living planet symposium | BONN 23–27 May 2022

TAKING THE PULSE OF OUR PLANET FROM SPACE

EUMETSAT ECMWF EUSPA

# MetOp Second Generation: System Overview

B5.01.2 Future Meteorological Missions: MetOp-SG 1 (25/05/2022)

# MetOp Second Generation: System Overview

ESA Living Planet Symposium
23-27 - May – 2022 – Bonn
B5.01.2 Future Meteorological Missions: MetOp-SG 1 on 25 – May - 2022

Fermín Álvarez López[1], Stéphane Rousseau[1], Graeme Mason[1], Michel Pendaries[2], Hervé Marcille[2], Markus Huchler[3], René Fayard[3]
[1] ESA/ESTEC, Noordwijk, The Netherlands
[2] AIRBUS Defence and Space, Toulouse, France
[3] AIRBUS Defence and Space, Friedrichshafen, Germany

# MetOp-SG Introduction

- MetOp-Second Generation (MetOp-SG) is a follow-on system to the first generation series of MetOp (**Met**eorological **Op**erational) satellites, which currently provide operational meteorological observations from polar orbit.
- MetOp-SG represents the European component of the space segment of the Joint Polar System, which is a collaboration between EUMETSAT and NOAA, whereby Europe is responsible for the “mid-morning orbit” and the US is responsible for the “afternoon orbit”.
- MetOp-SG is a collaborative programme between ESA and EUMETSAT, similar to previous successful cooperation between the two organisations.
- ESA is responsible for the development of the prototype satellites and, on behalf of EUMETSAT, for the procurement of the recurrent satellites.
  All contracts regarding the MetOp-SG Satellites are under ESA authority and in accordance with ESA rules and regulations.
- EUMETSAT is responsible for the overall user requirements, procurement of the launchers and LEOP services, development of the ground segment and also performs the operations.

# MetOp-SG Objectives

- To provide operational observations and measurements from polar orbit for **Numerical Weather Prediction** and **climate monitoring** from the 2020's, with at least 21 years of operations.
- In addition, to provide services to **atmospheric chemistry**, **operational oceanography** and **hydrology**.
- With respect to the first generation of MetOp satellites:
  - to ensure **continuity** of essential operational meteorological observations from polar orbit, without a gap;
  - to **improve the accuracy / resolution / dynamic range** of the measurements (e.g. MWS, RO, SCA as well as METimage, IASI-NG, Sentinel-5);
  - to **add new measurements / missions** (e.g. 3MI, MWI, ICI as well as Sentinel-5).

# MetOp-SG Satellites Overview

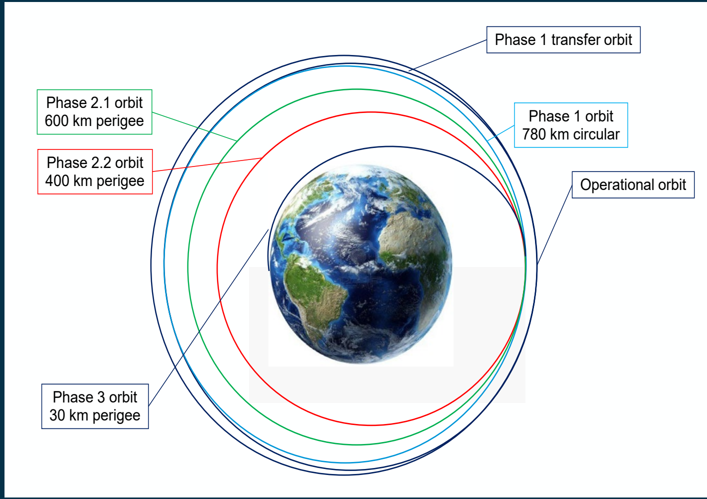
- MetOp-SG consists of two series of satellites (Sat-A and Sat-B), with with a maximum of commonality between the two series (design & operations).
- Baseline of three satellites in each series, to cover 21 years of in-orbit operations – with nominal launches for each series every 7 years.
- The MetOp-SG satellites will fly in the same orbit as the first generation MetOp (sun-synchronous, polar orbit, altitude 832 km, mean local solar time 09:30 (descending node), repeat cycle 29 days).
- A total of ten instruments are flown across the two satellites:
  - six Contractor Provided Item (**CPI**) instruments developed under the MetOp-SG contracts;
  - four Customer Furnished Item (**CFI**) instruments provided by ESA Copernicus or from DLR or CNES via EUMETSAT: Sentinel-5 (ESA Copernicus), METimage (DLR), IASI-NG (CNES), Argos-4 (CNES).
- More than **200 companies** working all over Europe on the satellite Programme.

