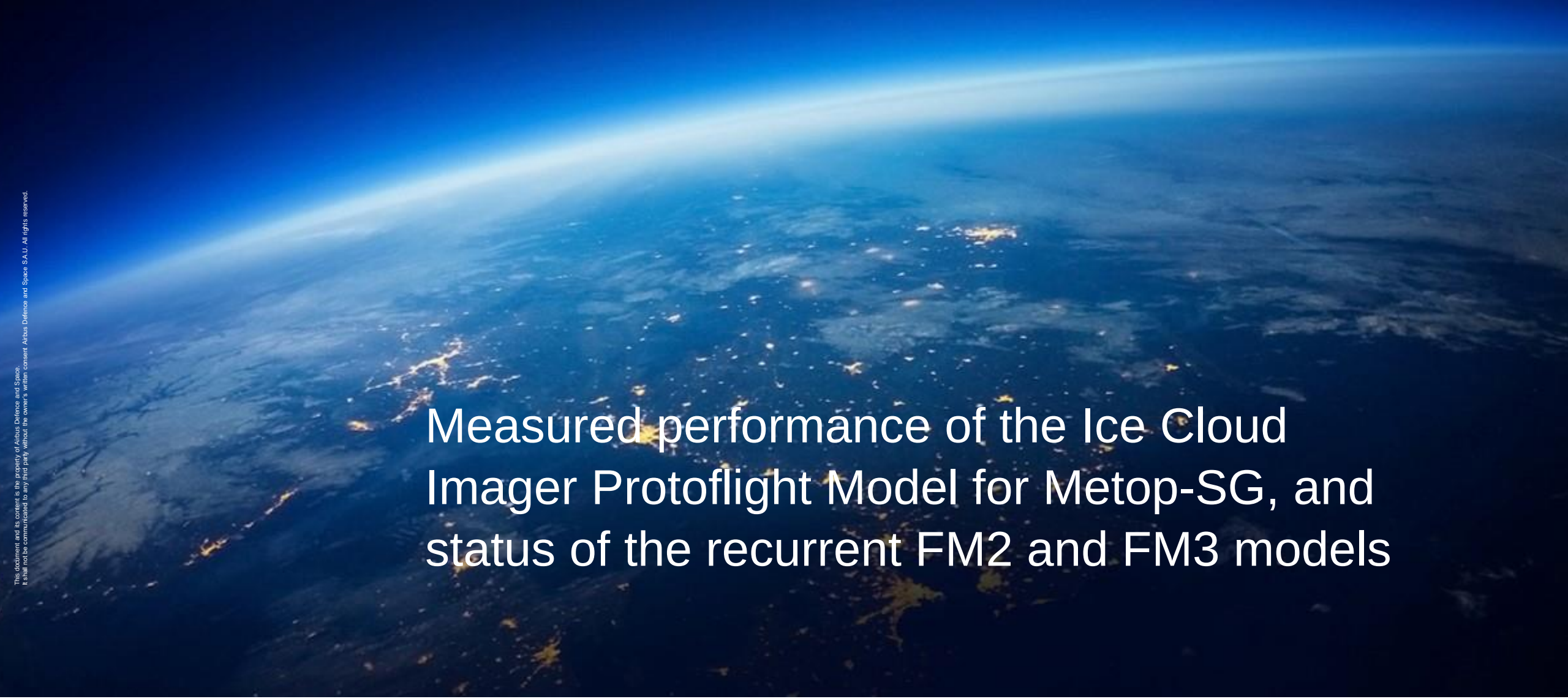

Measured performance of the Ice Cloud Imager Protoflight Model for Metop-SG, and status of the recurrent FM2 and FM3 models

DEFENCE AND SPACE

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[3] European Space Agency (ESA – ESTEC)
[4] EUMETSAT

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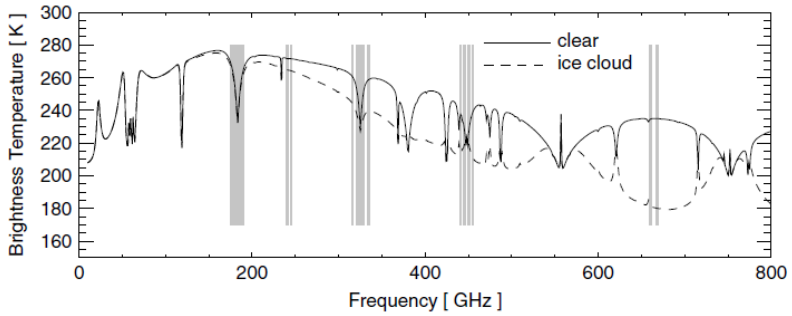
1. Metop-SG ICI mission objectives

- The **Ice Cloud Imager (ICI)** was included as part of *EUMETSAT Polar System* second generation (EPS-SG) in 2011
- Embarked on **Metop-SG sat B** for the first time in an operational mission of weather satellites, will improve weather and climate models
- Primary objective: quantification of cloud ice, as ice clouds play a key role in the hydrological cycle in the upper troposphere, with a strong impact on radiative exchanges and atmospheric energy budget
- Cloud Ice Water Path (IWP), Ice Particle Size and Mean Cloud Altitude measurements by means of sub-mmW passive instruments suggested already in 1995 (Evans and Stephens, Colorado State Univ.)
- ICI includes 13 frequency channels. Frequencies above 200 GHz have high sensitive towards ice particles

Channel name	Frequency (GHz)	Bandwidth (MHz)	Simplified Usage
ICI-1	183.31+/-7.0	2x2000	**Water vapour profile and snowfall**
ICI-2	183.31+/-3.4	2x1500	
ICI-3	183.31+/-2.0	2x1500	
ICI-4 (H&V)	243.2+/-2.5	2x3000	**Quasi-window, cloude ice retrieval, cirrus**
ICI-5	325.15+/-9.5	2x3000	**Cloud ice effective radius**
ICI-6	325.15+/-3.5	2x2400	
ICI-7	325.15+/-1.5	2x1600	
ICI-8	448+/-7.2	2x3000	**Cloud ice water path and cirrus**
ICI-9	448+/-3.0	2x2000	
ICI-10	448+/-1.4	2x1200	
ICI-11 (H&V)	664+/-4.2	2x5000	**Cirrus clouds, cloud ice water path**



Sub-mm spectrum of clear-sky and a cloudy midaltitude (8-10 km) winter atmosphere, with IWC of 0.04g/m3 and ice particles of 100um radius (Buehler et al., 2007). ICI DSB channels highlighted in grey bars.

