quasi-window, water-vapour profile, precipitation over land, snowfall
MWI-14	183.31±7.0	Water vapour profile and snowfall
MWI-15	183.31±6.1	
MWI-16	183.31±4.9	
MWI-17	183.31±3.4	
MWI-18	183.31±2.0	

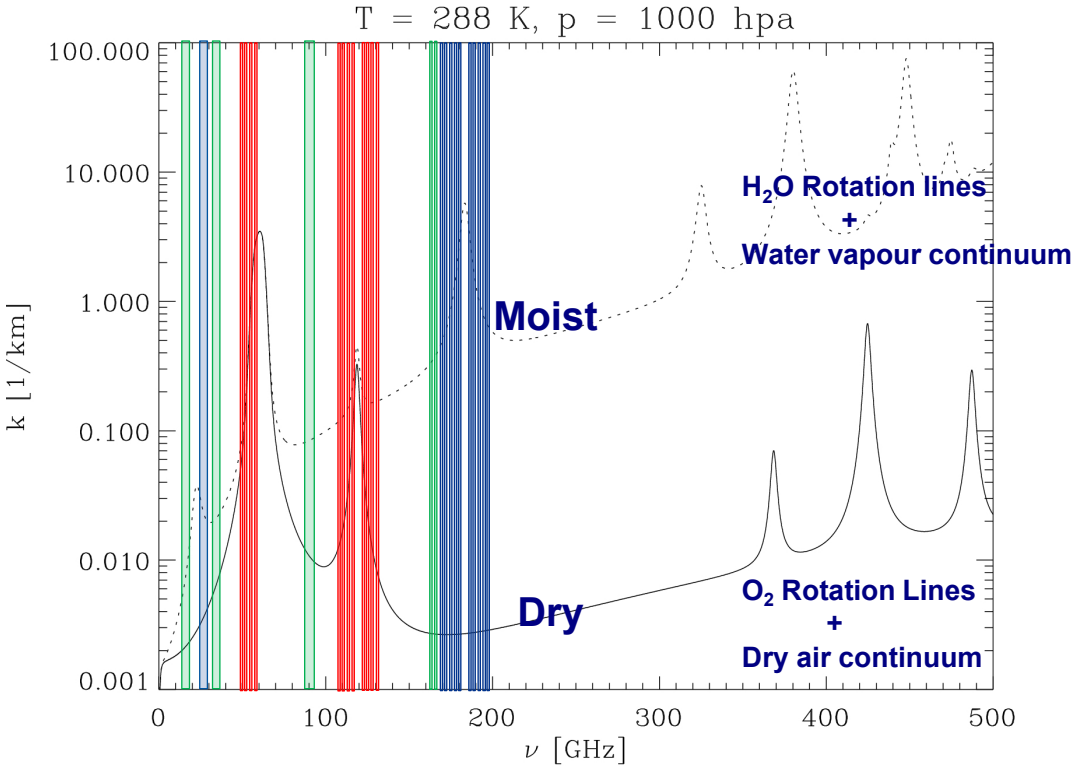
Gas Absorption Spectrum

- MWI is both an "imager" and a "sounder"!
- Imaging channels penetrate through the atmosphere
- Sounding channels scan different layers of the atmosphere
- Different frequencies observe different phenomena

Moisture Sounding:
22 GHz and 183 GHz water vapour lines

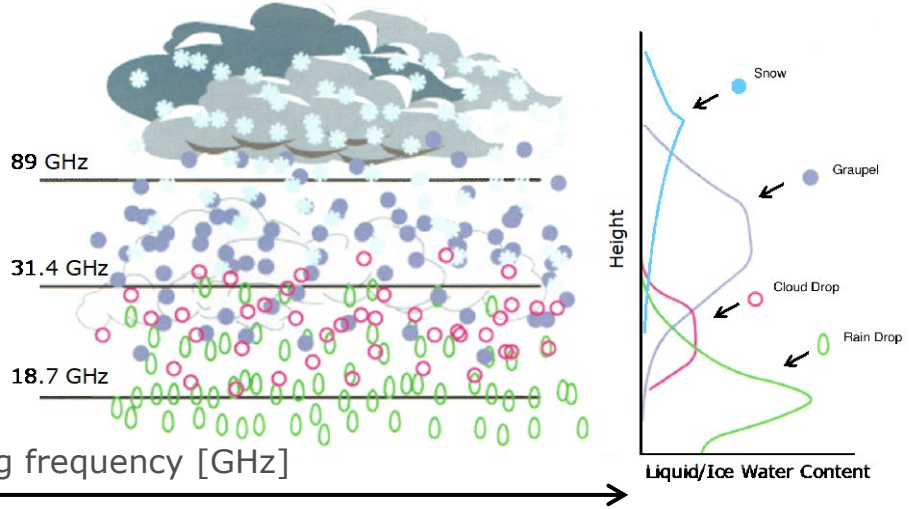
Temperature Sounding:
60 GHz and 118 GHz oxygen line