# Mission Phases Overview

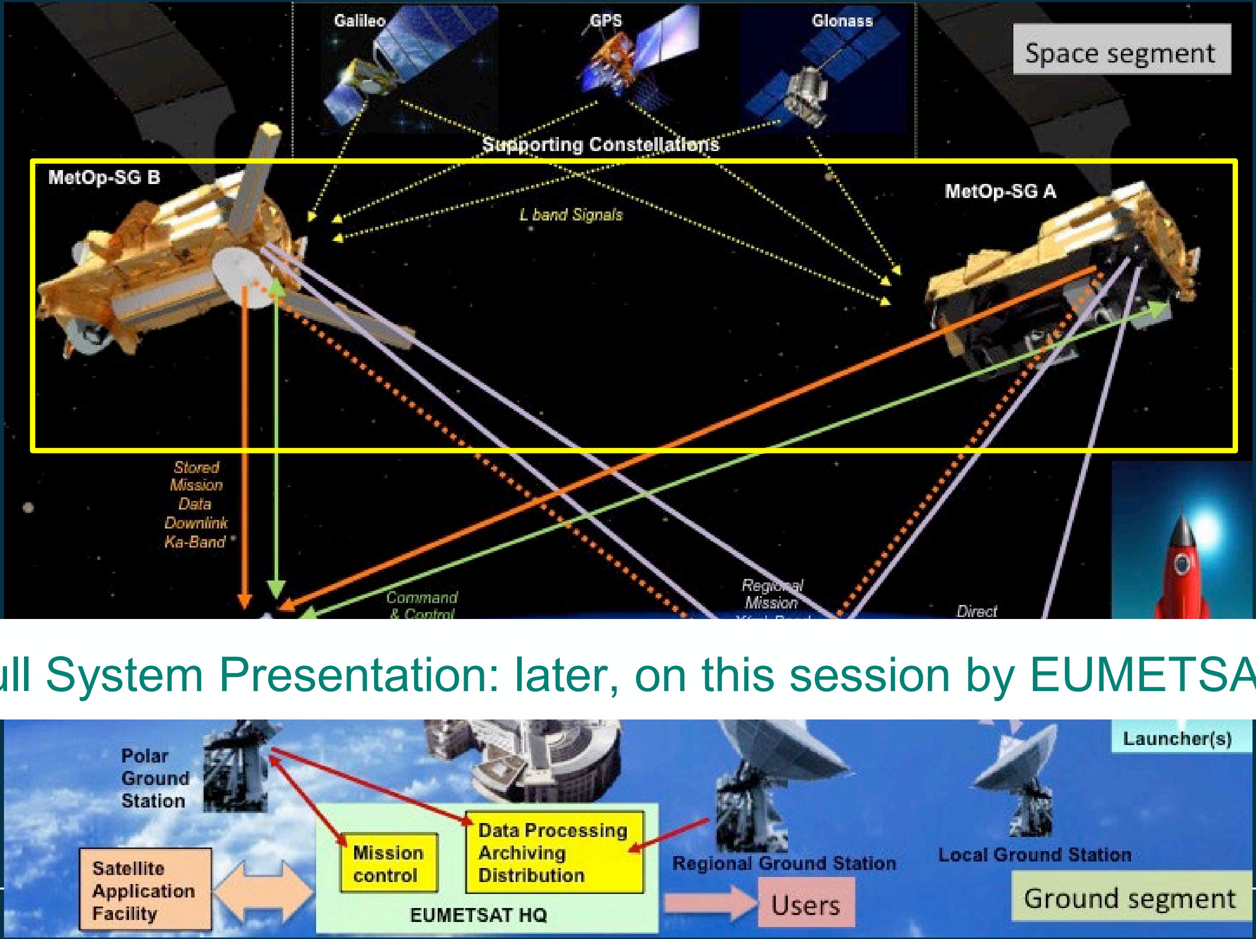
- **Launch and Early OPerations** (3 days + 5 to 27 days orbit drift)
  - Initial attitude tumbling + rate reduction with magnetometer and propulsion
  - Steady state based on B-dot law with magnetometer and magnetotorquers
  - Commanding to Earth Pointing after Star tracker and GNSS convergence
  - LEOP including phasing: 8 to 30 days
- **Commissioning phase** (SIOV + PL calibration) (3 + 3 months)
  - Decontamination phase (PL radiators heating)
  - Specific -120° roll slew in eclipse for Instruments cold space calibration
  - Geo-location and Co-registration assessment in flight

  *POSTER: GLANCE: A Multi-sensor Geolocation and Co-registration Verification Toolbox*

  *Poster Session Thursday 26th May – 18:20*
- **Nominal Mission** (7 years + 2 years extension)
  - Simultaneous/permanent operation of all instruments
  - Including during in-plane orbit maintenance and collision avoidance
  - Nominal pointing interruption limited to safe mode and inclination manoeuvres (90° slew, in eclipse)
- **Controlled Re-entry** (~ 1 week)
  - Use of re-pressurization system and specific 400N main engine
  - Back-up using the 8x20N thrusters (Nom + Red RCT)
  - Re-entry perigee of 30 km in both nominal & back-up cases fully compatible with the SPOUA authorized zone

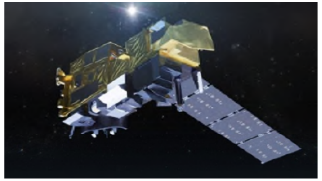
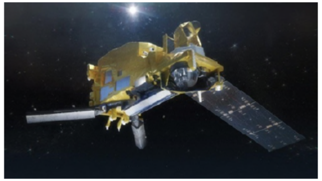


