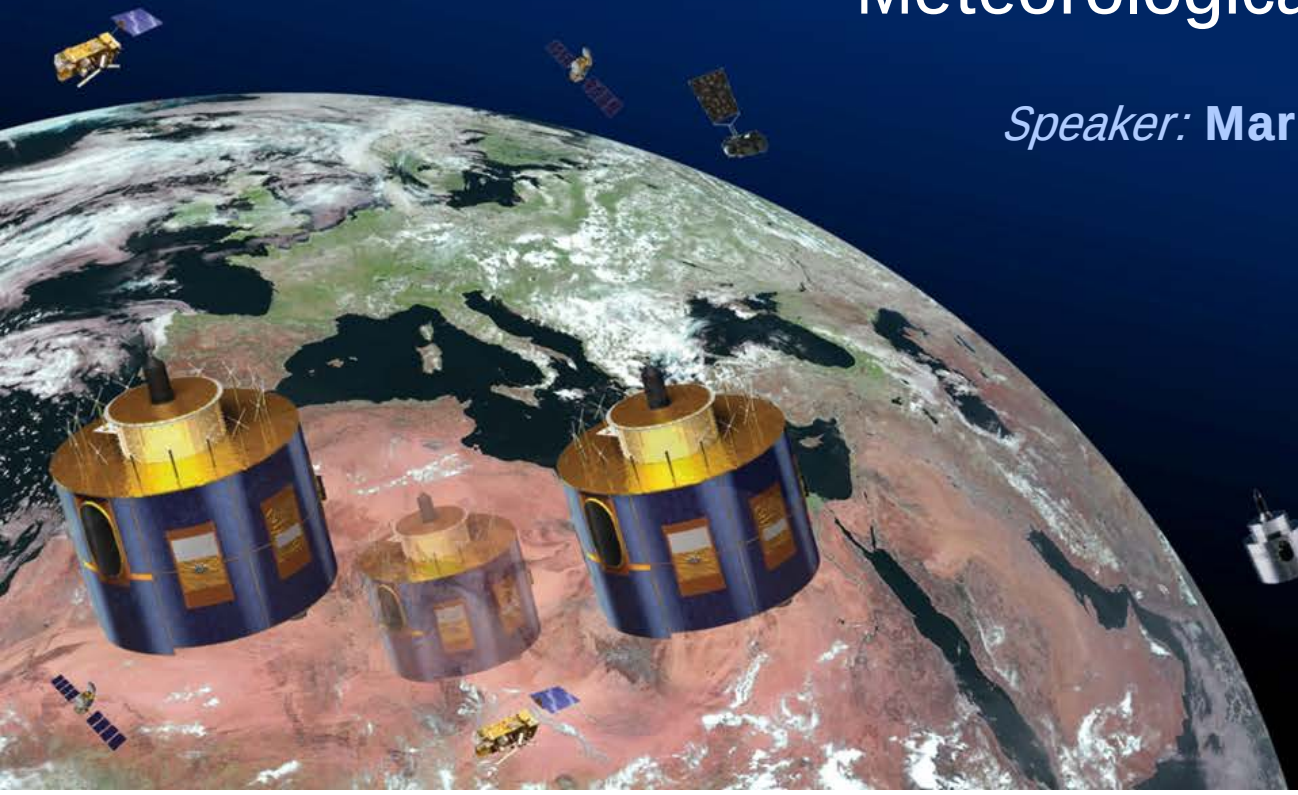
Second ITU/WMO Seminar "Use of Radio Spectrum for Meteorology: Weather, Water and Climate Monitoring and Prediction", Geneva, 23 to 24 October 2017

Current and future EUMETSAT Meteorological Satellite Networks

Speaker: **Markus Dreis** (EUMETSAT)



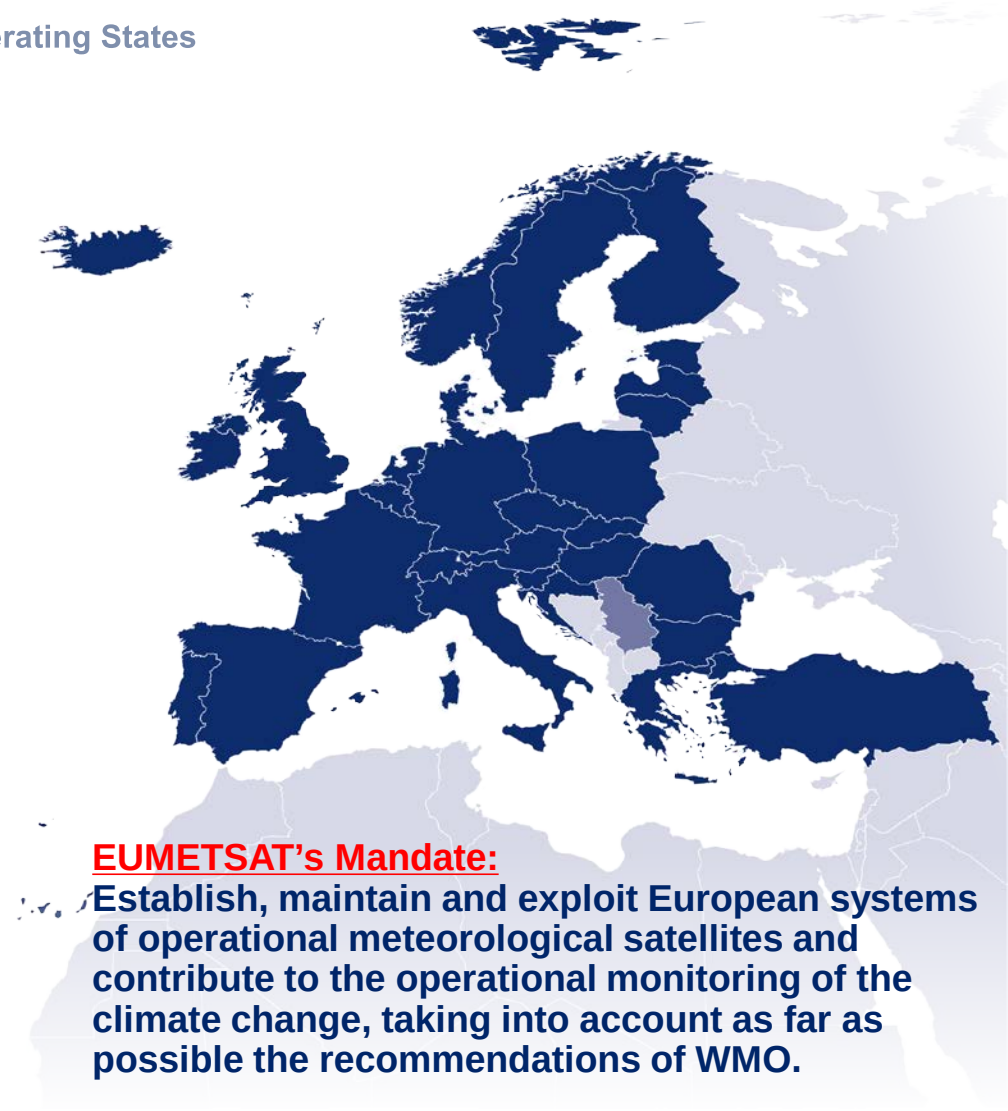
EUMETSAT is an intergovernmental organisation with 30 Member States and 1 Cooperating State

Member States

AUSTRIA
BELGIUM
BULGARIA
CROATIA
CZECH REPUBLIC
DENMARK
ESTONIA
FINLAND
FRANCE
GERMANY
GREECE
HUNGARY
ICELAND
IRELAND
ITALY
LATVIA
LITHUANIA
LUXEMBOURG
THE NETHERLANDS
NORWAY
POLAND
PORTUGAL
ROMANIA
SLOVAK REPUBLIC
SLOVENIA
SPAIN
SWEDEN
SWITZERLAND
TURKEY
UNITED KINGDOM

Cooperating States

SERBIA



EUMETSAT's Mandate:

Establish, maintain and exploit European systems of operational meteorological satellites and contribute to the operational monitoring of the climate change, taking into account as far as possible the recommendations of WMO.

EUMETSAT - An Operational Agency

Requirements

Customer

European National Meteorological Services

Private enterprises, value-added services, end-users

Operational Agency

EUMETSAT

- Interface with users and definition of user and system level requirements
- Overall system design and development
- Procurement of ground segment & launch services
- Operation of full satellite systems & ground infrastructure
- Delivery of data, products and support services to users

Satellite Development and Procurement

EUROPEAN SPACE INDUSTRY

Satellite research and development

Design and manufacturing

Delivery

Current EUMETSAT satellites in orbit
(Status October 2017)

Sentinel-3A & -3B (to be launched in 2018)
(LOW-EARTH, SYNCHRONOUS ORBIT)

COPERNICUS GLOBAL MARINE AND LAND ENVIRONMENT MISSION,
operated by EUMETSAT

METOP-A, -B and -C (to be launched October 2018)
(LOW-EARTH, SUN – SYNCHRONOUS ORBIT)

EUMETSAT POLAR SYSTEM/INITIAL JOINT POLAR SYSTEM

JASON-2/3, shared with CNES/NOAA/EU
(LOW-EARTH, 66° INCL. NON SYNCHRONOUS ORBIT)

OCEAN SURFACE TOPOGRAPHY MISSION

METEOSAT-9, -10, -11 (2nd GENERATION)
(GEOSTATIONARY ORBIT)

TWO-SATELLITE SYSTEM:

- METEOSAT-10: FULL DISK IMAGERY MISSION AT 0° (15 MN)
- METEOSAT-9: RAPID SCAN SERVICE OVER EUROPE AT 9.5°E (5 MN)
- METEOSAT-11: Stored in orbit at 3.4°W (until mid 2018)

METEOSAT-7 (1st GENERATION)
INDIAN OCEAN DATA COVERAGE FROM 57°5 E
(REORBITED to GRAVEYARD ORBIT IN APRIL 2017
(after 20 years of operation))

METEOSAT-8 (2nd GENERATION)