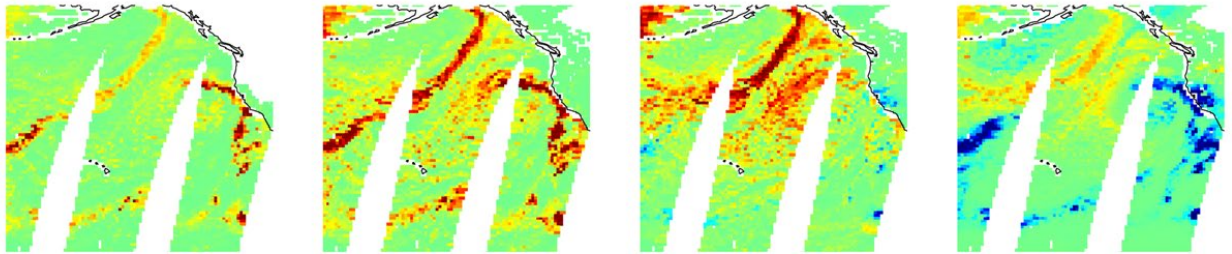
"Imaging channels" in the windows



Interaction with Rain

- Single frequency observations are not always sufficient to discriminate the effects of water vapour, rain, wind speed, sea/land emission, etc…
- Precipitation or Clouds are extracted by combining the information from observations/images at different frequencies.
- The combination of Tb images, at different frequencies, can be used to extract geophysical parameters such as water vapour, could, rain, temperature profile, etc…

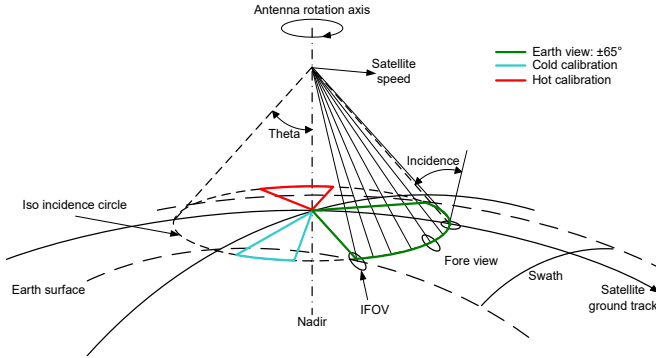




Hydrometeor effect: TB - TBclear [K]

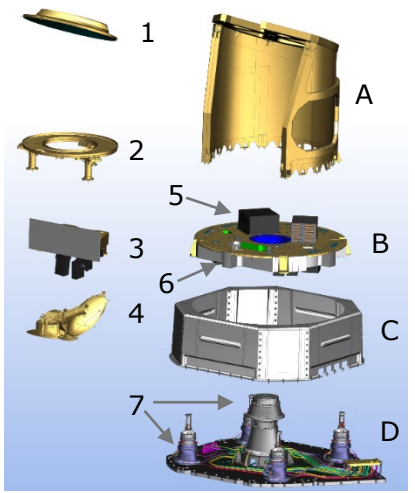
MWI Instrument description

Instrument key features:

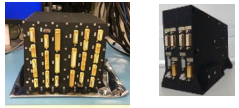


- **Mass: 259 kg**
  - **Rotating 135 kg**
  - **Fixed (including SCE and ICU): 124 kg**
- **Volume: 160 cm x 160 cm x 175 cm**
- **Power: 236 W in operational mode**
- Data rate: 930 kbps
- **Rotation speed: 45 rpm**
- **One calibration per rotation** through cold sky & on-board calibration target. Additional internal noise diodes for lower frequencies