# MetOp-SG Satellites Context

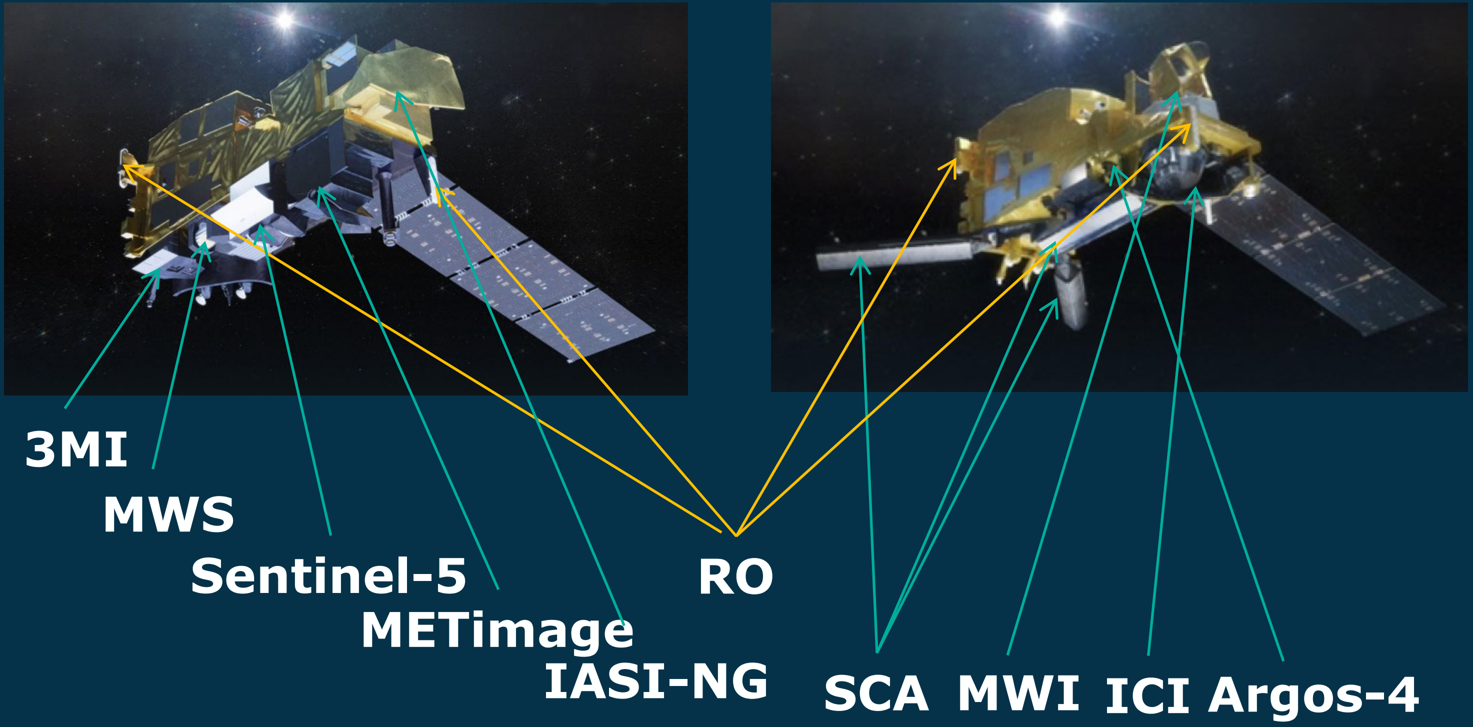



Full System Presentation: later, on this session by EUMETSAT

# MetOp-SG Satellites Key Parameters

| | Satellite A | Satellite B |
|---|---|---|
| **Configuration** |  |  |
| **Instrument Suite** | IASI-NG, METimage, Sentinel-5, MWS, 3MI, RO | SCA, MWI, ICI, RO, ADCS-4 |
| **Main Satellite Budgets** | Satellite launch mass = 4.4 tons max<br>Mean power consumption in operations = 3.0 kW<br>Mean day / night instruments data rate = 68 / 26 Mbps | Satellite launch mass = 4.4 tons max<br>Mean power consumption in operations = 2.2 kW<br>Mean day / night instruments data rate = 17 / 17 Mbps |
| **Mission** | Launchers: ~~Soyuz~~ in Kourou / ~~Ariane 5 (dual launch)~~ / Ariane 6 ~~(objective)~~ / Falcon 9<br>Operational orbit: SSO 835 km average altitude, 9h30 LTDN / Controlled Re-Entry on South Pacific Ocean Uninhabited Area | |
| **Mechanical Architecture** | Primary structure in CFRP providing a single, large, stable CFRP nadir panel for instruments heads and antennas<br>Secondary structures in Aluminum: 4 lateral panels for platform units, Power Units Bay (PUB), Payload Equipment Bay (PEB) | |
| **Thermal Control** | Platform thermal control based on SSM / MLI / heaters / embedded heat pipes on PUB zenith panel / instruments are thermally decoupled | |
| **Propulsion** | Single hydrazine tank filled with up to 760 kg of hydrazine / 4 Helium high pressure vessels / 2 x 6 20 N thrusters / 1 x 400 N engine | |
| **Data Handling** | SpaceWire for science data and command and control data / 1553-MIL-bus for platform units and ADCS-4 / MMFU of 745 Gbits EoL storage capacity | |
| **Communications** | SMD downlink in Ka-band, OQPSK modulation, (2 + 1) x 390.5 Mbps | SMD downlink in Ka-band, OQPSK modulation, (1 + 1) x 390.5 Mbps |
| | DDB in X-band, QPSK modulation, (1 + 1) x 80 Mbps information rate<br>TTR in S-band, uplink at 64 kbps, downlink in LR at 64 kbps with ranging / in HR at 1.6 Mbps (incl. formatting & coding) | |
| **Power** | Main power bus on 50V unregulated, 30V unregulated available for specific users | |
| | 1 single solar array wing, 1-axis rotated, 23.9 $m^2$ populated with triple junction GaAs solar cells<br>7.3 kWh BoL power / 20 sections / 6600 cells | 5.4 kWh BoL power / 16 sections / 5040 cells |
| | 4 x 54 Ah battery modules (12S12P) = 216 Ah | 3 x 54 Ah battery modules (12S12P) = 162 Ah |
| **AOCS** | Magnetic safe mode based on magnetometer and magnetotorquers / Propulsion for initial rate reduction only<br>Attitude and orbit determination based on standard GNSS receiver and 3 star tracker heads (gyroless) | |
| | Actuators: cluster of 5 wheels (65 Nms each) | Actuators: cluster of 6 wheels (65 Nms each) |
| **Operations & FDIR** | Enhanced autonomy with time-tag, orbit position-tag and event-tag programming / FDIR concept: fail operational on first failure, fail-safe on second failure | |
| **Lifetime & Reliability** | Nominal mission lifetime = 7.5 years / Resources sized for mission extension up to 9.5 years / Each mission reliability = 0.75 after 7.5 years | |