INDIAN OCEAN DATA COVERAGE FROM 41°5 E
(operational since 31 JANUARY 2017)
(in trial mode since October 2016)

Future EUMETSAT satellite systems

6 Metop-SG satellites (2nd GENERATION)
(LOW-EARTH, SUN – SYNCHRONOUS ORBIT)

EUMETSAT POLAR SYSTEM Second Generation (EPS-SG)
3 Metop-SG A and 3 Metop-SG B satellites
carrying different sets of instruments

2 JASON-CS/SENTINEL-6 satellites
(LOW-EARTH, 66° INCL. NON SYNCHRONOUS ORBIT)

JASON CONTINUATION OF SERVICE MISSION

Sentinel-3C/D
(LOW-EARTH, SUN – SYNCHRONOUS ORBIT)

COPERNICUS PROGRAMME
4 satellites (Sentinel-3A/B/C/D)

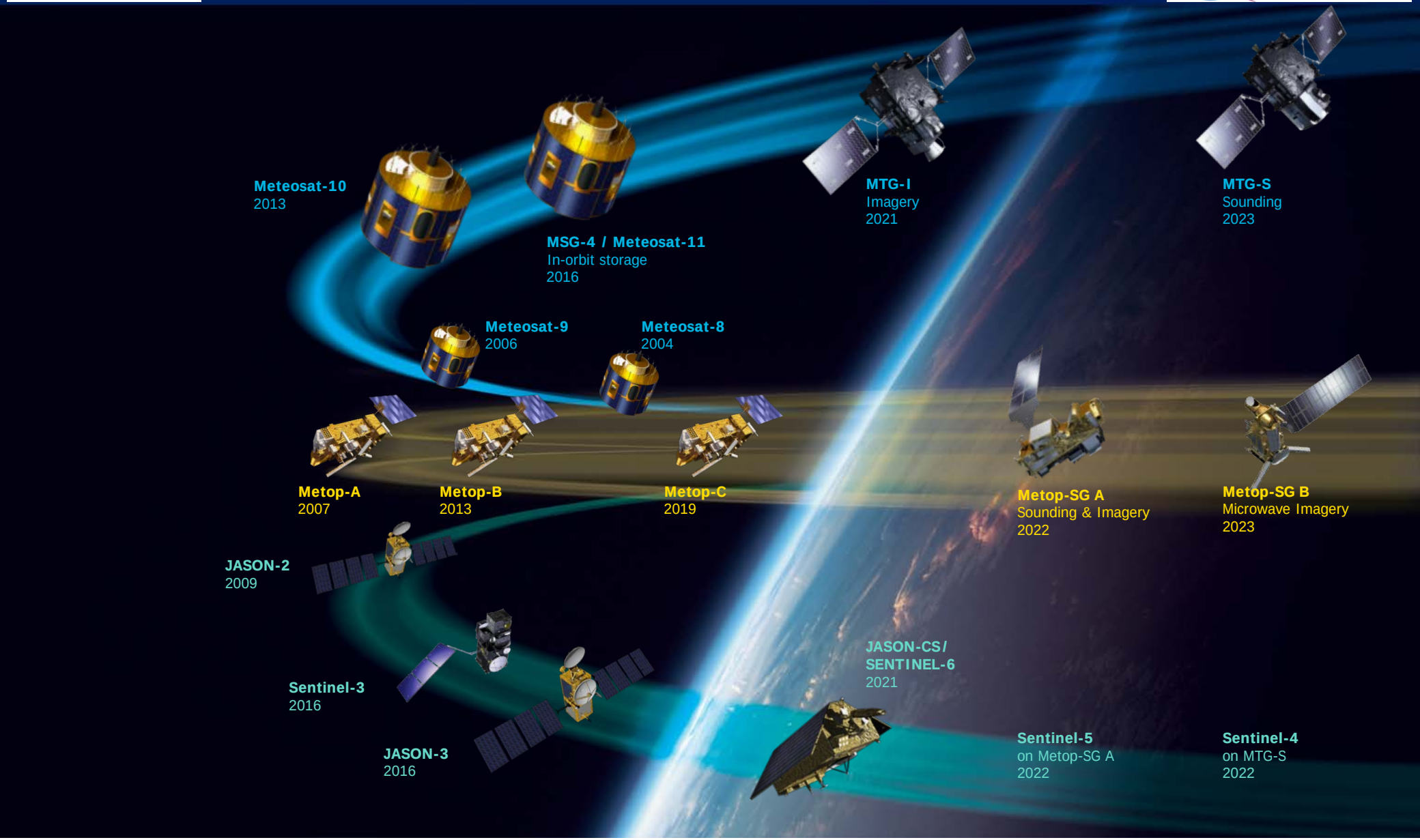
6 MTG satellites (3rd GENERATION)
(GEOSTATIONARY ORBIT)

4 IMAGING and 2 SOUNDING SATELLITE SYSTEM

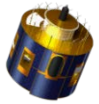
1 METEOSAT (2nd GENERATION)
(GEOSTATIONARY ORBIT)

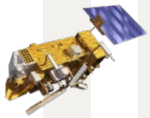
INDIAN OCEAN DATA COVERAGE MISSION
AT 41.5°E

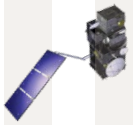
EUMETSAT satellites - next to fly



EUMETSAT systems timeline till 2040







YEAR... 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40

METEOSAT SECOND GENERATION (MSG)
METEOSAT-8
METEOSAT-9
METEOSAT-10
METEOSAT-11*
METEOSAT THIRD GENERATION (MTG)
MTG-I-1 : IMAGERY
MTG-S-1: SOUNDING
MTG-I-2: IMAGERY
MTG-I-3: IMAGERY
MTG-S-2: SOUNDING
MTG-I-4: IMAGERY

Mandatory Programmes

EUMETSAT POLAR SYSTEM (EPS)
METOP-A
METOP-B
METOP-C
EUMETSAT POLAR SYSTEM SECOND GENERATION (EPS-SG)
METOP-SG A: SOUNDING AND IMAGERY
METOP-SG B: MICROWAVE IMAGERY

JASON (HIGH PRECISION OCEAN ALTIMETRY)
JASON-2
JASON-3
SENTINEL 6 (JASON-CS)

Optional Programmes

COPERNICUS
SENTINEL-3 A/B/C/D
SENTINEL-4 ON MTG-S
SENTINEL-5 ON METOP-SG A

Third Party Programmes

YEAR... 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40

History of Meteosat satellites

History:

Meteosat first generation

- 3 channels
- Image every 30 min
- First image: 9 Dec. 1977

Today:

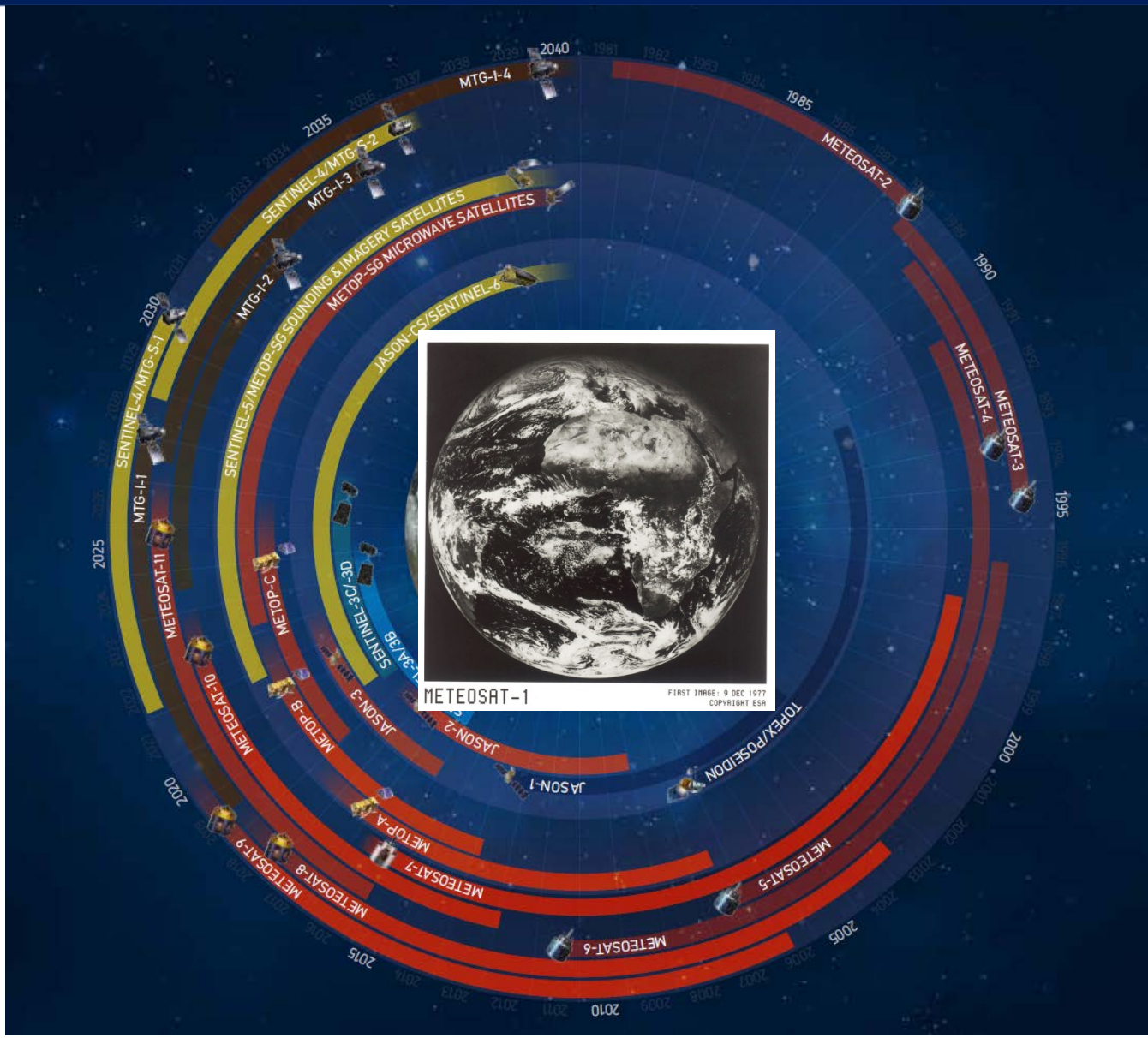
Meteosat Second Generation (MSG) in operation