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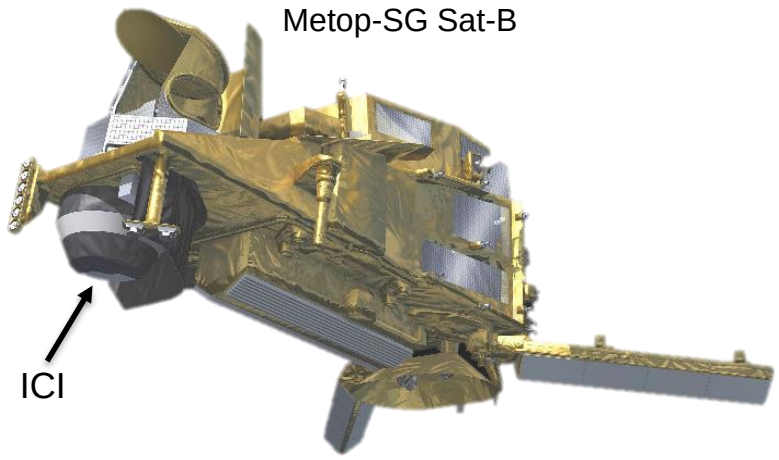
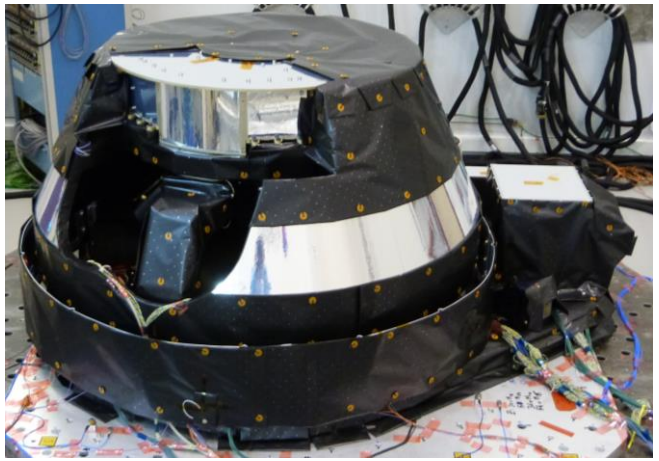
2. Metop-SG ICI development

- Conical scanning sub-mmW total power radiometer – 13 channels,183 to 664 GHz
- Two-point calibration (hot and cold targets) at every rotation cycle (1.3 sec)
- Developed by Airbus Defence and Space in Madrid, with ADS-FHN and ESA
- More than 15 contractors around Europe

Parameter	Performance
Incidence angle	*53º +/-1.65º*
Rotation speed	*45 rpm*
Swath width	*1700 km*
Geometric resolution	*16 km (avg on-ground)*
Mass	*158 kg (76 fix / 82 rot)*
Avg power	*133 W @42Vdc*





*Airbus Defence & Space - Madrid

*Airbus Defence & Space - Friedrichshafen

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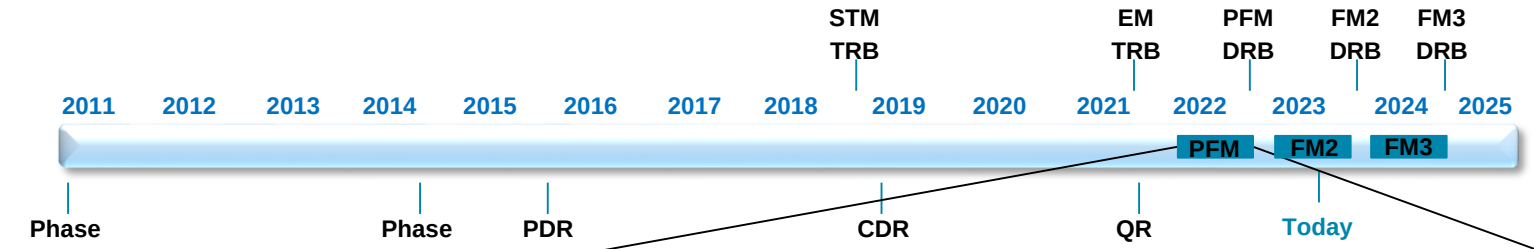
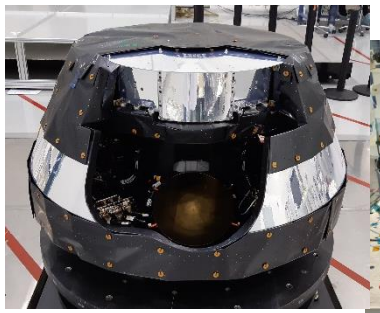
2. Metop-SG ICI development

- ICI PFM qualification test campaign completed, and delivered for satellite integration in July'22
- ICI FM2 under test, to be delivered end of 2023. ICI FM3 to be integrated and tested in 2024.