# MetOp-SG Satellite A and Satellite B

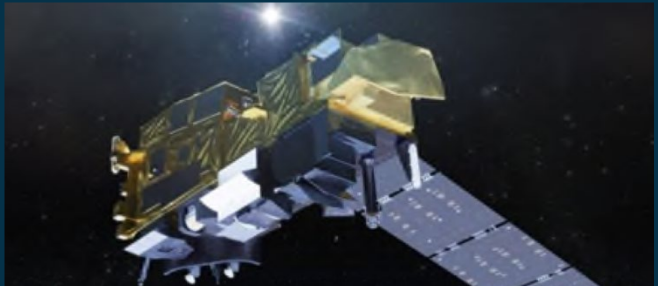



***The ten instruments onboard***

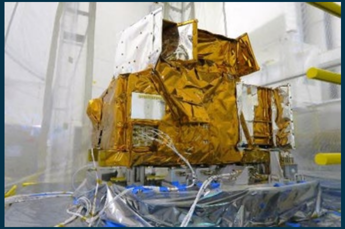
# MetOp-SG Payload Overview

***RO***

**SATELLITE A**

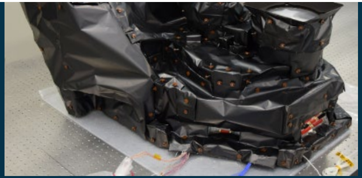


***IASI-NG***

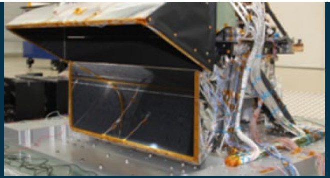


See dedicated presentations
METimage, IASI-NG and Sentinel 5 : B5.01.2 (Afterwards)
MWS, RO and 3MI: B5.01.3 (Here, after lunch)

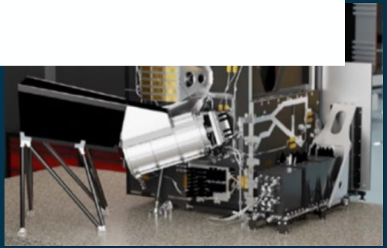
***MWS***



***3MI***



***Sentinel-5***



***METimage***

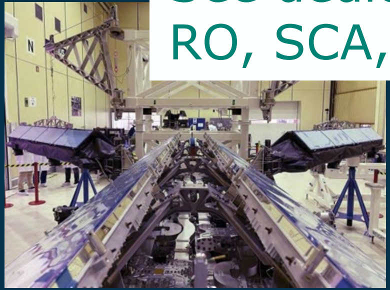
# MetOp-SG Payload Overview

RO

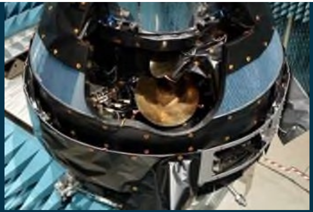
SATELLITE B

MWI

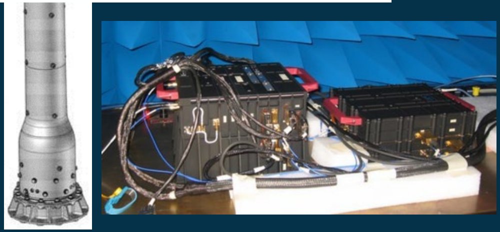
See dedicated presentations
RO, SCA, MWI and ICI : B5.01.3 (Here, After lunch)