- 12 channels
- Image every 15 min or 5 min in rapid scan mode

Future:

Meteosat Third Generation (MTG)

- 16 channels
- Image every 10 min or 2.5 min in rapid scan mode



Meteosat Second Generation (MSG) Satellites currently in orbit

- **Meteosat-8**
  - **Meteosat-8, launched on 28 August 2002, has been on station at 3.5°E since 11 February 2013. The satellite has been available for use as a hot backup for the Meteosat-10 prime service and to fill the monthly 48h interruptions of the Meteosat-9 RSS until mid-2016. In July 2016 Meteosat-8 was relocated to 41.5°E where it provides EUMETSAT's Indian Ocean Data Coverage service (IODC) since February 2017.**

- **Meteosat-9**
  - **Meteosat-9, launched on 21 December 2005, has been on station at 9.5°E since 5 February 2013 and supports the Rapid Scanning Service (RSS) since 9 April 2013.**

- **Meteosat-10 (prime operational satellite)**
  - **Meteosat-10, launched on 5 July 2012, following January 2013 relocations, has been the prime Meteosat satellite for the 0° service since 21 January 2013.**

- **Meteosat-11**
  - **Meteosat-11, launched on 15 July 2015, is currently in an in-orbit storage configuration at 3.4° West, with a tentative planned de-storage in early 2018.**

METEOSAT THIRD GENERATION (MTG)

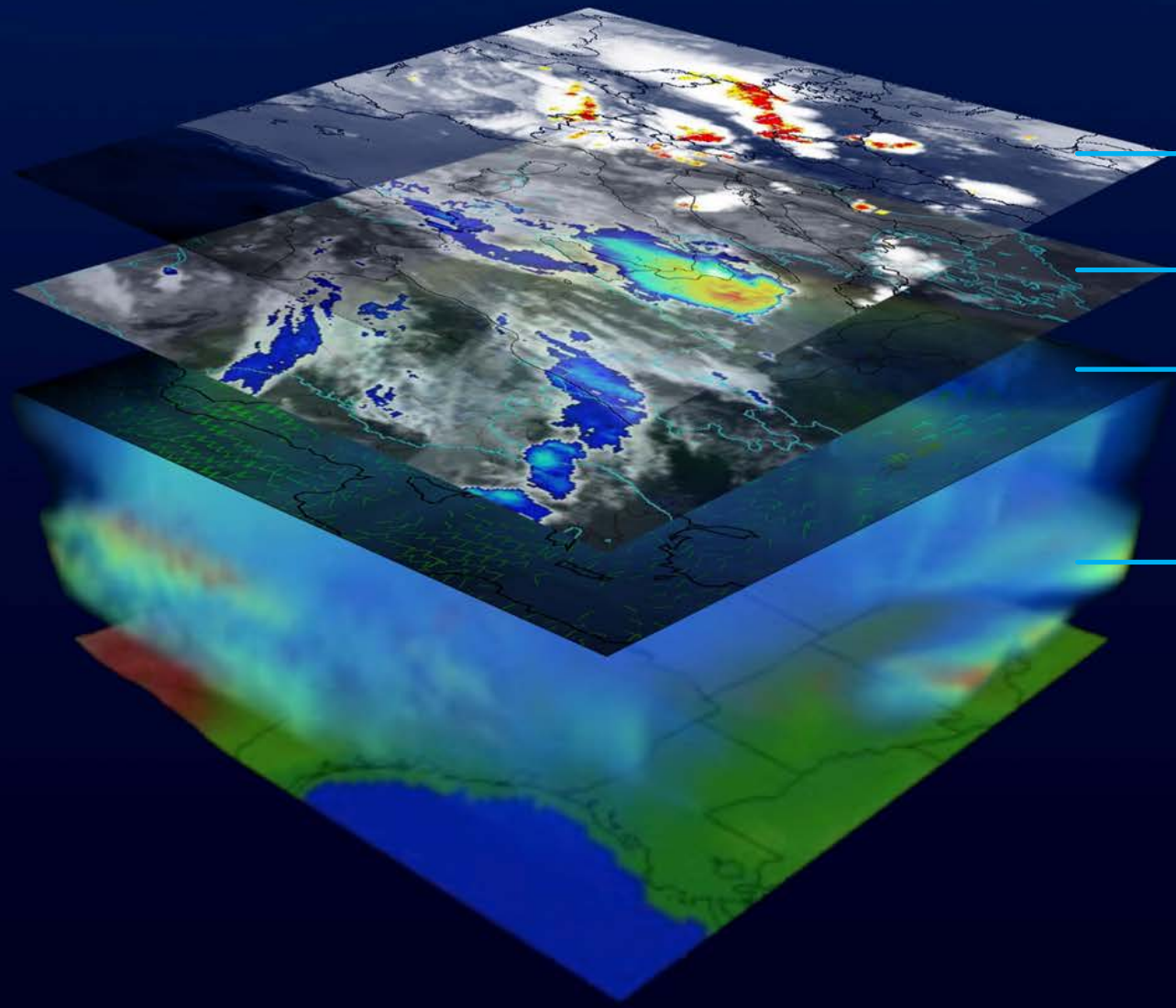
- *Primary mission:* Nowcasting of high impact weather
  - Continuity and enhancement of MSG imagery services
  - Addition of a new lightning imaging capability
  - Infrared hyper-spectral sounding mission: world premiere
- *Secondary mission*: Air quality monitoring over Europe
  - Synergy with Copernicus Sentinel-4, IRS and imagery
- 6-satellite programme to cover 2021-2042
- *Ground station network*:
  - 2 ground stations for the Main Data Acquisition (MDA) in the frequency band 26.2 - 27 GHz in Lario and Leuk

Need for protection of the MTG data reception in Lario and Leuk in the 26 GHz band from fixed and mobile (IMT-2020 (5G)) is essential !!!

METEOSAT THIRD GENERATION (MTG)

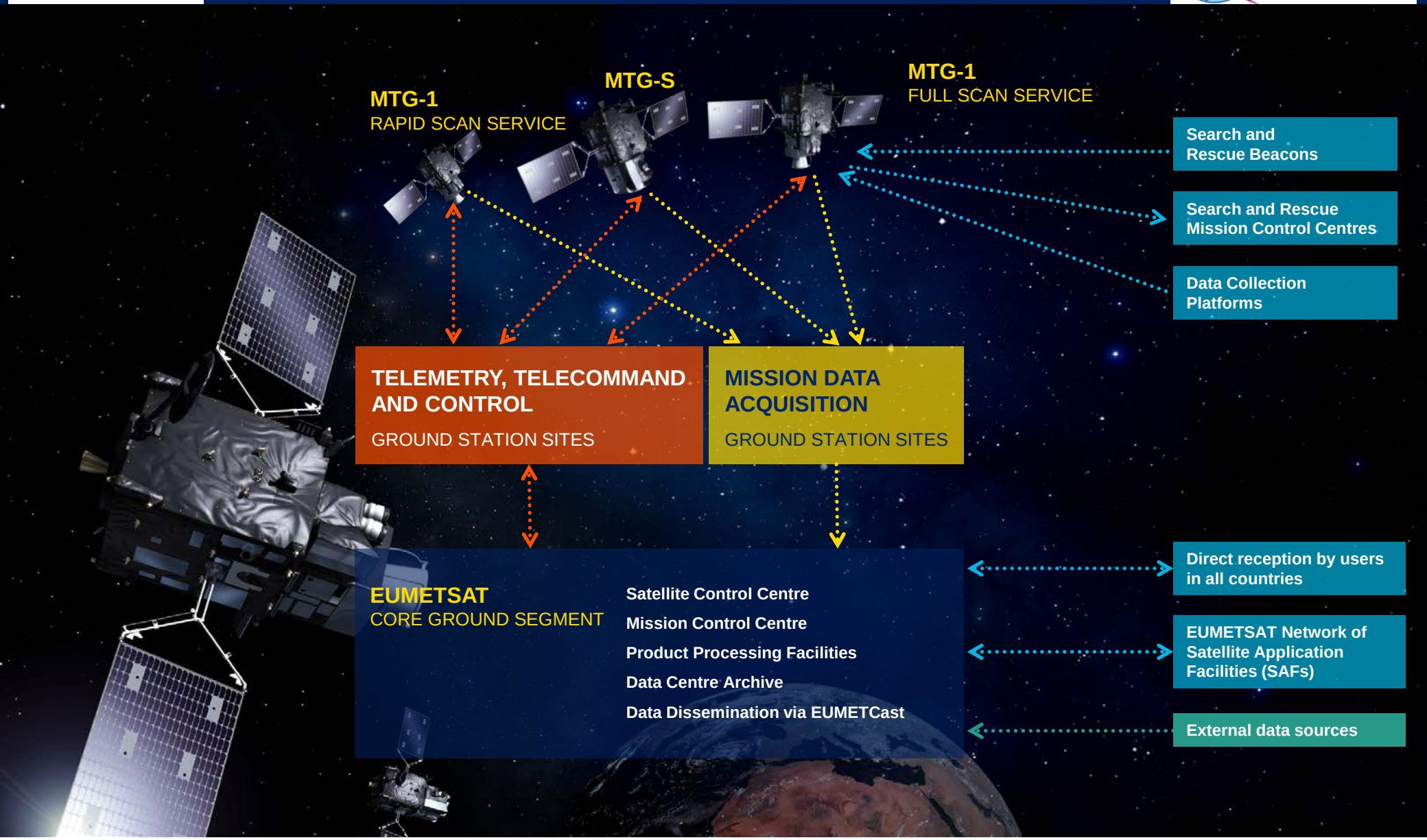
- *Imagery Mission implemented by a two-satellite MTG-I system:*
  - Full disk imagery every 10 minutes in 16 spectral bands
  - Fast imaging of European weather every 2.5 minutes
  - New Lightning Imager (LI)
- *Hyperspectral Infrared Sounding (IRS) Mission:*
  - Full disk 3D weather cube: temperature, water vapour, O3 (every 30 minutes over Europe)
  - Air quality monitoring and atmospheric chemistry in synergy with Sentinel-4
- Start of operations in 2021 and 2023
- Operational exploitation: 2021 - 2042+

MTG operational exploitation



- Lightning
- Convection
- Winds
- Atmosphere

MTG overall system configuration



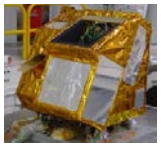
EUMETSAT Polar System - Metop satellites

Three Metop spacecrafts:

- **Metop-A – Launched on 19/10/2006**
- **Metop-B – Launched on 17/09/2012**
- **Metop-C – Launch foreseen for 10/2018**

- Flying at an altitude of 817 km, each Metop satellite carries the same dedicated, sophisticated suite of 10 instruments (with a total of >500 channels).
- They provide fine-scale global data, which can only be gathered in the low Earth orbit, such as:
  - vertical profiles of atmospheric temperature and moisture;
  - wind speed and direction at the ocean surface;
  - some atmospheric trace gases.
- The satellites deliver data for NWP – the basis of modern weather forecasting – and climate and environmental monitoring.