ICI PFM Test Campaign

✓ Balancing

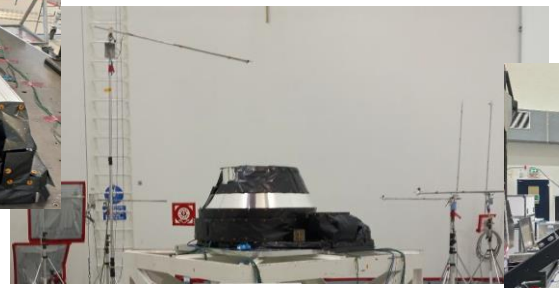


✓ iFFT

✓ Vibration

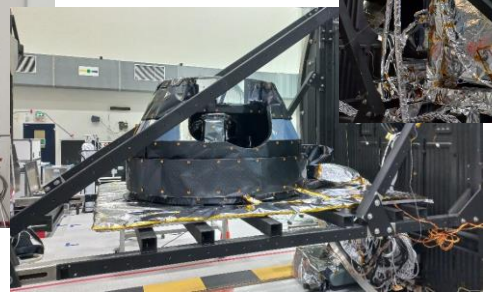
✓ Release

✓ Acoustic



✓ Microvib

✓ TVC

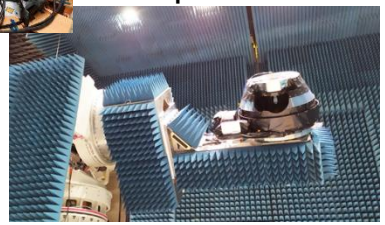


✓ TVAC Rad Perfo

✓ EMC

✓ fFFT

✓ Antenna pattern



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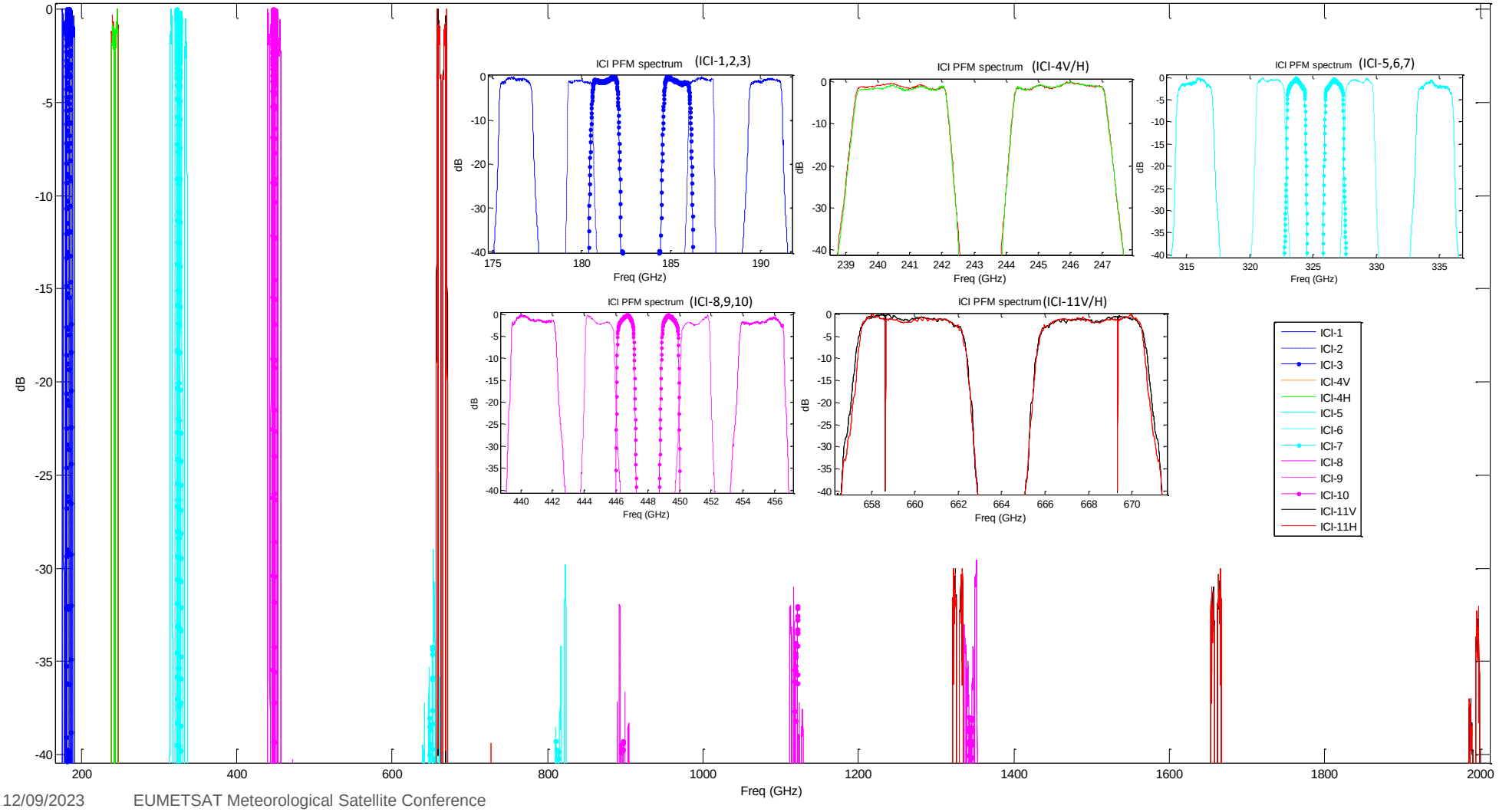
3. Metop-SG ICI PFM measured performance

- ICI PFM **Spectral Response** for all 13 DSB channels, including hamonic responses up to 2 THz