SCA



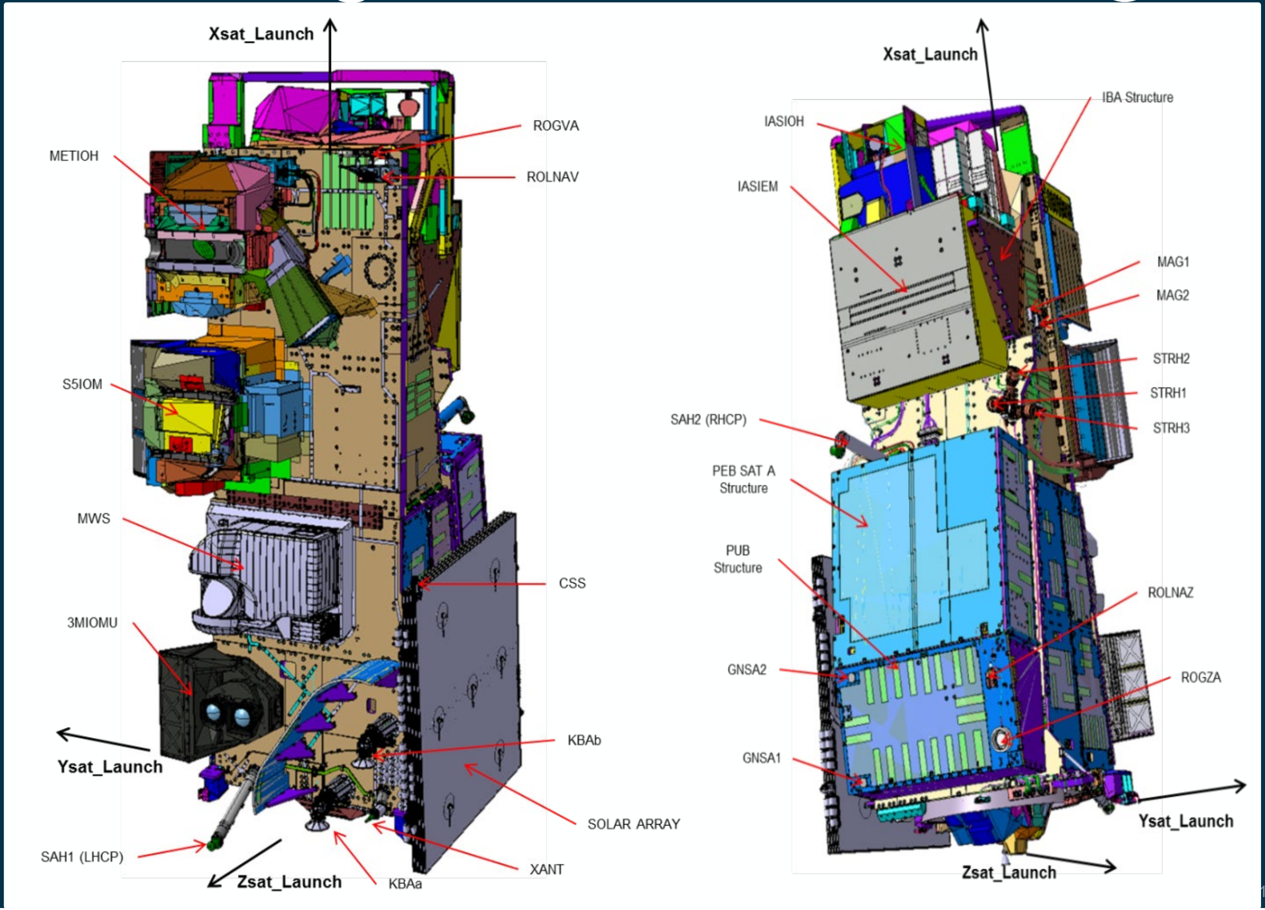
ICI



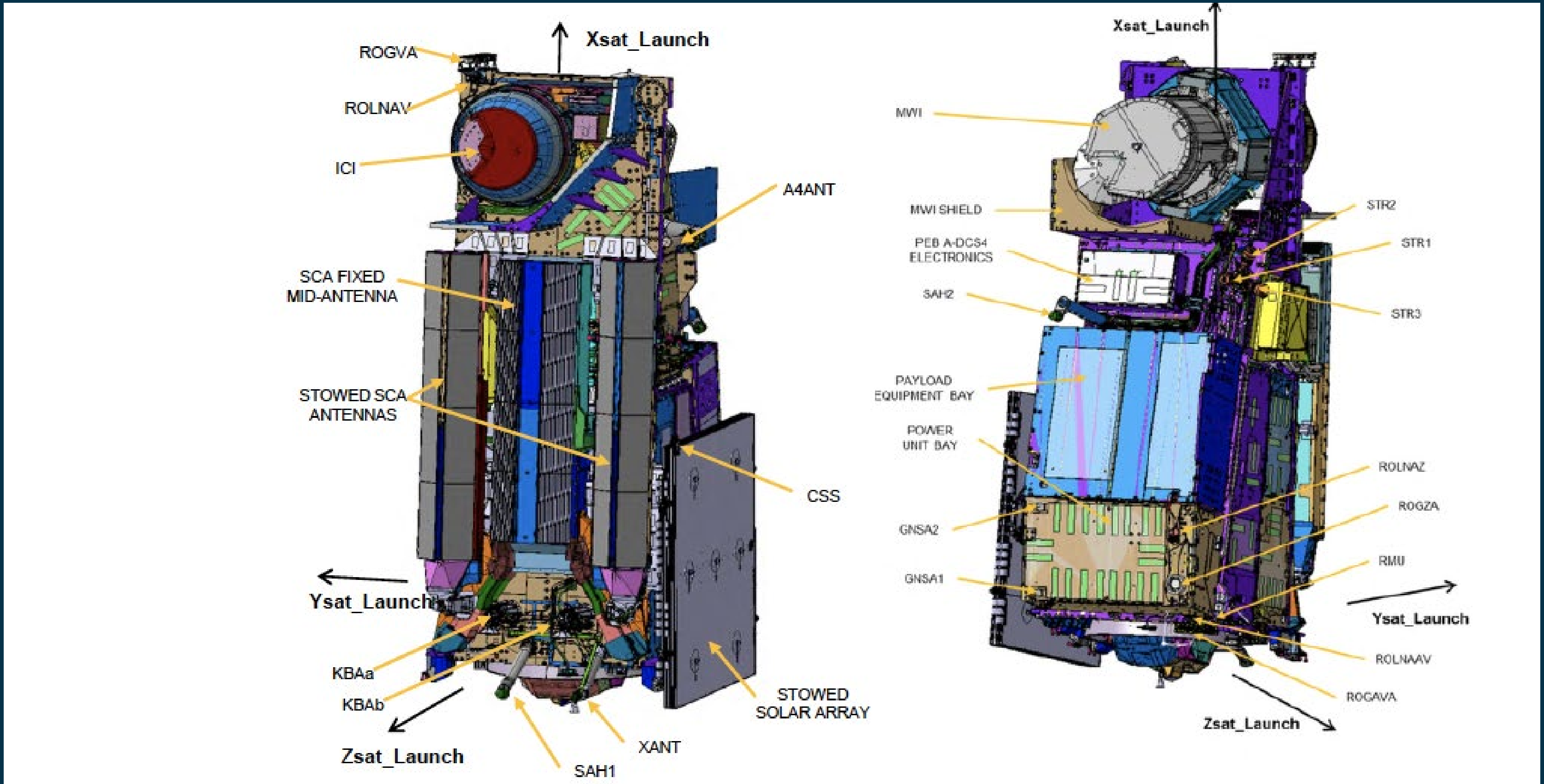
ARGOS-4

# Satellite-A Configuration

- Coarse Earth Sensor removed since change to full magnetic acquisition and safe mode

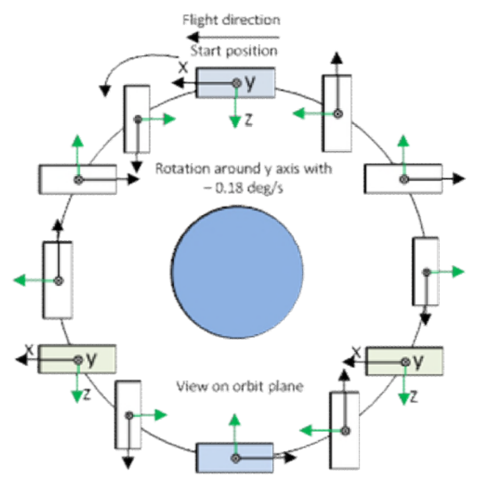


# Satellite-B Configuration



# MetOp-SG System Evolution since CDRs

- **<u>Safe Mode based on Earth pointing replaced by Full Magnetic safe mode</u>**
- Critical temperature sensitivity of the CES sensor, confirmed by test, not compatible with unambiguous Earth detection from lost-in-space attitude
- An alternative full magnetic Safe mode was defined (based on magnetometer only) at the time of SAT B CDR close out
- Two full satellite rotations per orbit about normal to orbit plane, Solar Array Sun pointed
- The New Magnetic Safe Mode has been validated with Satellite Simulator and the avionic test bench (Electrical Functional Model)
- Global power budget has been improved
- Instruments compatibility (e.g. thermal, power) with new Safe Mode confirmed