Instruments on Metop satellites (1)

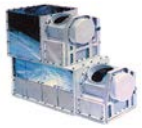




Instrument	IASI	GRAS	MHS	GOME	ASCAT
Stands for	**I**nfrared **A**tmospheric **S**ounding **I**nterferometer	**G**NSS **R**eceiver for **A**tmospheric **S**ounding	**M**icrowave **H**umidity **S**ounder	**G**lobal **O**zone **M**onitoring **E**xperiment	**A**dvanced **Scat**terometer
General Mission	Fourier Transform Spectrometer with an imaging system. It is based on a Michelson Interferometer and is designed to measure the infrared spectrum emitted by the Earth.	A GPS (Global Positioning Satellite) receiver that operates as an atmospheric-sounding instrument. GRAS provides a minimum of 500 atmospheric profiles per day by a process of GPS radio occultation.	The Microwave Humidity Sounder (MHS) is an instrument designed to collect information on various aspects of the Earth's atmosphere and surface, in particular, atmospheric humidity and surface radiation (temperature).	Spectrometer that collects light arriving from the Sun-illuminated Earth's atmosphere or a direct view to the Sun and decomposes it into its spectral components.	Primary function is to provide measurements of wind velocity over the world's oceans using radar.
Measurements	Temperature profiles in the troposphere and lower stratosphere, moisture profiles in the troposphere, as well as some of the chemical components playing a key role in the climate monitoring, global change and atmospheric chemistry.	Gras will provide atmospheric soundings of temperature and humidity of the Earth atmosphere. Also, GRAS will provide navigation solutions for the MetOp satellite position along its orbit.	Humidity at various altitudes in the atmosphere, including atmospheric ice, cloud cover and precipitation (rain, snow, hail and sleet). Temperature information at the Earth's surface can also be determined.	Atmospheric content and profile of ozone, nitrogen dioxide, water vapour, oxygen / oxygen dimmer, bromine oxide and other gases.	Wind measurements. Will also find roles in areas as diverse as land and sea ice monitoring, soil moisture, snow properties and soil thawing.

Instruments on Metop satellites (2)






Instrument	AVHRR	HIRS	AMSU-1&2	SEM-2	A-DCS	SARP-3	SARR
Stands for	**A**dvanced **V**ery **H**igh **R**esolution **R**adiometer	**H**igh Resolution **I**nfra **R**ed **S**ounder	**A**dvanced **M**icrowave **S**ounding **U**nit	**S**pacecraft **E**nvironment **M**onitor	**A**dvanced **D**ata **C**ollection **S**ystem	**S**earch **A**nd **R**escue **P**rocessor	**S**earch **A**nd **R**escue **R**epeater
General Mission	Six channel radiometric imaging, though only 5 channels used at a time. It provides day and night imaging of land, water and clouds.	20 channel radiometric sounder, measures radiance in the infrared (IR) spectrum within its field of view of the Earth. used in conjunction with data from the Advanced Microwave Sounding Unit (AMSU) instruments.	Used in conjunction with HIRS, measures radiance in the microwave spectrum within its field of view of the Earth.	Multi-channel, charged-particle spectrometer, which senses the flux of charged particles from the Sun-ionized plasma (at the satellite altitude) and contributes to the solar terrestrial energy knowledge.	Also known as ARGOS, the Advanced Data Collection System (A-DCS) collects data from platform transmitters (PTTs) located on continents and oceans in UHF frequency, and retransmits them.	Receives and processes emergency signals from the 406 MHz beacons of aircraft and ships in distress. It determines the name, frequency and time of the signal. These pre-processed data are then fed in real time to the Search And Rescue Repeater (SARR).	Receives and down-links emergency signals from aircraft and ships in distress. In addition, it provides a down-link for data received by the Search and Rescue Processor (SARP-3).
Measure-ments	Sea surface temperature, ice, snow and vegetation cover.	Atmosphere's vertical temperature profile and pressure from the Earth's surface to about 40 km altitude. The data is also used to determine ocean surface temperatures, total atmospheric ozone levels, precipitable water, cloud height and coverage, and surface radiance.	Same as HIRS.	Senses and quantifies the intensity in the selected energy bands. The particles of interest have energies ranging from 0.05 to 20 keV. The MEPED senses protons, electrons, and ions with energies from 30 keV to levels exceeding 6900 keV.	Meteorological measurements data (e.g. temperatures, wind direction and force) from remote buoys to the meteorological community.	406 MHz emergency beacons from distressed vessels.	The SARR receives distress beacon signals on three separate frequencies, translates them to L-band and retransmits them to Local User Terminals on the ground.

EPS Second Generation (EPS-SG)

- *Primary mission:* further improve observational inputs to Numerical Weather Prediction models
- Continuation and enhancement of service from mid-morning polar orbit
- Significant contributions to other real time applications:
  - Nowcasting at high latitudes
  - Marine meteorology
  - Operational oceanography
  - Operational hydrology
  - Air quality monitoring
- Climate monitoring: expand by 20+ years the climate data records initiated in 2006 with EPS

EPS Second Generation (EPS-SG)

- *Two series of 3 successive satellites in twin satellite in-orbit configuration:*
  - *Metop-SG A:* Optical imagery and sounding mission, incl. MWS
    - Hosts the Copernicus Sentinel-5 instrument
  - *Metop-SG B:* microwave imaging mission, incl. MWI and ICI
- Start of operations in 2022 and 2023
- Operational exploitation: 2022 - 2042+
- European contribution to the Joint Polar System (JPS) shared with the US/NOAA
  - *Ground station network*: 2 ground stations for the Stored Mission Data (SMD) acquisition in the frequency band 25.5 - 27 GHz in Svalbard and McMurdo.

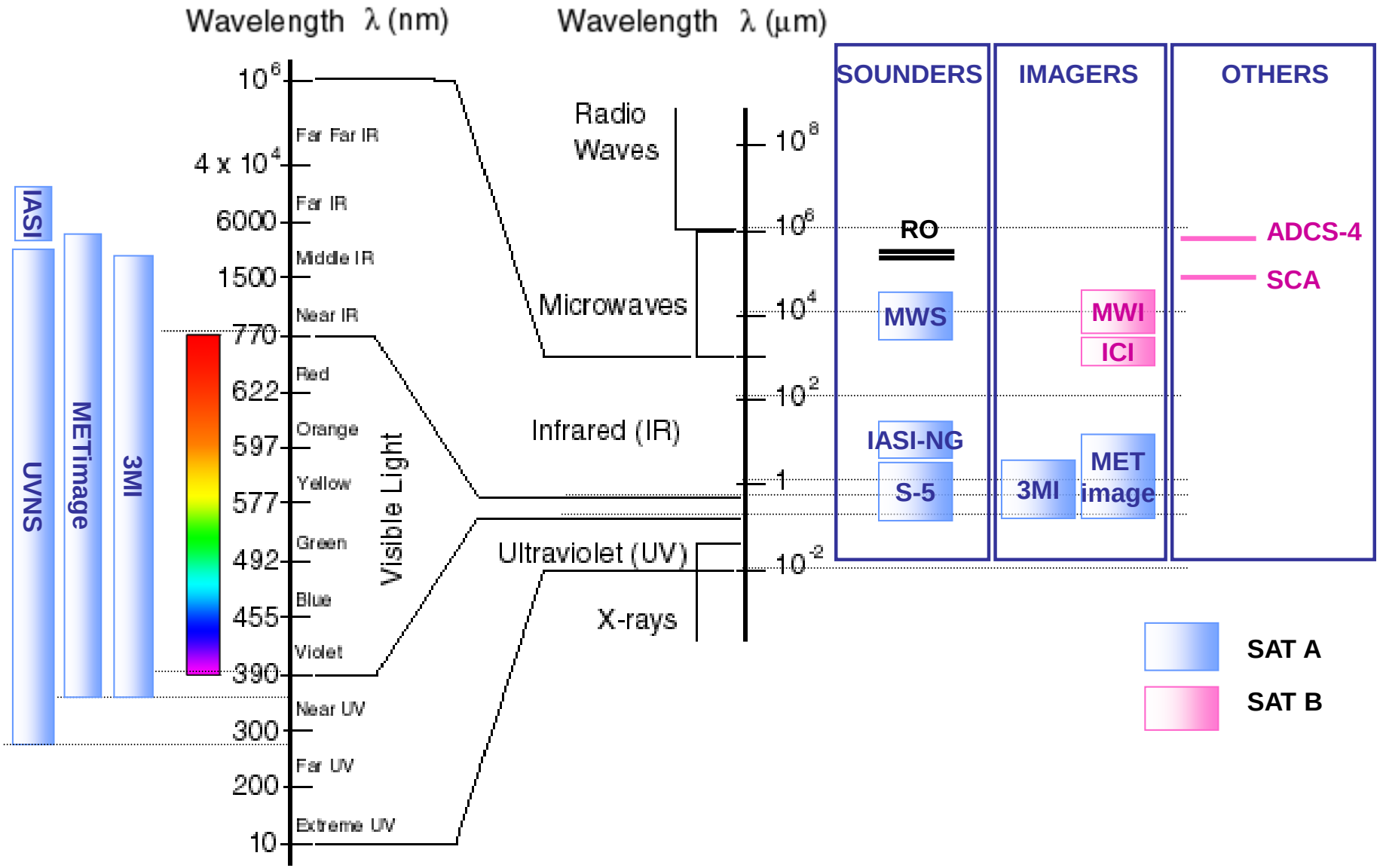
Need for protection of the passive microwave sensing channels from unwanted emissions of mobile networks (IMT-2020 (5G)) is essential !!!