- Receivers technologies:
  - MMIC direct detection at 23.8/31.4 and 89GHz
  - Heterodyne detection with Schottky diode mixers for other frequencies
- Feed cluster of 7 horns & 1 single offset parabolic reflector
- Measurements done at 18 different frequencies, from 18GHz to 183GHz. Channels up to 89 GHz have **dual polarisation.**
- Scene viewing angle: +/-65°
- Observation zenith angle (OZA): 53° +/- 1.5°
- Footprint:
  - **MWI-1/2 (18.7/23.8): 48km**
  - **MWI-3/7 (31.4:50-54): 29km**
  - **MWI-8-18 (89/118/165.5/183): 10km**
- RFI mitigation: at 18.7GHz based on Kurtosis method and time/frequency segmentation



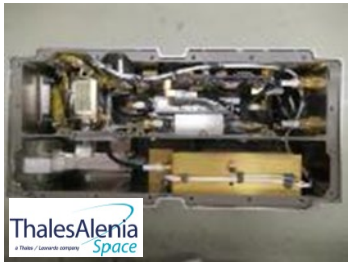
A. Tube and Roof structure
B. Rotating Deck
C. Baseplate cover
D. Baseplate
1. Main reflector
2. OBCT Racetrack
3. Front End SubAssembly
4. Calibration Assembly
5. FEE, CDPU
6. Low Frequency receivers
7. Scan Mechanism, LLDs

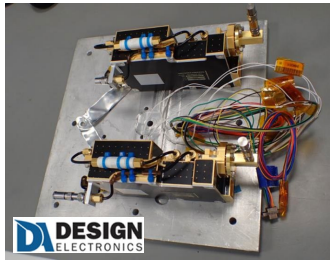


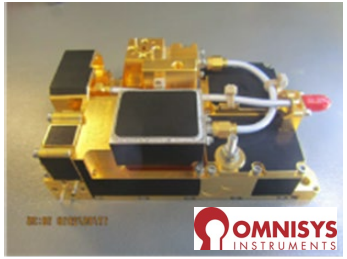
Instrument Control Unit and Scan Control Electronics are housed in the Satellite bay

RF technology

- Receiver technology: European cutting edge M-HEMT technologies and innovative Schottky diode technologies are extensively used to achieve outstanding receiver performances
  - Extensive effort has been done to bring state of the art technology to the reliability level required for a long term operative program. For the key critical receiver components (mixers, multipliers, low noise amplifiers and detectors), pre development and evaluation activities have been performed. All flight models are currently going through LAT







- Antenna technology

MWI Design challenges

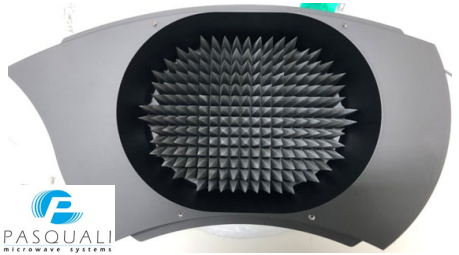
- To meet challenging envelope, mass and power consumption together with state-of-the-art noise figure performances for the receivers in a very compact design of the Focal plane (FESA). This required a significant phase of mechanical and thermal design optimization to maintain the balanced instrument inside the very stringent mechanical specification.

- To achieve constant and spatially uniform temperature on the OBCT. To meet this objective, the OBCT includes a baffle which together with its closely matched racetrack located on the rotating part prevents from sun intrusion.

- To detect and mitigate interference generated in the 18.7 GHz by using an RFI processor.