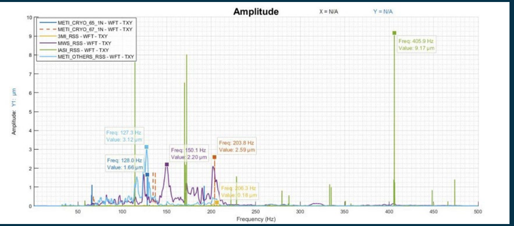


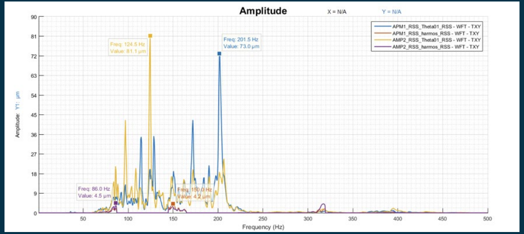

ASM steady-state
- Pitch rate ~0.18°/sec
- Initial attitude unknown
- Y axis pointing < 25°

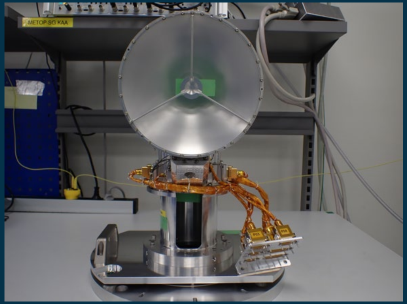
# MetOp-SG System Evolution since CDRs



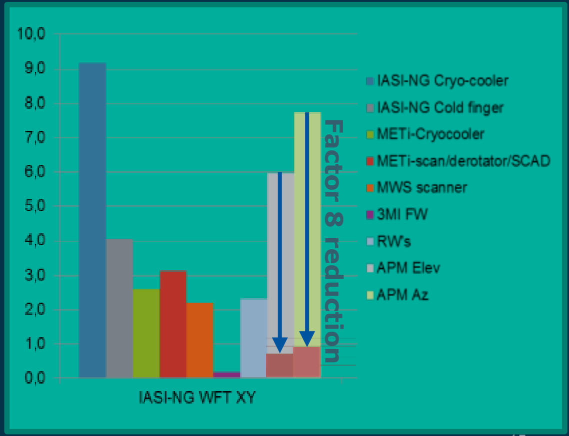
- **<u>Ka-Band antenna (KAA) guidance law change due Micro-vibrations</u>**
- Following the qualification campaign of the KAA antenna, the exported microvibration were much higher than anticipated and well beyond IASI-NG acceptable level.