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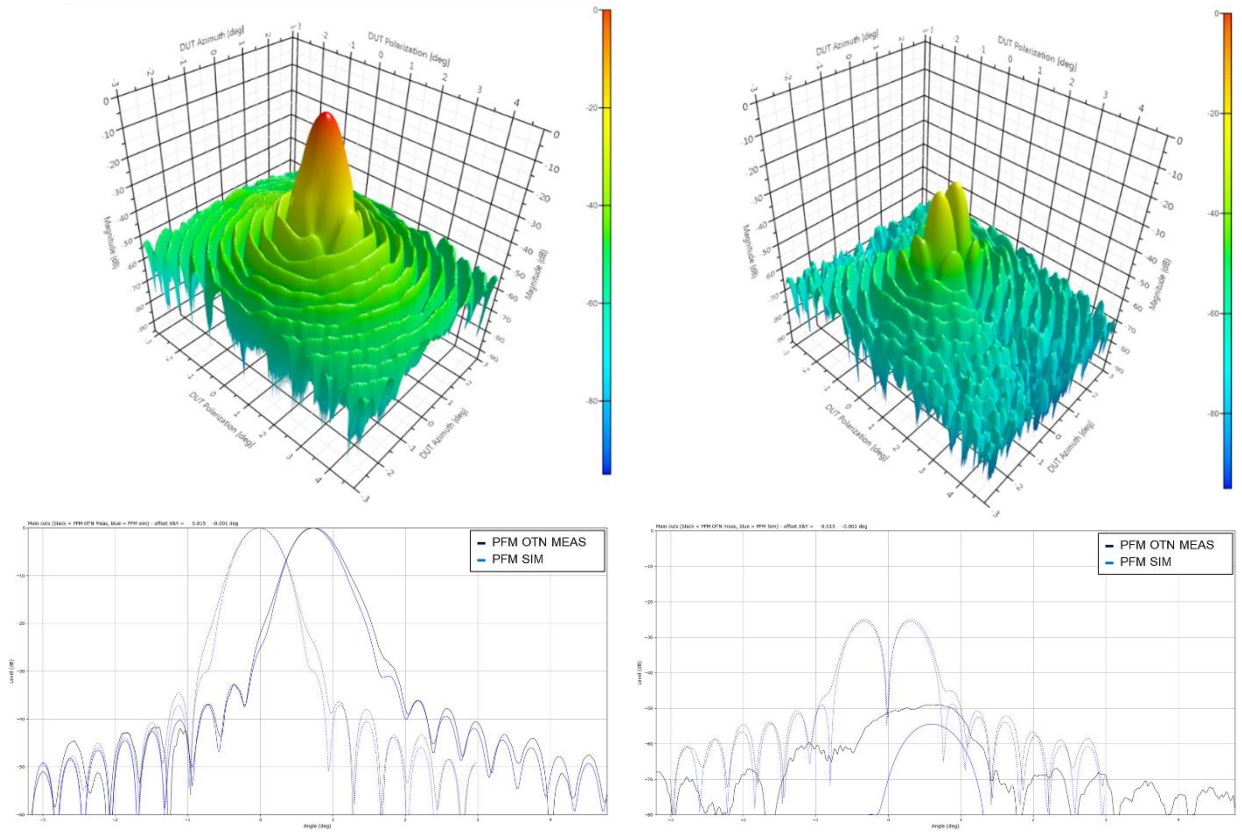
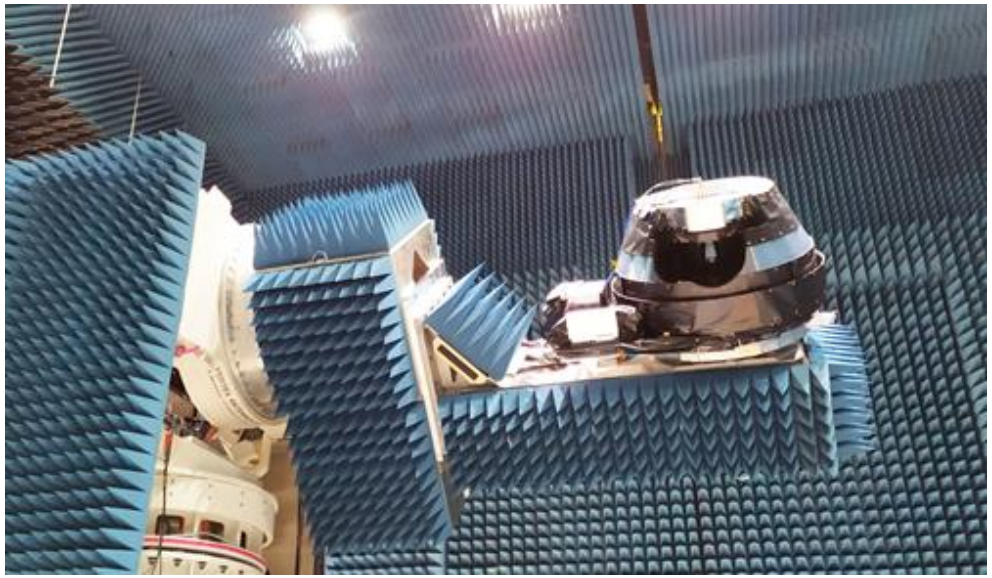
3. Metop-SG ICI PFM measured performance

- ICI PFM **antenna patterns** for Earth and Cold sky antennas for all channels in 1 and 2 scan positions respectively
- Good correlation with the simulations

Copol Earth antena 183 GHz Xpol





*Airbus Defence & Space – Ottobrunn – Compact Range

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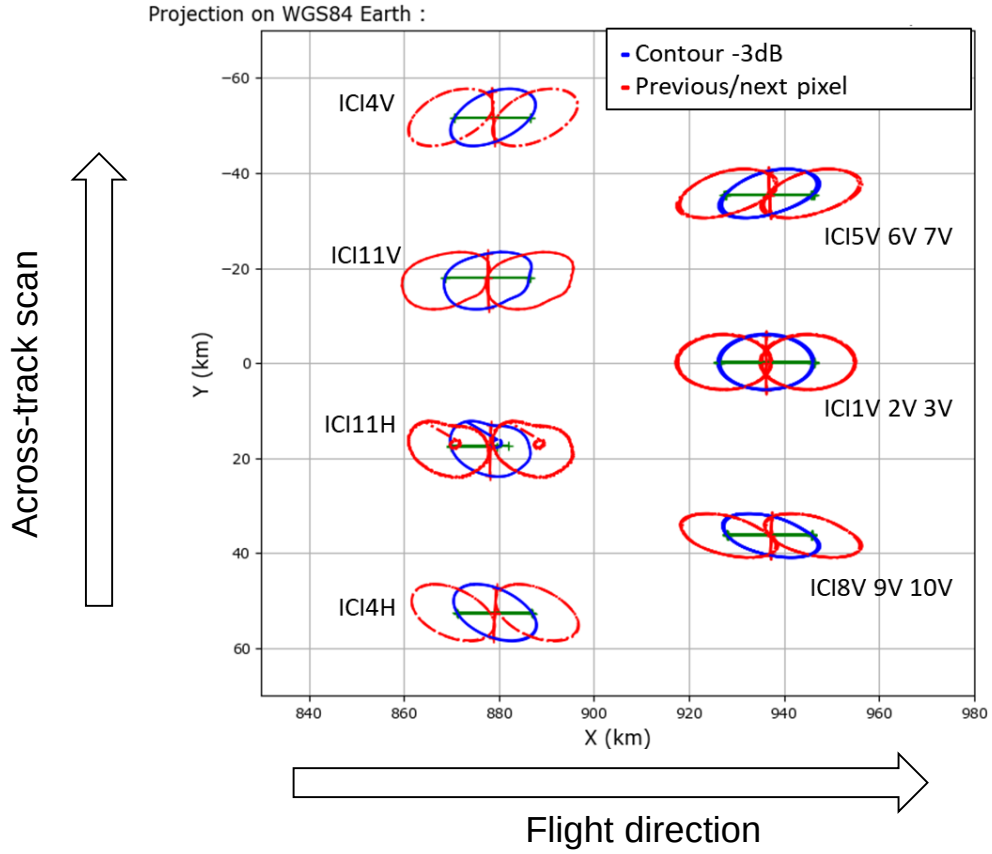
3. Metop-SG ICI PFM measured performance

- ICI PFM **antenna patterns projection** on-ground, forming 7 elliptical footprints
- Antenna performance compliant to requirements