- The MWI design shows compliance to the stringent radiometric sensitivity/accuracy and footprint requirements

FESA, prior to its integration on the MWI instrument



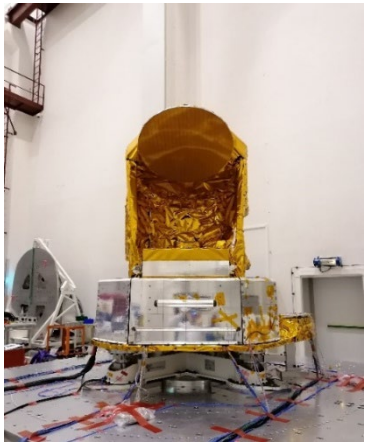
OBCT, prior to its integration on the MWI Calibration Assembly

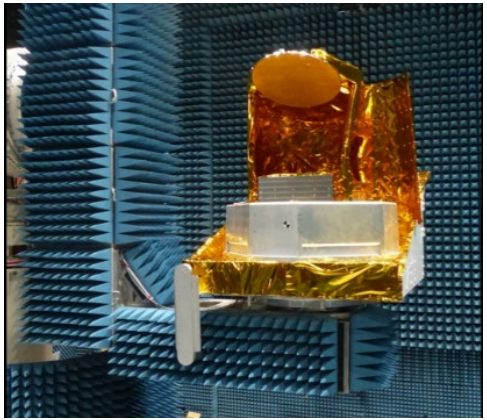
MWI Model Philosophy and achievements

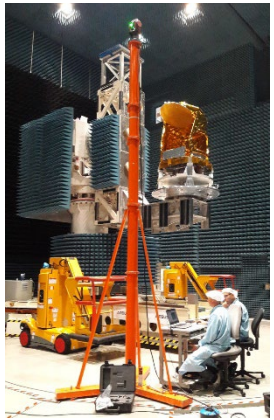
The following models are foreseen at Instrument level:		
• Structural and Thermal Model (**STM**): the STM will be representative of the structural and thermal aspects of the subsequent PFM and FMs. The STM will be subjected to environmental testing at qualification levels and durations, but not delivered to the satellite. The results of the tests will be used for correlation of Structural and Thermal Models.		
• Refurbished STM (**STM***) with fully populated feed array will be submitted to antenna testing.		
• Engineering Model (**EM**): the EM will be fully representative of the subsequent PFM and FMs (including software), with the only exceptions that appropriate MIL-STD components and parts will be used instead of space qualified parts and the EM will not contain redundancy. Since structural qualification is achieved with the STM, the verifications on the EM will be focused on functional, performance, EMC, and thermal-vacuum tests (including performance).		
• Proto-Flight Model (**PFM**): the PFM will be the first flight model (including space qualified parts, materials and processes and the on-board software in flight version) and will be subjected to environmental testing at qualification levels and acceptance durations. After verification completion, it will be the first Flight Unit (FM1).		
• Flight Models (**FM2** and **FM3**): the Flight Models will be recurrent models after the PFM. They will include space qualified parts, materials and processes and the on-board software in flight version, and will be subjected to environmental testing at acceptance levels and durations.		

MWI Structural and Thermal Model

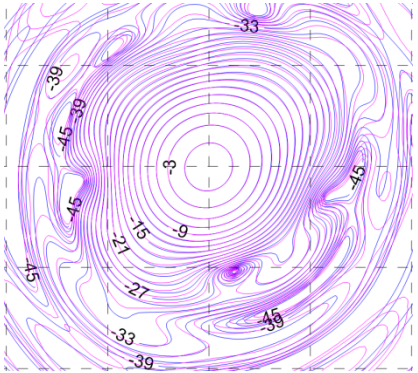
- The STM is fully representative of the structural and thermal behaviour of the instrument
- The STM has been subjected to a full structural qualification (sine vibration, acoustic, shock) and to a thermal vacuum/thermal balance test
- After a partial refurbishment it has been used for the first antenna pattern measurement session

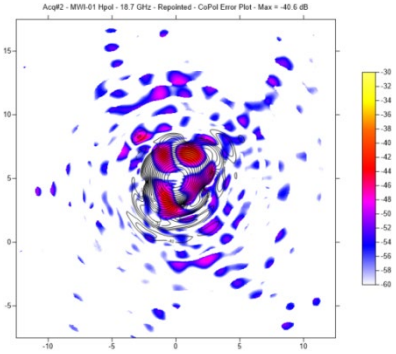






Main Beam zoom at 18.7 GHz (red: measured, blue: simulated)