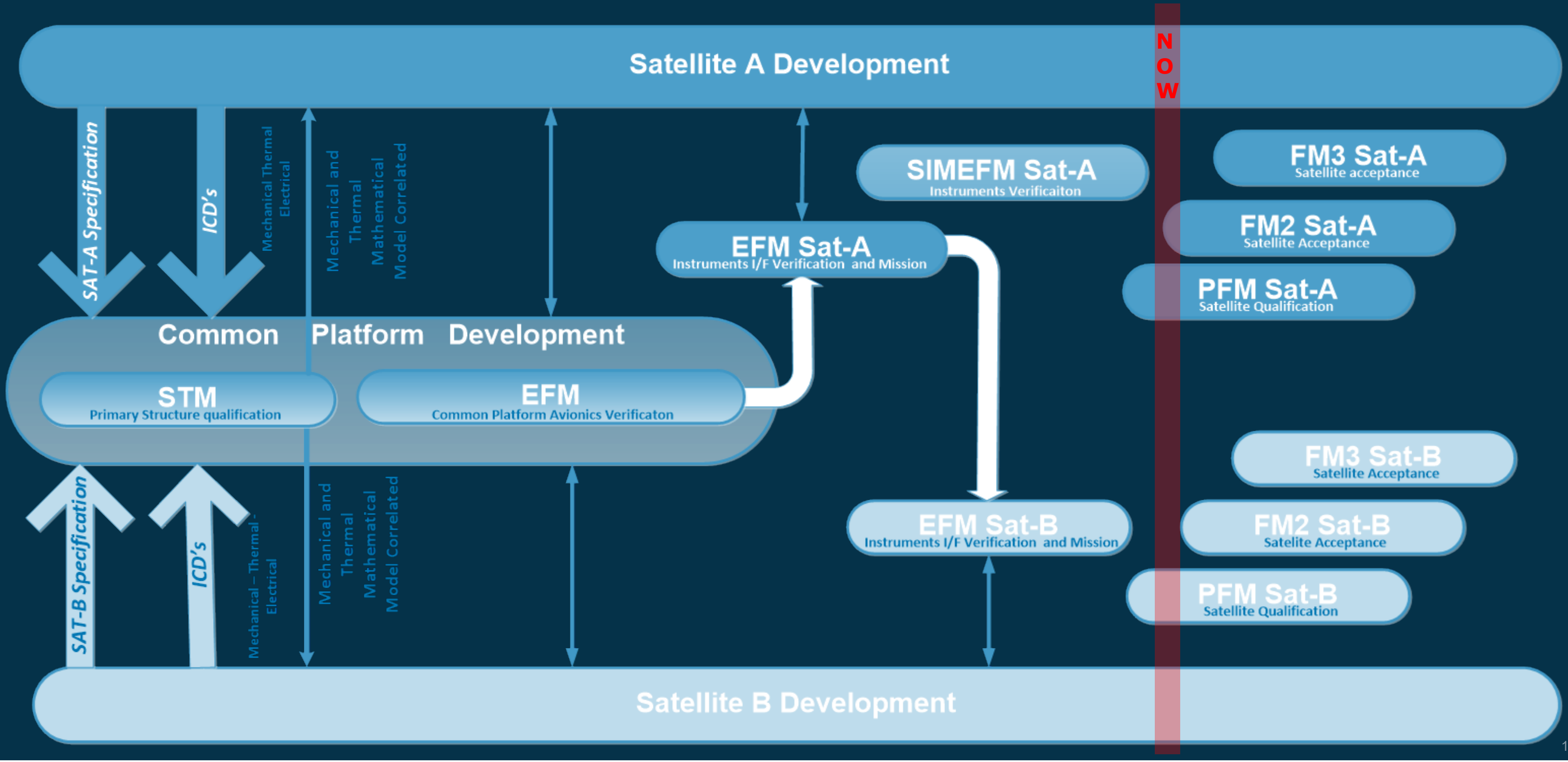



- An extensive activity has been implemented to tackle this issue.
- A relation has been established between the angular rate of the antenna and the IASI-NG exited frequencies. As a consequence a new antenna guidance law has been implemented to avoid the critical frequencies.
- The exported perturbation level have been derived by a factor of 8, the issue is considered now solved. The final verification will be performed during the satellite Thermal vacuum campaign.

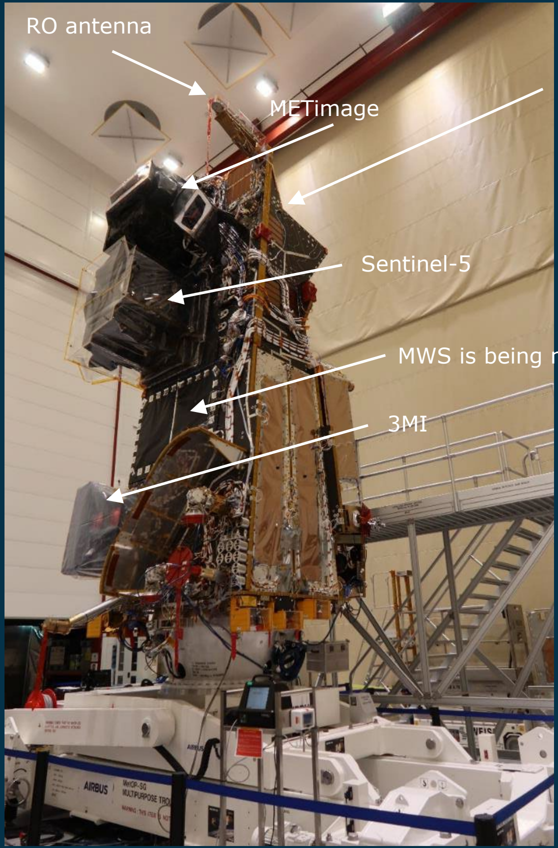


# MetOp-SG Development and Verification



# MetOp-SG A1 AIT

- Platform complete
  - Functional Tests under completion
- 4/6 instruments mounted
  - MWI Intermediate flight model
  - 3MI mounted, tests in May-22
  - MWS mounting and tests in May-22
  - IASI-NG expected in August-22 for immediate mounting and tests
- Environment test campaign starts end-22
  - Mechanical tests: Dec-22
  - TVAC: March-23
- Late PFM mounting: S5 (Q4-23), METi (Q1-24)