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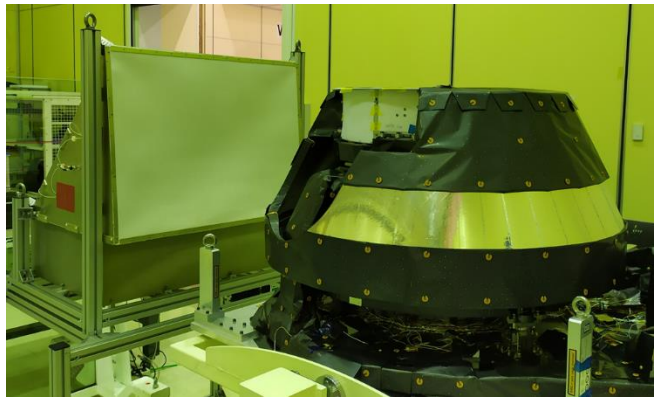
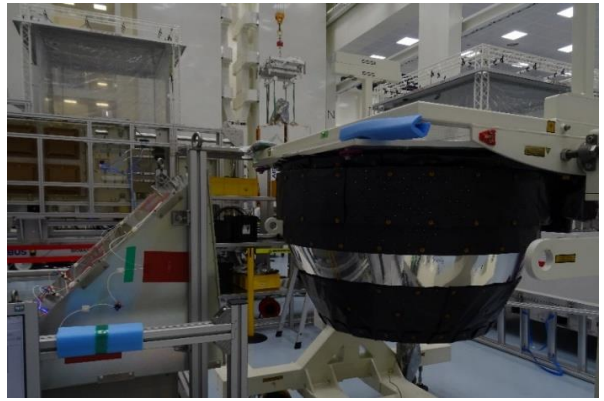
3. Metop-SG ICI PFM measured performance

- ICI PFM **radiometric performance** in **ambient** conditions, with hot (OBCT) and cold (CAT) targets
- Radiometric gain and NeDT evolution between beginning and end of test campaign (incl. integration on satellite) were monitored