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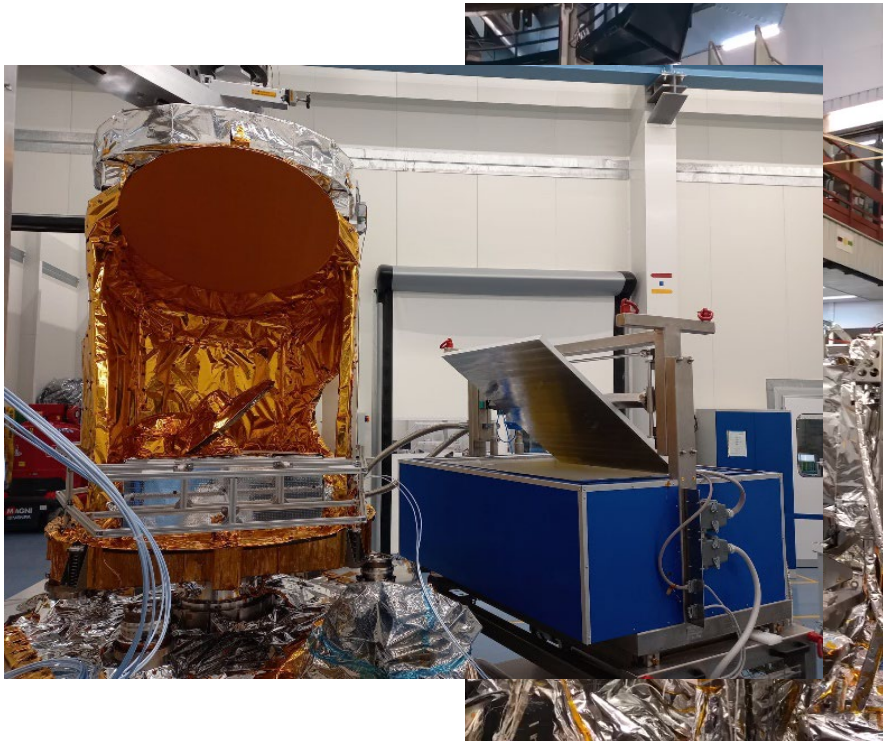
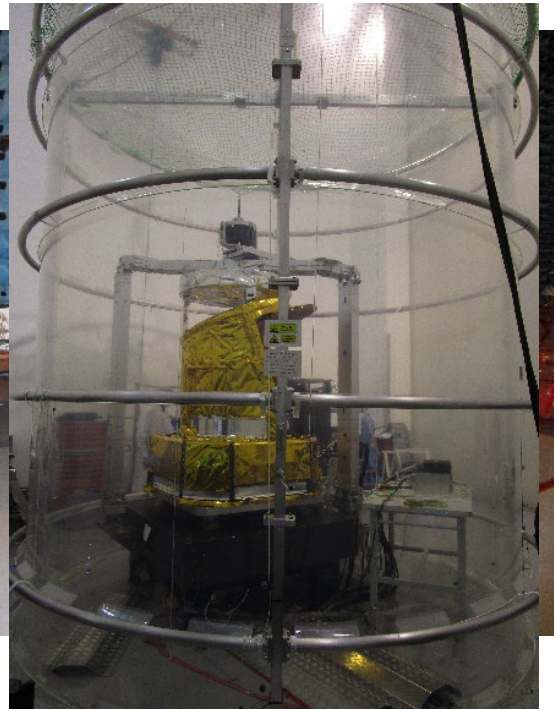
MWI EM Test Campaign