EPS-SG Instruments and Heritage from Metop

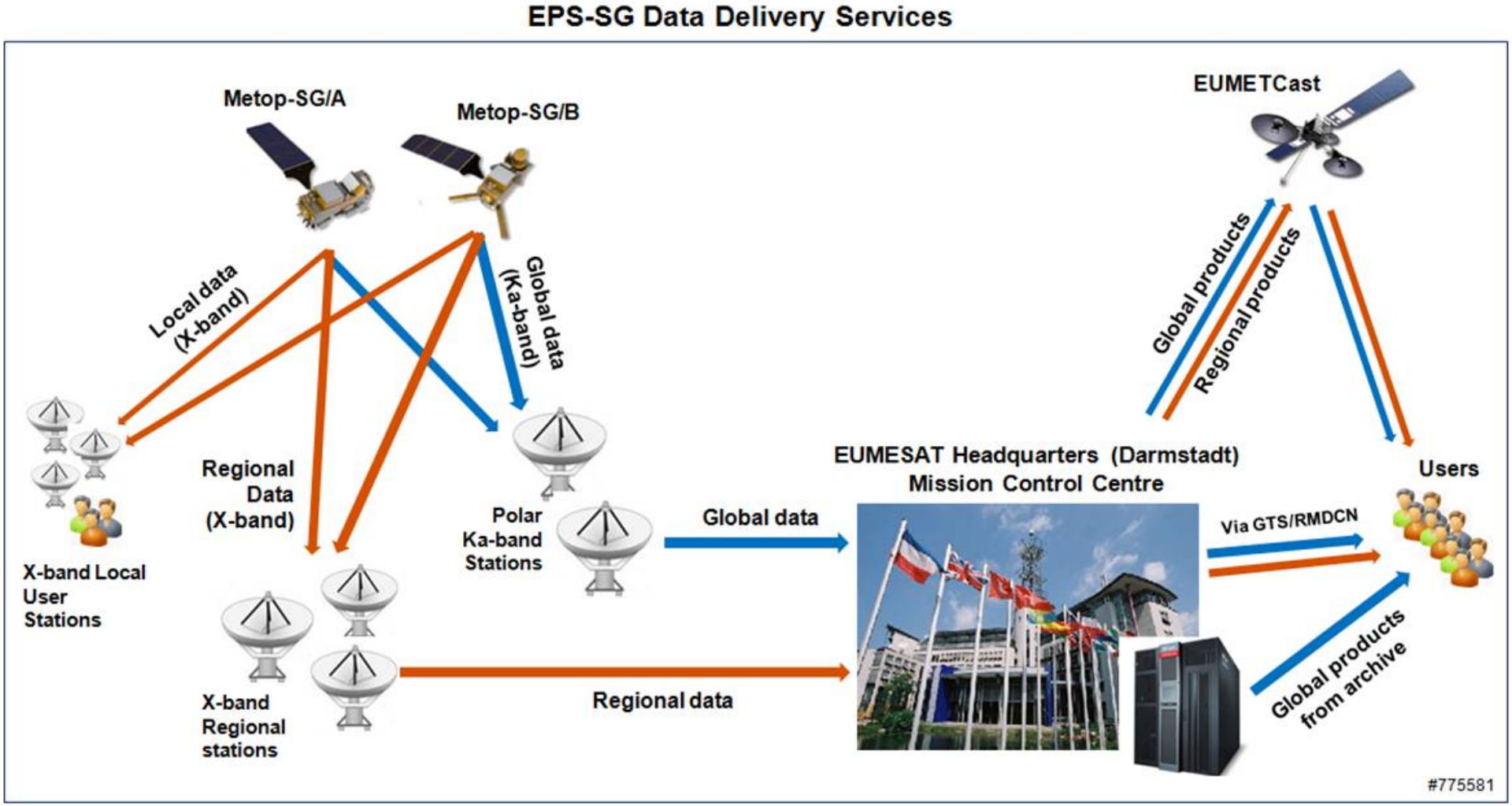
Metop-SG A Optical Imagery and Sounding	Instrument	Predecessor on Metop
Infrared Atmospheric Sounding (IAS)	IASI-NG	IASI
Microwave Sounding (MWS)	MWS	AMSU-A, MHS
Visible-infrared Imaging (VII)	METimage	AVHRR
Radio Occultation (RO)	RO	GRAS
UV/VIS/NIR/SWIR Sounding (UVNS)	Sentinel-5	GOME-2
Multi-viewing, -channel, -polarisation Imaging (3MI)	3MI	-/-

Metop-SG B Microwave Imaging	Instrument	Predecessor on Metop
Scatterometer (SCA)	SCA	ASCAT
Radio Occultation (RO)	RO	GRAS
Microwave Imaging for Precipitation (MWI)	MWI	-/-
Ice Cloud Imager (ICI)	ICI	-/-
Advanced Data Collection System (ADCS)	Argos-4	A-DCS

EPS-SG Instruments coverage in the electromagnetic Spectrum

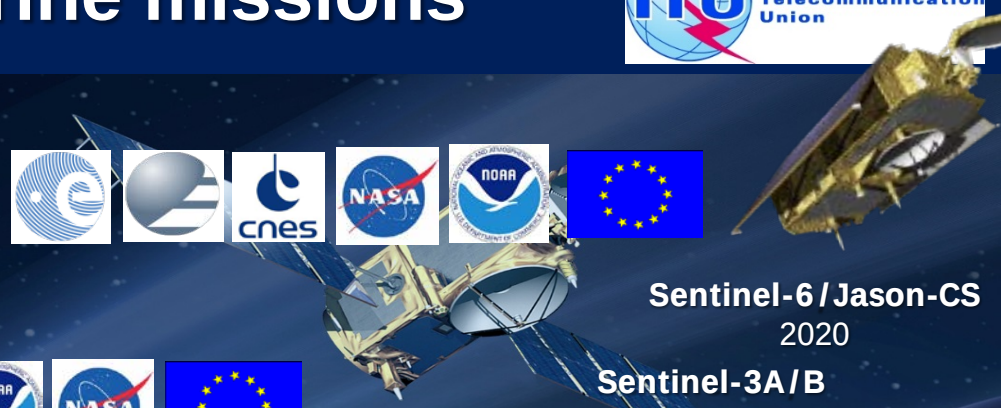


EPS-SG Global, Regional and Local Data Services



Cooperative marine missions

- **EUMETSAT operates other (marine) LEO missions in the context of Copernicus**
  - **Jason-3 in partnership CNES and NOAA/NASA**
  - **Sentinel-3A marine missions in partnership with ESA**
- **EUMETSAT supports development and prepares for operations of follow on missions (continuity)**
  - **Up to four Sentinel-3 satellites**
  - **Two Jason-CS/Sentinel-6 satellites**