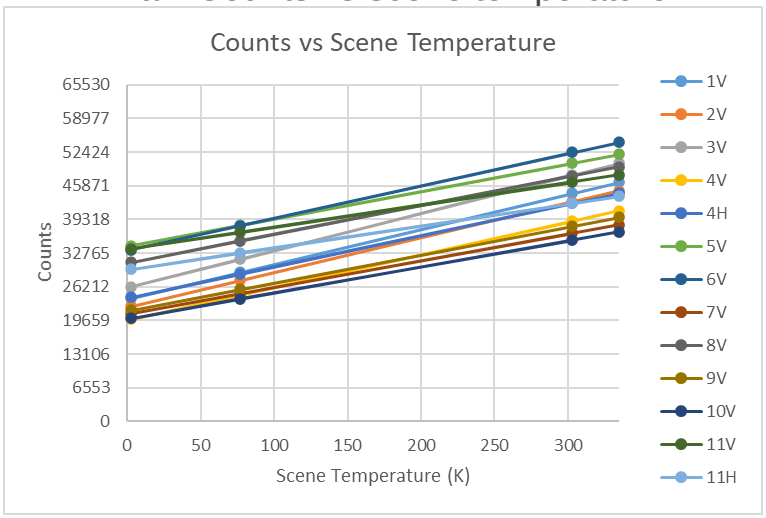
ICI in +1g



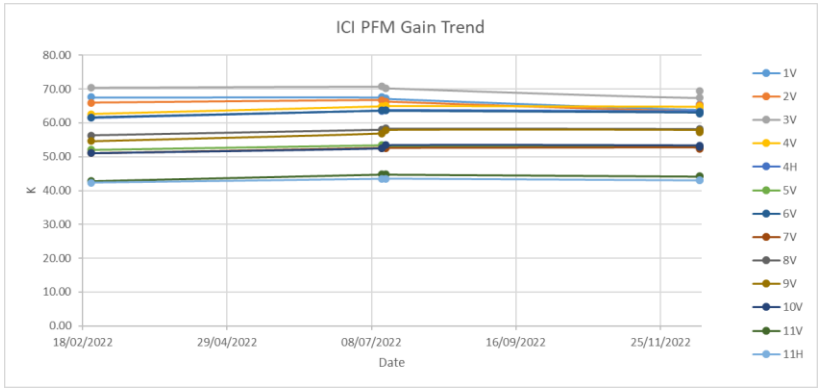
ICI in -1g



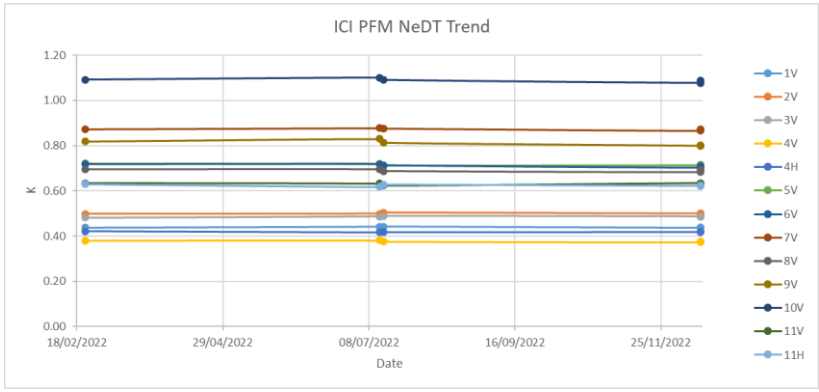
Raw Counts vs scene temperature



Gain trend



NeDT trend



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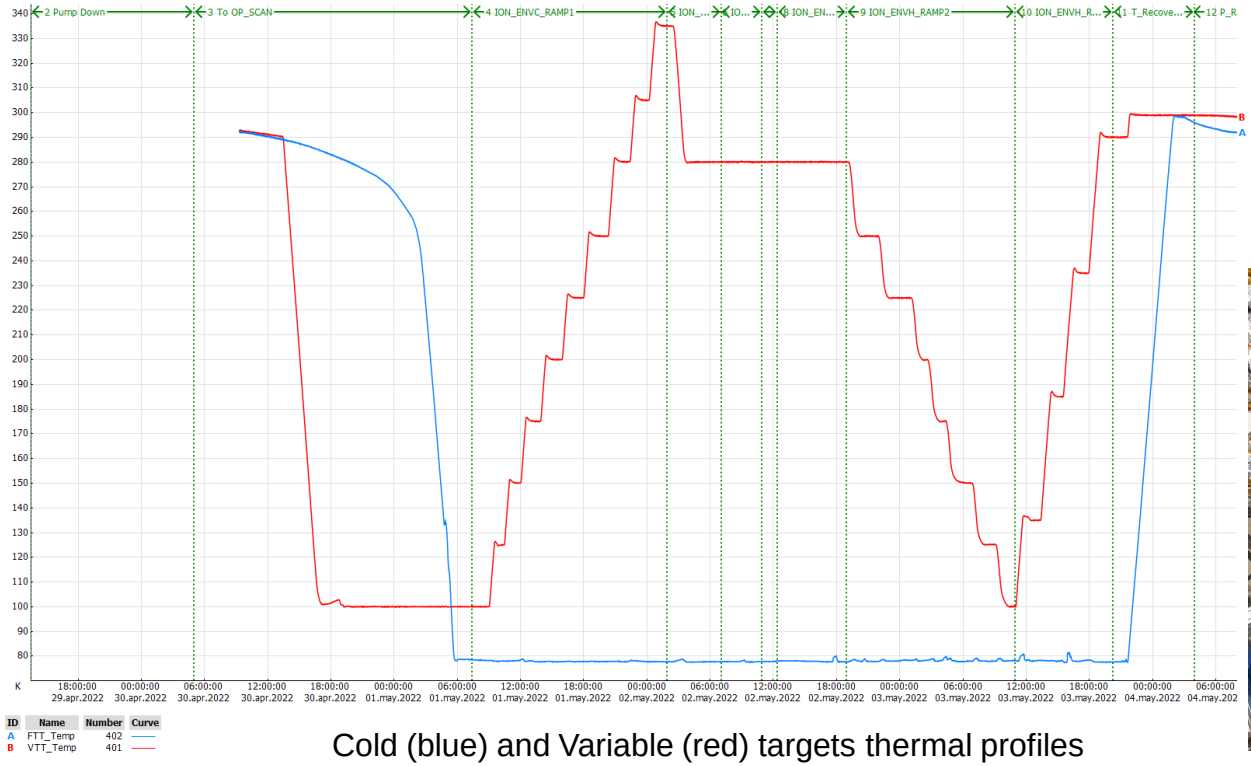
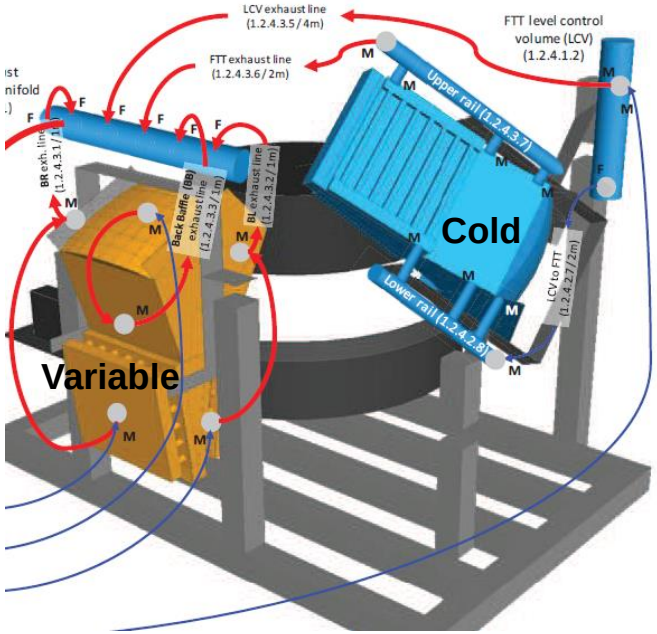
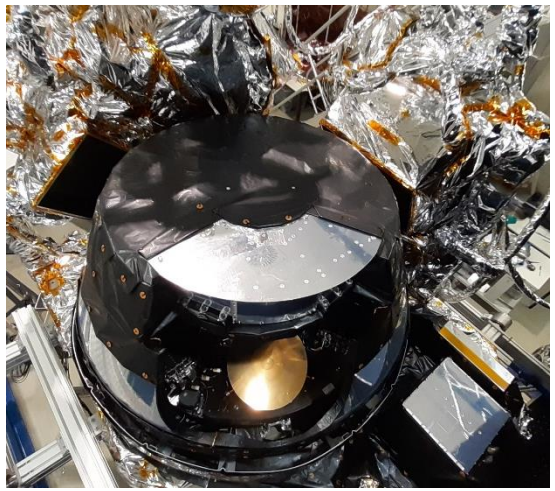
3. Metop-SG ICI PFM measured performance

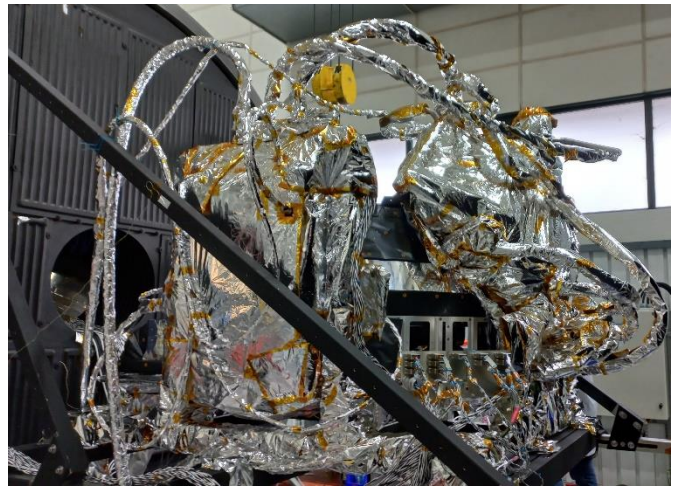
- ICI PFM **radiometric performance** in **TVAC** with external cold and variable temperature targets
- Cold target in front of cold sky reflector kept at LN2 temperature, variable target in front of the Earth antenna with steps of 25K



Cold (blue) and Variable (red) targets thermal profiles







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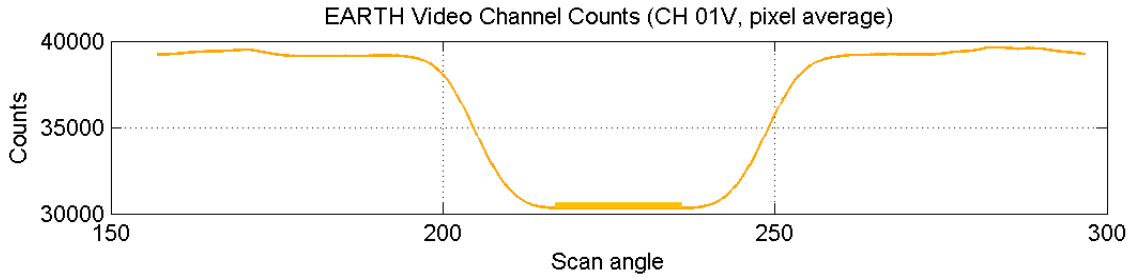
3. Metop-SG ICI PFM measured performance