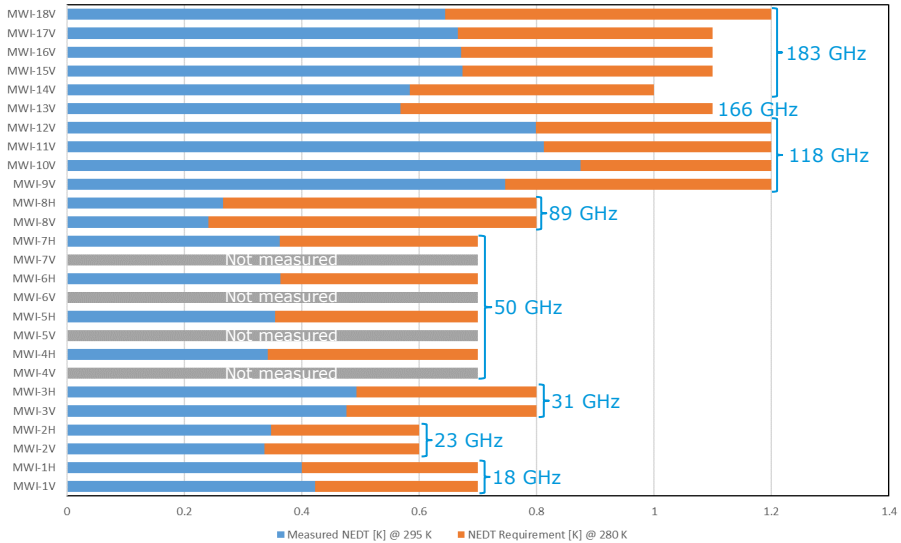
Initial Functional and Performance test → Performance test at ambient → TVac test (including performance) → EMC → Deployment test → Microvibration test → Final Functional and Performance test





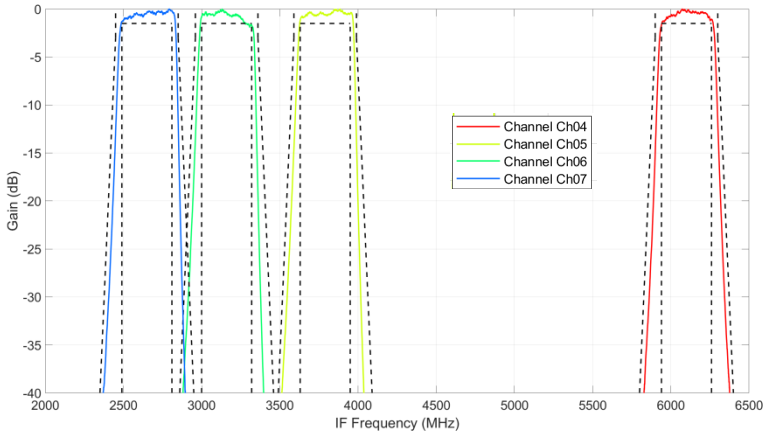
MWI EM Radiometric test

- **NEDT has been measured during Instrument Thermal Vacuum test:**



  - All channels confirmed to be compliant with NEDT requirements. Degradation for EoL is not considered in the plot, but the margin in all channels allows for maintaining performance till the end of mission.
  - Excellent NF correlation across the different test conditions

- **Spectral performances of the instrument are verified through the common Y-factor method using both reference temperature targets at about 77K and 295K**
- **4 channels @54GHz performances:**



  - Spectral performances show very good rejection
  - 1.5dB ripple over 80% of the 3dB bandwidth is also almost compliant for most of the channels

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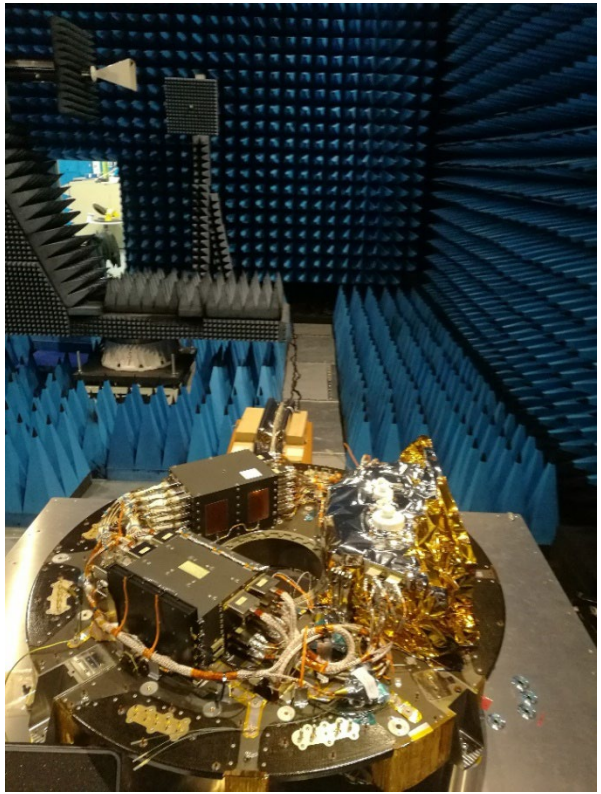
• Flight Models (**FM2** and **FM3**): the Flight Models will be recurrent models after the PFM. They will include space qualified parts, materials and processes and the on-board software in flight version, and will be subjected to environmental testing at acceptance levels and durations.		