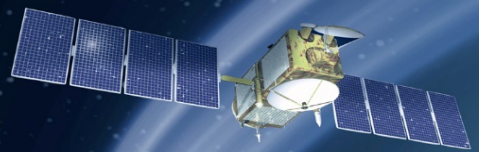


Sentinel-6 / Jason-CS
2020

Sentinel-3A / B
2016/2018

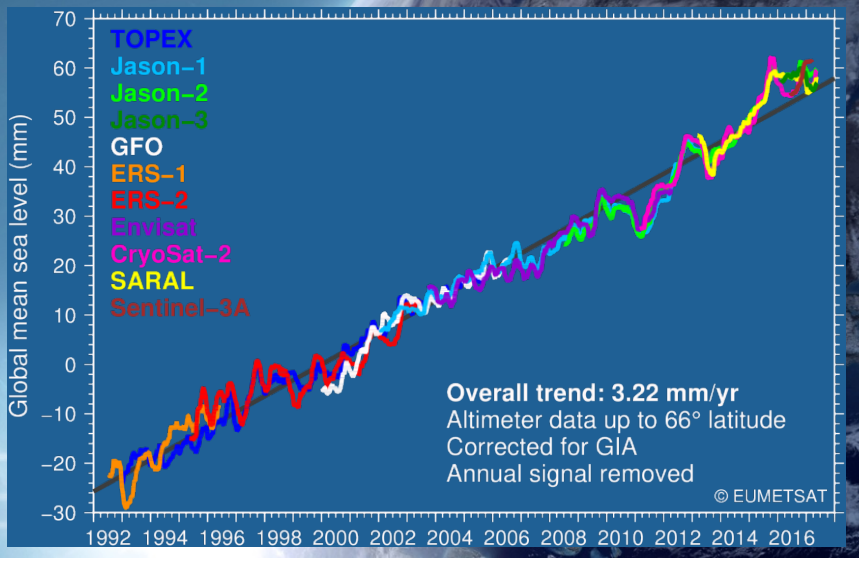
Jason 3
2015

OSTM/Jason 2
2008

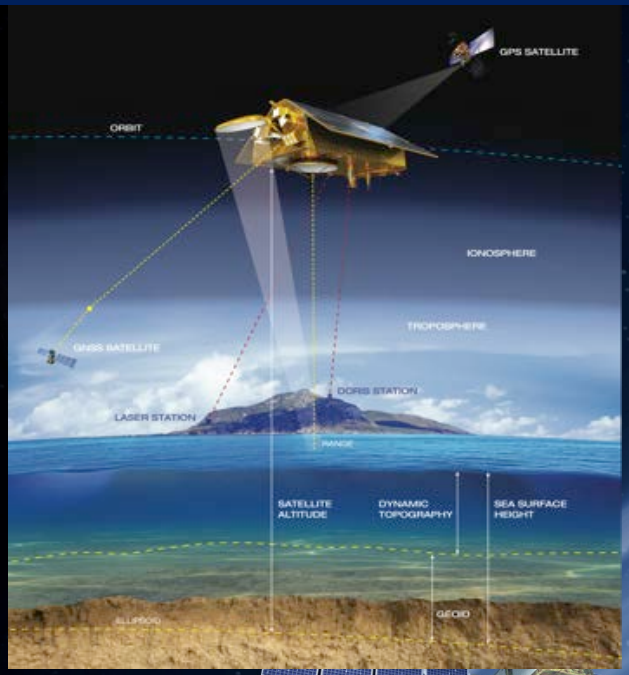


Jason 1
2001

TOPEX/Poseidon
1992–2006



Sentinel-6/Jason-CS Mission Overview



Mission Objective

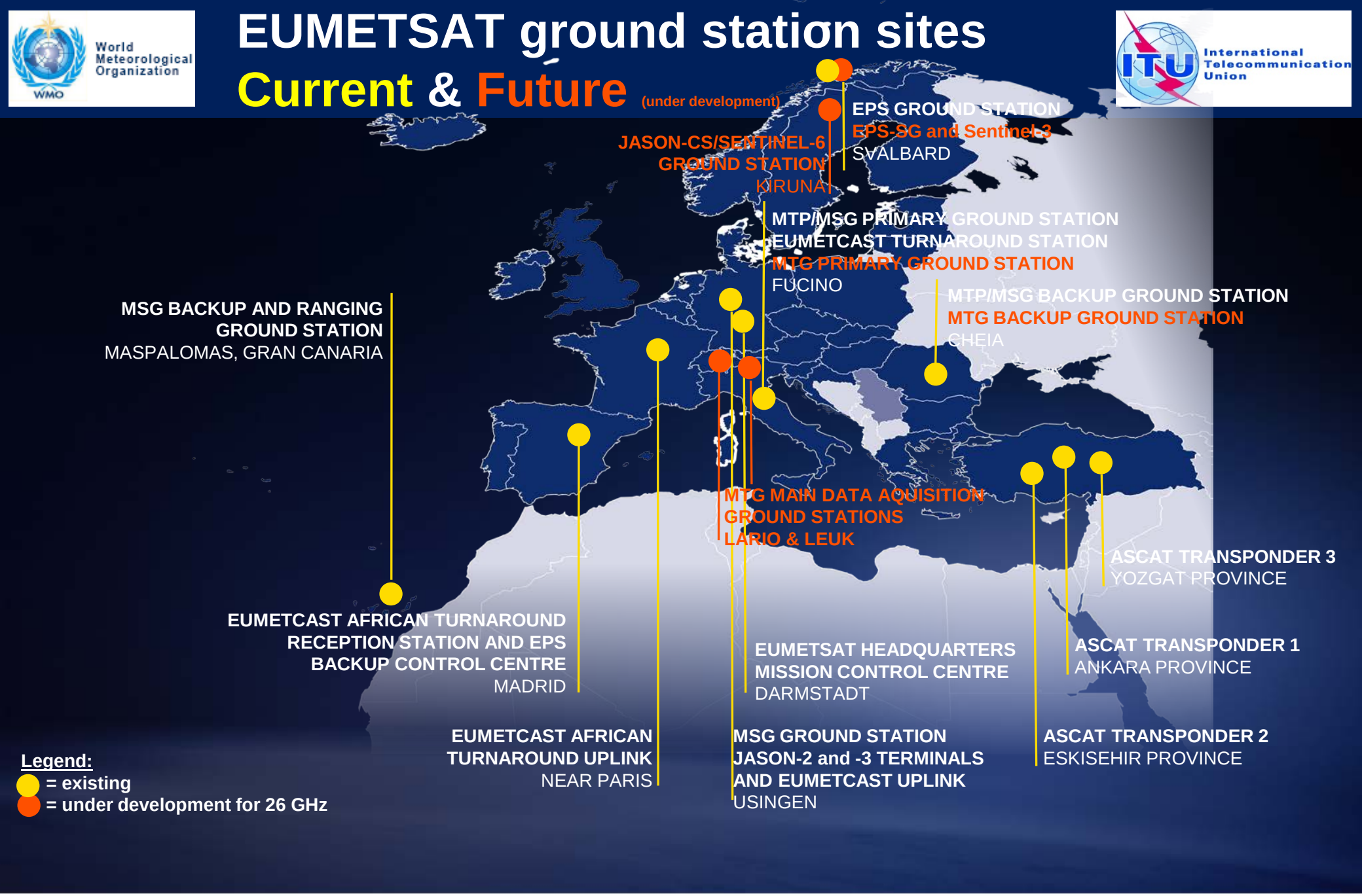
- Operational ocean altimetry to provide continuity of ocean topography measurements beyond Jason-3;
- Global sea surface height to an accuracy of $\leq$ 4 cm every 10 days, for determining ocean circulation, climate change and sea level rise;
- NASA, EUMETSAT, ESA and NOAA partnership with CNES providing technical support;
- Operational mission as part of a *two-satellite* European Copernicus/Sentinel program.
- Start of operations in 2021
- Operational exploitation: 2021 - 2035+

Instruments

- Ku/C-Band Radar Altimeter (Next gen Poseidon: Thales);
- DORIS (Precise Orbit Determination System);
- GNSS Receiver (POD System);
- Advanced Microwave Radiometer – Climate Quality (AMR-C);
- GNSS-Radio Occultation (GNSS-RO);
- Laser Retro-Reflector Array (LRA).

EUMETSAT ground station sites

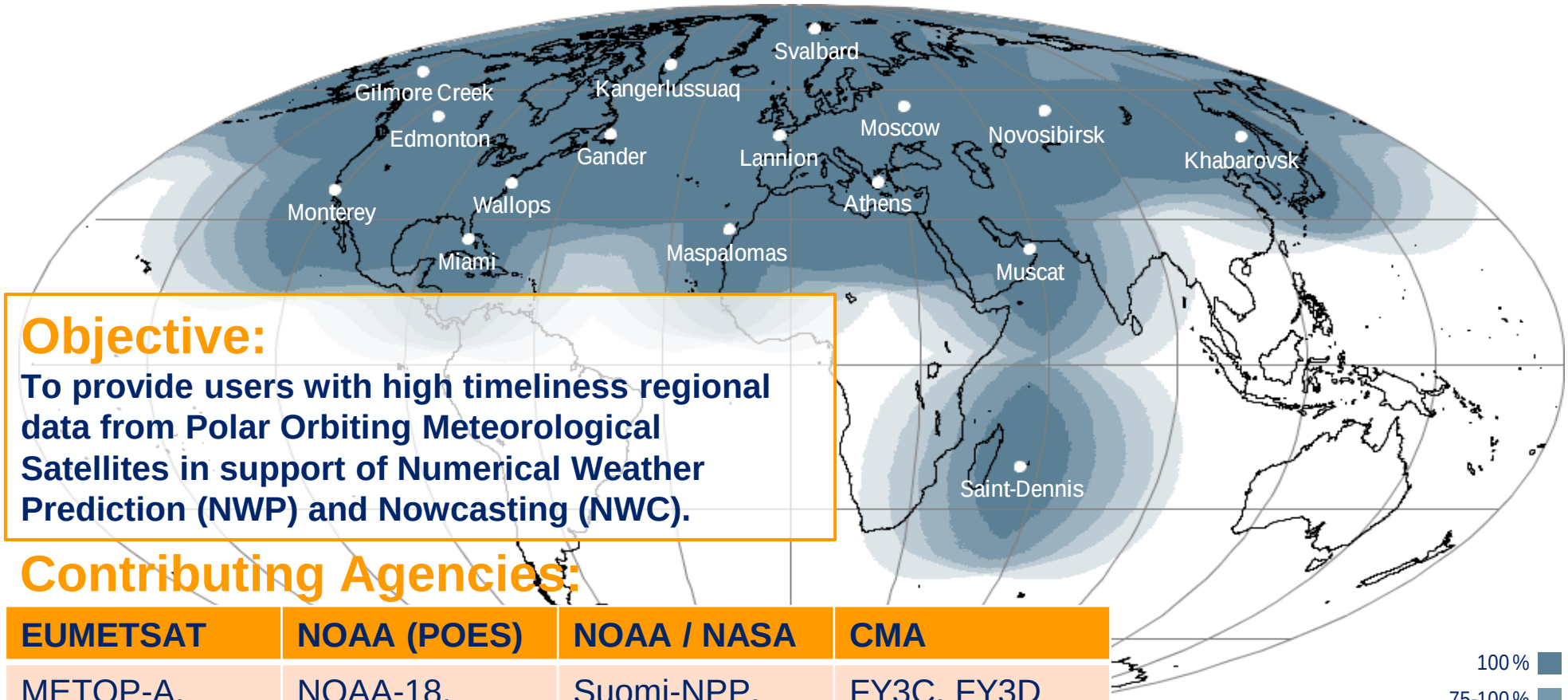
Current & Future (under development)



EUMETSAT Advanced Retransmission Service (EARS)

Global network EARS stations

(Currently in the process of upgrading into full L (1698-1710 MHz) & X-Band (7750-7900 MHz) reception capability.)