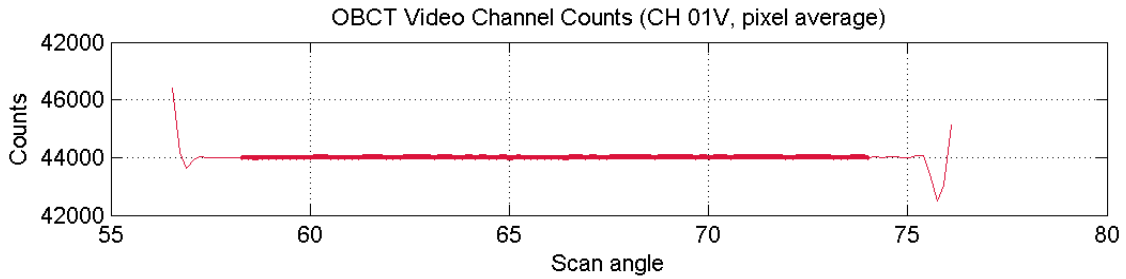
- Three measurement windows (Earth, Hot (OBCT) and Cold) were acquired while scanning
- Selected pixels in target regions were used as reference data

Earth window (VTT)



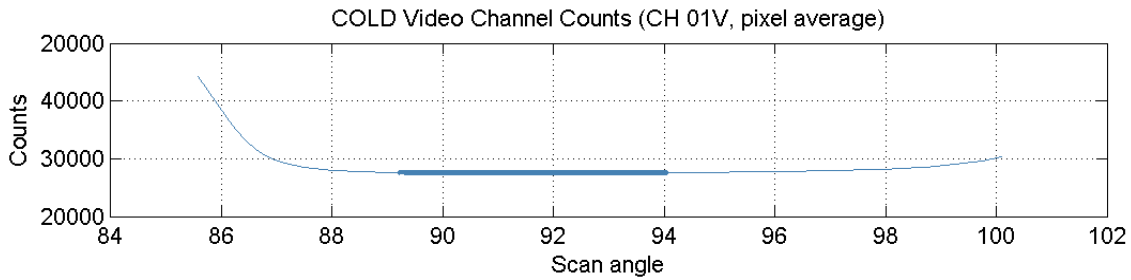
~100K

Hot window (OBCT)



~303K

Cold window (FTT)



~77K

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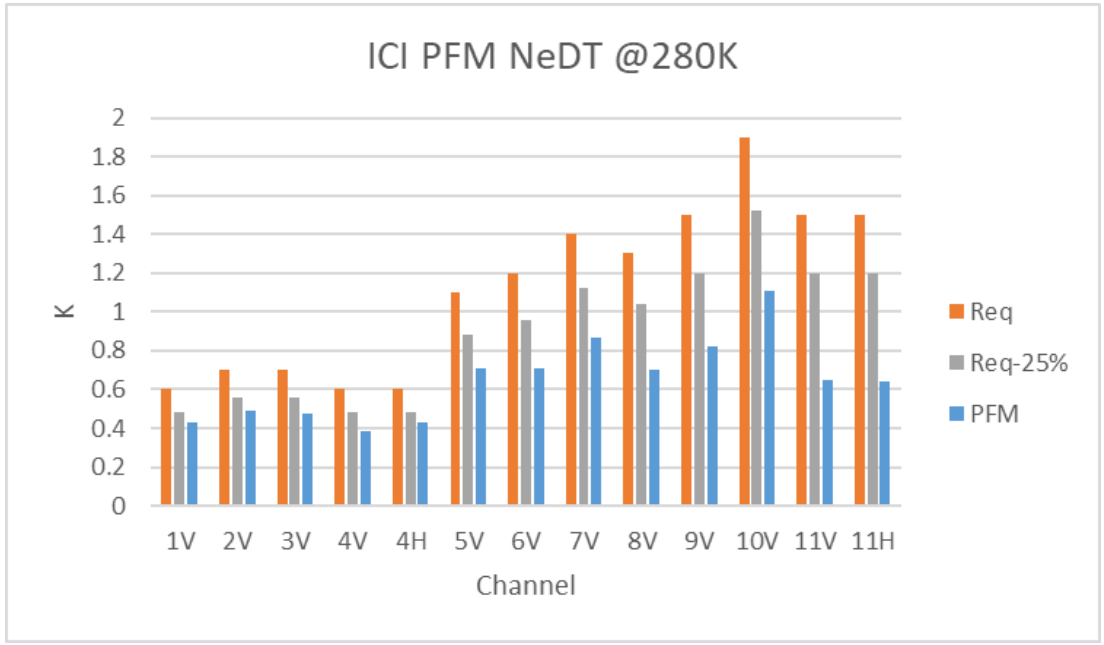
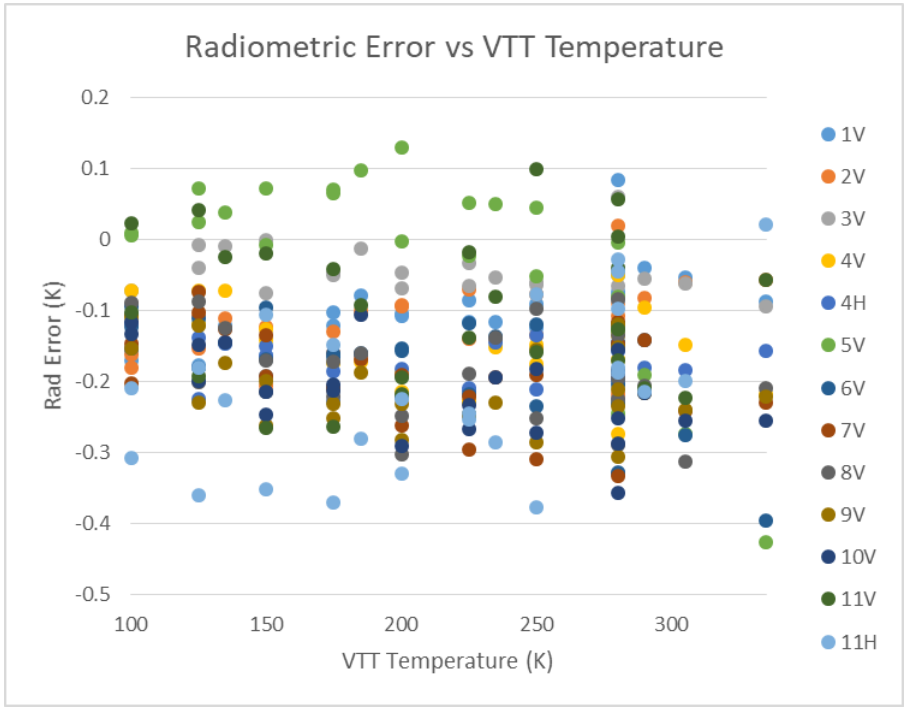
3. Metop-SG ICI PFM measured performance