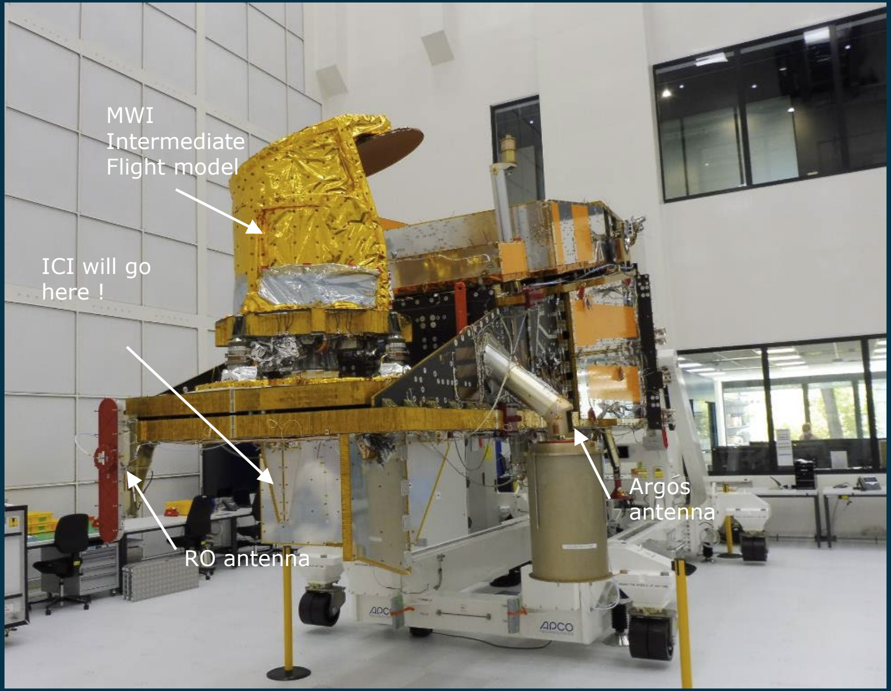


# MetOp-SG B1 AIT

- Platform complete
  - Functional Tests on-going

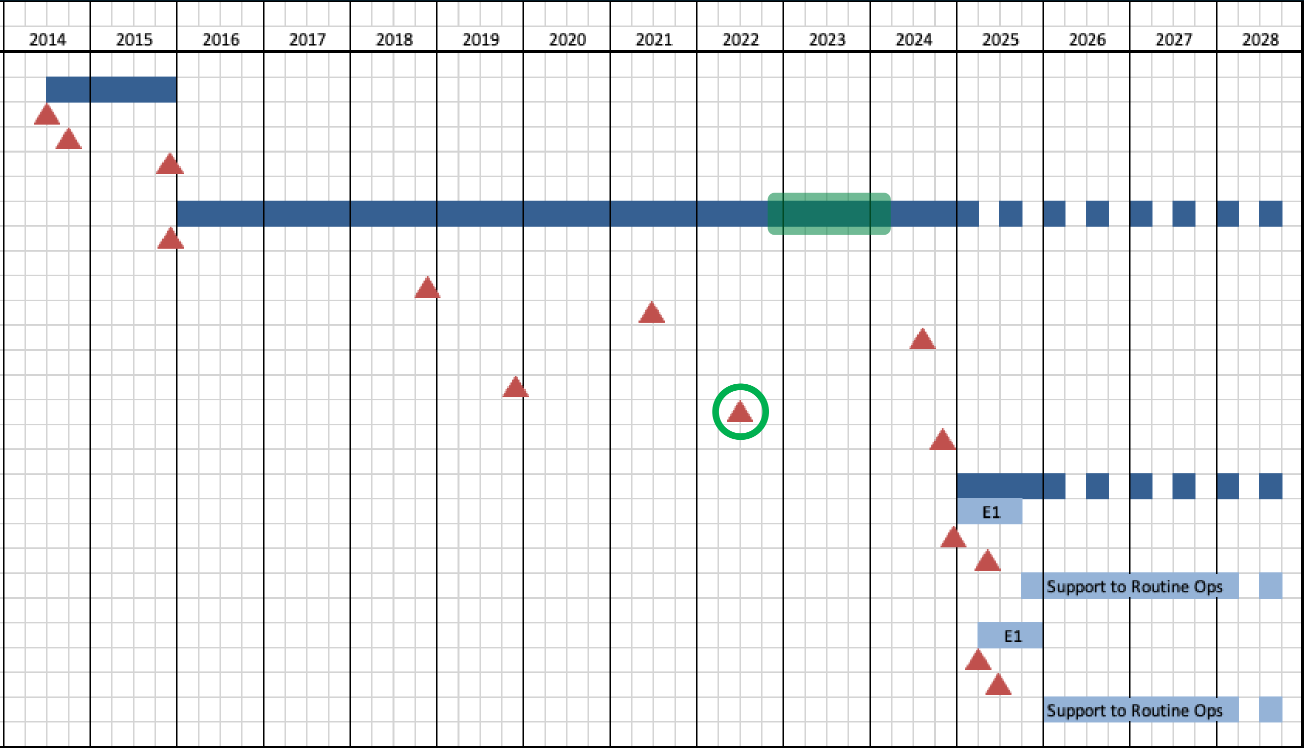
- 3/5 instruments mounted
  - RO, Argos tested
  - MWI IFM mounted in May-22
  - ICI expected July 22
  - SCA expected in Nov 22
  - MWI PFM Q2 2023

- Environment test campaign starts end-23
  - Mechanical tests: Q4-23
  - TVAC: Q1-24



# MetOp-SG Overall Schedule

| MetOp-SG Phasing | | | |
|---|---|---|---|
| **Phase B2** | | | |
| Phase B2 Kick-Off | T0 | | 28/05/2014 |
| SRR | T0 + 3m | 3 | 01/09/2014 |
| PDR (inc. CPI Insts) | T0 + 15m | 15 | 01/09/2015 |
| **Phase C/D** | | | |
| Phase C/D Kick-Off | T0 + 17m | 17 | 23/11/2015 |
| Sat-A CDR | T0 + 51m | 51 | 08/09/2018 |
| Sat-A QR | T0 + 84m | 84 | 11/06/2021 |
| Sat-A PFM FAR | T0 + 122m | 122 | 25/08/2024 |
| Sat-B CDR | T0 + 63m | 63 | 10/09/2019 |
| Sat-B QR | T0 + 94m | 94 | 14/04/2022 |
| Sat-B PFM FAR | T0 + 125m | 125 | 01/11/2024 |
| **Phase E** | | | |
| Sat-A PFM Phase E1 | | | |
| Sat-A PFM Launch | T0 + 126m | 126 | 25/12/2024 |
| Sat-A PFM SIOVR | T0 + 117m | 117 | 25/03/2024 |
| Support to Sat-A Routine Ops | | | |
| Sat-B PFM Phase E1 | | | |
| Sat-B PFM Launch | T0 + 129m | 129 | 01/03/2025 |
| Sat-B PFM SIOVR | T0 + 133m | 133 | 01/07/2025 |
| Support to Sat-B Routine Ops | | | |



# MetOp-SG Milestones

| | | |
|---|---|---|
| ✓ | Phase B2 Kick-off: | 28 May 2014 |
| ✓ | System Requirements Review: | September – October 2014 |
| ✓ | Contract Signature Event: | 16 October 2014 |
| ✓ | Satellite & CPI Instruments PDR: | September – November 2015 |
| ✓ | Phase C/D Kick-off: | 23 November 2015 |
| ✓ | Lower level PDRs & CDRs ("V" shape): | November 2015 – July 2018 |
| ✓ | Satellite-A System CDR: | 8 September – 27 November 2018 |
| ✓ | Satellite-B System CDR: | 10 September – 20 November 2019 |
| ✓ | Satellite-A CPI instrument QR: | Sep 2019 – Jan 2021 |
| ✓ | Satellite-A QR: | June - July 2021 |
| ✓ | Satellite-B QR: | 14 April – 21 June 2022 |

Today → ----------------------------------------------------------------

- Satellite-A PFM FAR: August 2024
- Satellite-A Launch: December 2024
- Satellite-B FAR: November 2024
- Satellite-B Launch: March 2025

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