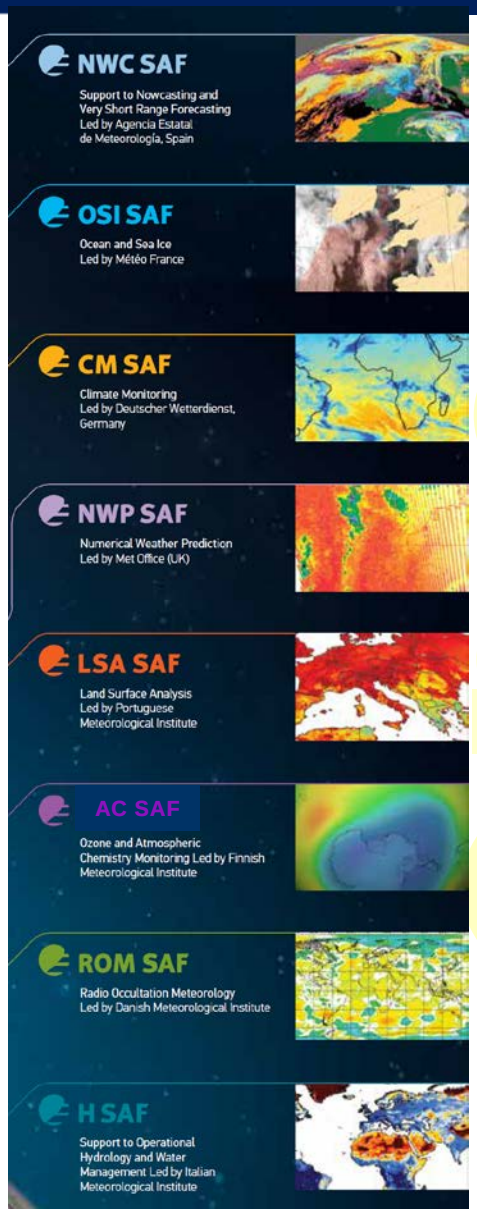
Objective:

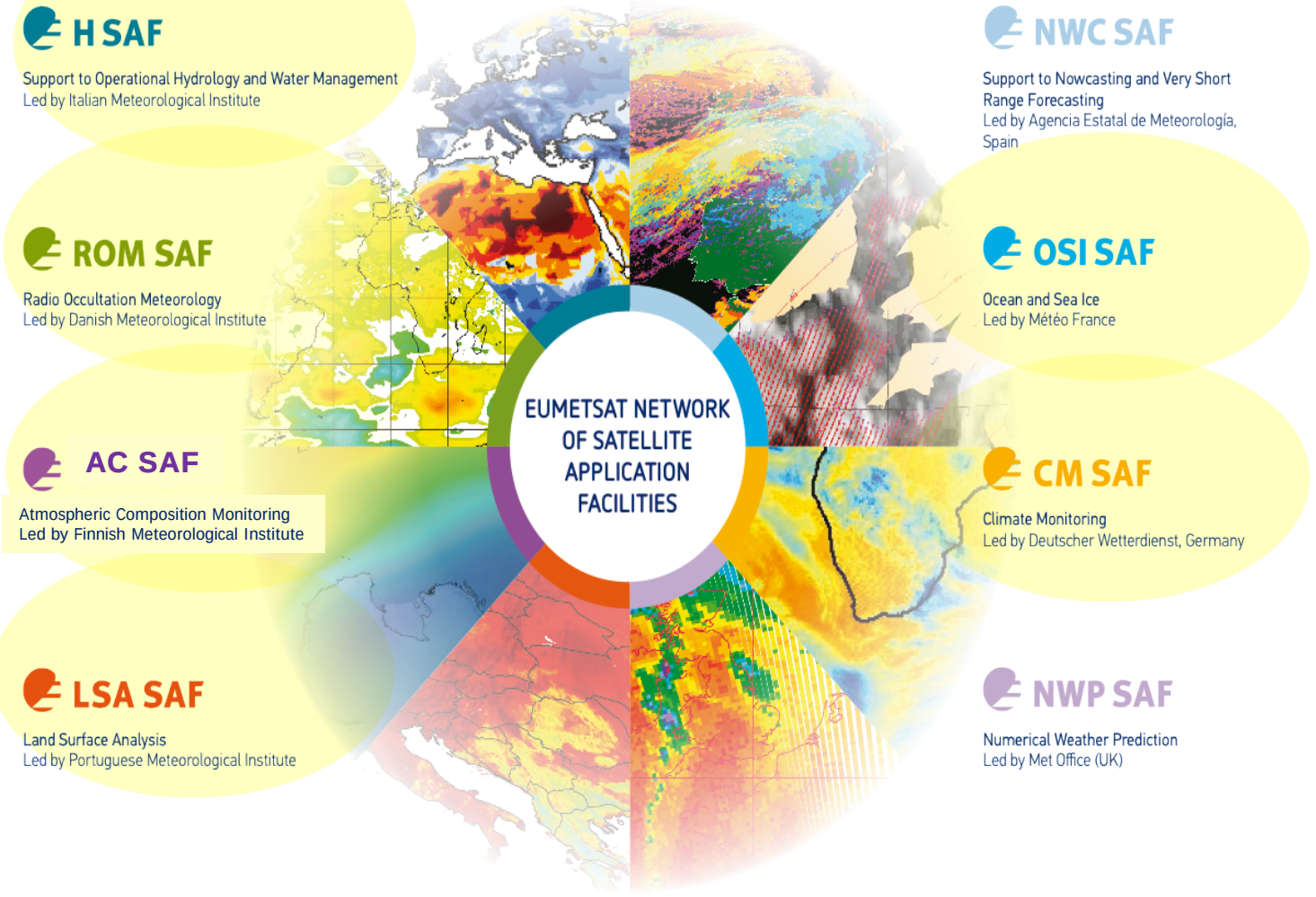
To provide users with high timeliness regional data from Polar Orbiting Meteorological Satellites in support of Numerical Weather Prediction (NWP) and Nowcasting (NWC).

Contributing Agencies:

EUMETSAT	NOAA (POES)	NOAA / NASA	CMA
METOP-A, METOP-B, METOP-C (2018)	NOAA-18, NOAA-19	Suomi-NPP, JPSS-1 (2017)	FY3C, FY3D (2017-2018)

EUMETSAT SAF Network in Europa

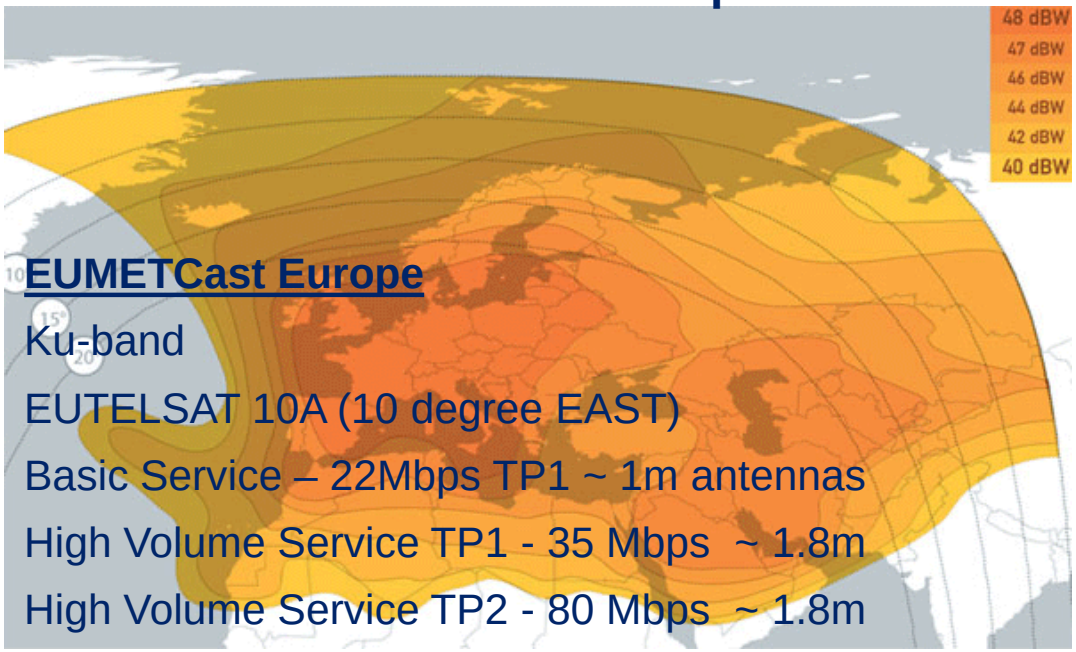




EUMETCast and its European & African Footprints

Key Features:

- **EUMETSAT's primary near real time dissemination system based on multicast using standard DVB technology and low cost, user-friendly commercial-off-the-shelf satellite receiving equipment;**
- **Dissemination via transponder on commercial geostationary satellites;**
- **One-stop-shop secure delivery mechanism allowing users to receive many data streams via one Reception Station.**



EUMETCast Europe

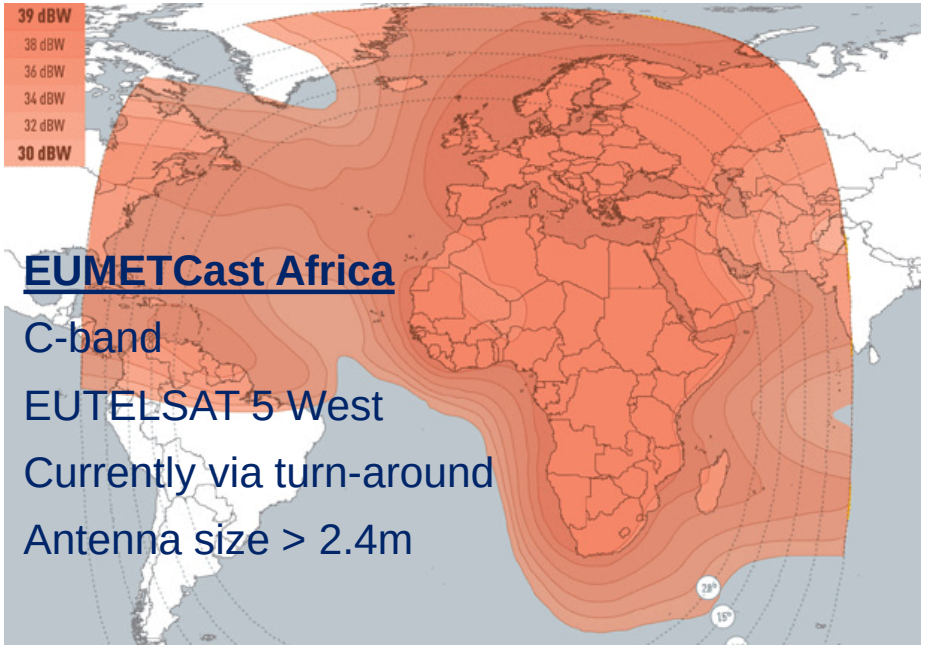
Ku-band

EUTELSAT 10A (10 degree EAST)