- NeDT and Radiometric error was computed for every Earth target temperature between 100K and 335K
- NeDT requirement placed at 280K is met with large margins (for ground and orbit degradations)
- Radiometric error bias is bounded between -0.4K and 0.1K for all channels and scene temperatures



*Integration time = pixel time of around 2ms



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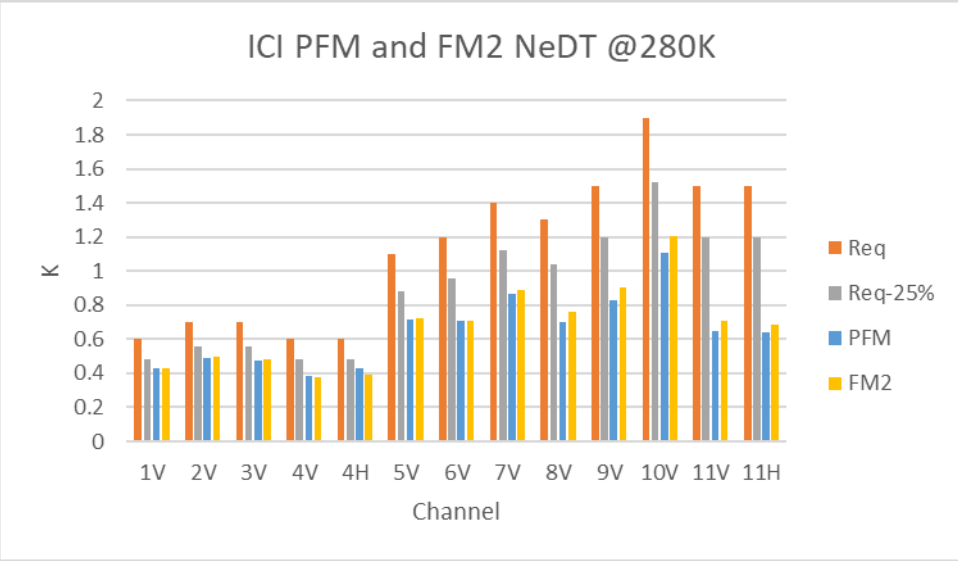
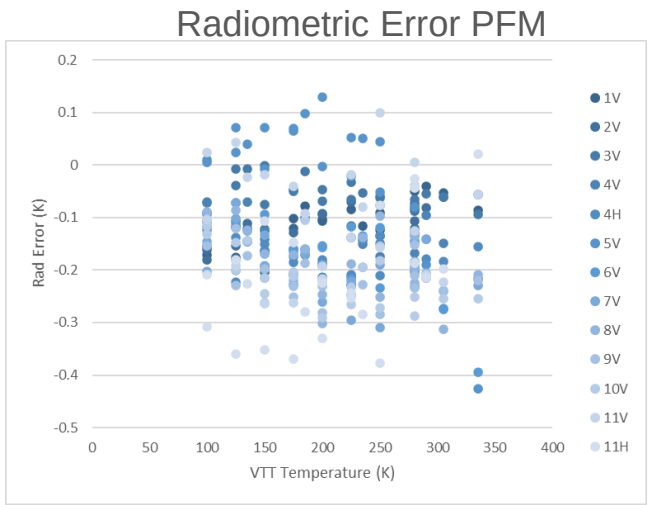
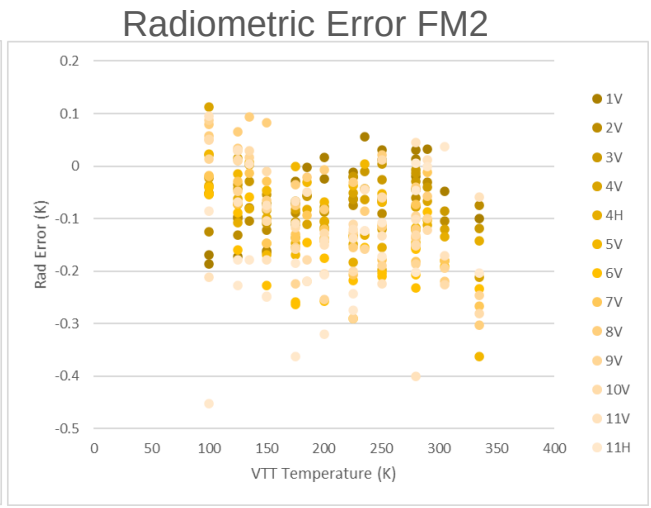
4. Metop-SG ICI FM2 status and first results

- ICI FM2 has been fully integrated and has completed already 75% of the acceptance test campaing (Initial Functional, Vibration, Acoustic, Release, TV cycling, TVAC calibration and part of EMC)
- Outstanding tests are EMC (on-going), Microvibrations, Antenna Pattern and Final Functional tests
- Test results obtained so far are compliant to the requirements and similar to the PFM ones







*Same integration time for PFM and FM2

NEDT (K)	ICI-1	ICI-2	ICI-3	ICI-4V	ICI-4H	ICI-5	ICI-6	ICI-7	ICI-8	ICI-9	ICI-10	ICI-11V	ICI-11H
PFM @280K	0.43	0.49	0.48	0.38	0.43	0.71	0.71	0.87	0.70	0.83	1.11	0.65	0.64
FM2 @280K	0.43	0.49	0.48	0.38	0.39	0.72	0.71	0.89	0.76	0.90	1.20	0.70	0.69

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5. Conclusions and way forward

- The Ice Cloud Imager (ICI) instrument status and main performance has been presented.

- The first flight model (PFM) has been qualified and delivered to the satellite prime and integrated onto the satellite in summer 2022
  ICI PFM performance is compliant to the requirements, which have been deeply verified.

- The seconf flight model (FM2) is under test campaign (75% completed) and will be delivered by the end of 2023. The measured performance is so far very similar to the PFM.

- The third fight model (FM3) is expected to be integrated and tested by 2024.
  All FM3 units are available for integration except the Front-end, expected to come in the next months, and a piece of structure (calibration arm), to be repaired.
  After the acceptance campaign, the FM3 instrument might remain in storage for some time before delivery to satellite prime.

Thank you

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