MWI next steps

- The instrument EM (with fully redundant flight units in the fixed-part) is now integrated on the satellite PFM for preliminary verification at system level

- Proto-flight model (PFM) integration is ongoing
- Preliminary performance verification shows good performances of the receivers and electronic chain
- The rotating part testing campaign will be completed beginning of July
- Antenna pattern measurement in July-August
- Vibration and balancing in September-October
- Integration of full instrument will be completed in November
- Full environmental test campaign will follow until March ‘23



PFM deck during preliminary EMC test

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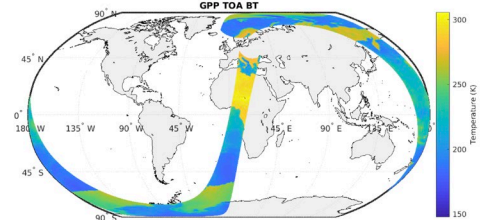
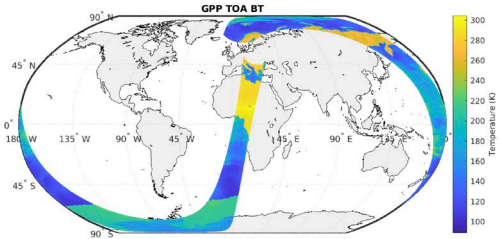
• Flight Models (**FM2** and **FM3**): the Flight Models will be recurrent models after the PFM. They will include space qualified parts, materials and processes and the on-board software in flight version, and will be subjected to environmental testing at acceptance levels and durations.	✗	Equipment procurement is almost completed and integration of FM2 is started.

MWI Performance and Processing

- Ground Prototype Processor (GPP): Ingests raw instrument data, auxiliary data (Instrument Calibration Data Base) and ancillary data (S/C Navigation and Attitude data)
  - Two main modules: Geometric and Radiometric
  - in-orbit data during commissioning phase
  - on-ground data in test phase
- Output: Geolocated and calibrated Brightness Temperatures (L1b)
- Performance Assessment Tool (PAT) for manipulation and visualization of the data

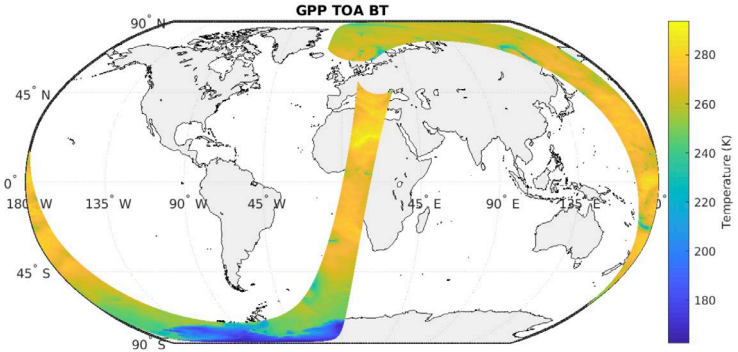


MWI-2 (V) @23.4 GHz



MWI-2 (H) @23.4 GHz

MWI-14 (V) @ 183 GHz



GPP retrieved Top Of the Atmosphere data, based on IDS simulated data Orbit 4655 from MetOp-A on 12/09/2007 from 08:43 to 10:22

Conclusions

- MWI is a new instrument on MetOp-SG with extended capabilities with respect to previous similar instruments (e.g. SSMI, MADRAS);
- MWI will provide imaging and sounding in 18 channels from 18 to 183 GHz with dual polarization measurements up to 89 GHz;
- The first MWI instrument model has been delivered to the Satellite-B Prime Contractor in April 2022, despite this not being yet a flight model;
- The MWI PFM will be delivered to Satellite-B Prime Contractor by spring 2023;
- Three flight instruments will be built, one for each of the MetOp-SG-B satellites;
- MWI, together with the European built MetOp-SG instruments, will provide the best ever Scientific Products, measured simultaneously over the same area.