Basic Service – 22Mbps TP1 ~ 1m antennas

High Volume Service TP1 - 35 Mbps ~ 1.8m

High Volume Service TP2 - 80 Mbps ~ 1.8m



EUMETCast Africa

C-band

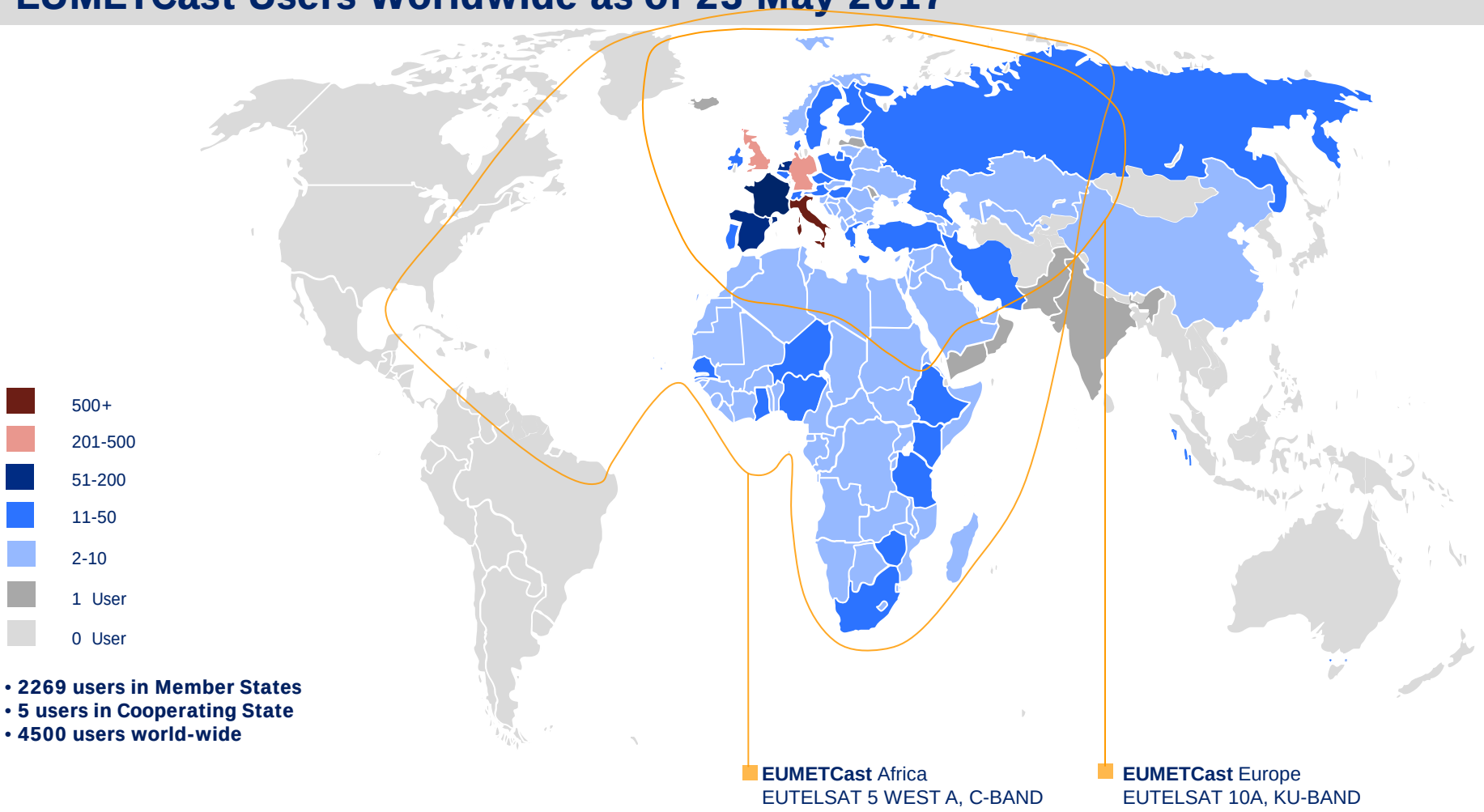
EUTELSAT 5 West

Currently via turn-around

Antenna size > 2.4m

EUMETCast Global User Community

EUMETCast Users Worldwide as of 23 May 2017



Frequency bands used by EUMETSAT satellite systems

Communications	Passive Sensing		Active Sensing	Other Instruments
401 – 403 MHz	18.6 – 18.8 GHz	RR 5.340	5150 – 5250 MHz	1164 – 1215 MHz
406 – 406.1 MHz	23.6 – 24 GHz	RR 5.340	5250 – 5350 MHz	1215 – 1240 MHz
460 – 470 MHz	31.3 – 31.5 GHz	RR 5.340	5350 – 5460 MHz	1559 – 1610 MHz
1544 – 1545 MHz	50.2 – 50.4 GHz	RR 5.340	5360 – 5470 MHz	
1675 – 1710 MHz	52.6 – 54.25 GHz	RR 5.340	5470 – 5570 MHz	
2025 – 2110 MHz	54.25 – 59.3 GHz	shared	13.4 – 13.75 GHz	
2200 – 2290 MHz	86 - 92 GHz	RR 5.340		
3700 – 4200 MHz	114.25 – 116 GHz	RR 5.340		
7750 – 7900 MHz	116 – 122.25 GHz	shared		
8025 – 8400 MHz	155.5 – 158.5 GHz	shared		
10.7 – 12.5 GHz	164 – 167 GHz	RR 5.340		
25.5 – 27 GHz	174.8 – 182 GHz	shared		
	182 – 190 GHz	RR 5.340		
	190 – 191.8 GHz	shared		
	190 – 191.8 GHz	RR 5.340		
	226 – 231.5 GHz	RR 5.340		
	238 – 248 GHz	RR 4.4		
	313 – 356 GHz	RR 5.565		
	439 – 467 GHz	RR 5.565		
	657 – 692 GHz	RR 5.565		

WRC-19 agenda items of relevance to EUMETSAT (with EUMETSAT interests in red and passive sensor protection issues in yellow)

1.2 Introduction of power limits in the frequency band 401-403 MHz (Protection of Data Collection Systems (DCS) from small satellites);

1.3 Upgrade of the secondary allocation to the MetSat and EESS service (space-to-Earth) to primary status in the frequency band 460-470 MHz (Improve the status of the ARGOS use in this band);

1.6 Development of a regulatory framework for non-GSO FSS satellite systems that may operate in the frequency bands 37.5-39.5 GHz (space-to-Earth), 39.5-42.5 GHz (space-to-Earth), 47.2-50.2 GHz (Earth-to-space) and 50.4-51.4 GHz (Earth-to-space) (Protection of the passive sensing bands adjacent to the considered bands);

1.7 Identification of spectrum needs for telemetry, tracking and command in the space operation service for non-GSO satellites with short duration missions, including potential new allocations in specific bands below 1 GHz (Protection of the band 400.15 - 403 MHz used for DCS systems (DCP and ARGOS));

1.13 Identification of frequency bands for the future development of International Mobile Telecommunications (IMT), including possible additional allocations to the mobile service on a primary basis (Appropriate provisions in the authorization for 5G are needed in the band 25.5 - 27 GHz to ensure protection of existing and future Earth stations. Protection of several passive sensing bands adjacent to the bands studied under this agenda item);

1.14 Identification of bands for HAPS (Protection of the passive sensing bands adjacent to the considered bands);

1.15 Identification of frequency bands for use by administrations for the land-mobile and fixed services applications operating in the frequency range 275-450 GHz (Protection of the frequencies to be used by the currently developed Ice Cloud Imager (ICI) instrument which will be embarked on the second generation Metop satellites);

1.16 Consideration of issues related to wireless access systems, including radio local area networks (WAS/RLAN), in the frequency bands between 5150-5925 MHz, and take the appropriate regulatory actions, including additional spectrum allocations to the mobile service (Protection of the ASCAT and SCA scatterometers on Metop and Metop-SG satellites as well as protection of altimeters on Jason-2 and -3 & Sentinel-3 and -6);

9.1.9 Possible allocation of the frequency band 51.4-52.4 GHz to the fixed-satellite service (Earth-to-space) (Protection of the passive sensing bands adjacent to the considered bands);

10 Draft Agenda for WRC-23

Summary of frequency bands targeted by WRC-19 (highlighted in yellow)

Frequency bands used or planned to be used by EUMETSAT systems

Communications	Passive Sensing		Active Sensing	Other Instruments
401 – 403 MHz	18.6 – 18.8 GHz	RR 5.340	5150 – 5250 MHz	1164 – 1215 MHz
406 – 406.1 MHz	23.6 – 24 GHz	RR 5.340	5250 – 5350 MHz	1215 – 1240 MHz
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1675 – 1710 MHz	52.6 – 54.25 GHz	RR 5.340	5470 – 5570 MHz	
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7750 – 7900 MHz	116 – 122.25 GHz	shared		
8025 – 8400 MHz	155.5 – 158.5 GHz	shared		
10.7 – 12.5 GHz	164 – 167 GHz	RR 5.340		
25.5 – 27 GHz	174.8 – 182 GHz	shared		
	182 – 190 GHz	RR 5.340		
	190 – 191.8 GHz	shared		
	190 – 191.8 GHz	RR 5.340		
	226 – 231.5 GHz	RR 5.340		
	238 – 248 GHz	RR 4.4		
	313 – 356 GHz	RR 5.565		
	439 – 467 GHz	RR 5.565		
	657 – 692 GHz	RR 5.565		

Thank you for your attention!

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