

# Future ESA Missions for SST: Providing Enhanced Continuity for Copernicus

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# Copernicus Context

## CURRENT GENERATION SENTINELS

**Sentinel-1 A + B**  
C-Band Radar

**Sentinel-1 C + D**  
C-Band Radar

**Sentinel-2 A + B**  
High Res Optical

**Sentinel-2 C + D**  
High Res Optical

**Sentinel-3 A + B**  
MR Optical + Altimeter

**Sentinel-3 C + D**  
MR Optical + Altimeter

**Sentinel-4 A**  
Atm. Chemistry (GEO)

**Sentinel-4 B**  
Atm. Chemistry (GEO)

**Sentinel-5P**  
Atm. Chemistry (LEO)

**Sentinel-5**  
Atm. Chemistry (LEO)

**Sentinel-6 A**  
Altimeter

**Sentinel-6 B**  
Altimeter

## NEXT GENERATION SENTINELS

**Sentinel-1 NG**  
C-Band Radar

**Sentinel-2 NG**  
High Res Optical

**Sentinel-3 NG Topogr.**  
Altimeter

**Sentinel-3 NG Optical**  
MR Optical

## COPERNICUS EXPANSION

### ROSE-L

L-Band Radar for Arctic and Cryosphere Monitoring, Land and Emergency Mapping, Ground Motion, Soil Moisture

### CO2M

Carbon Dioxide Monitoring

### CRISTAL

Polar Ice & Snow Topogr Altim.

### CHIME

Hyperspectral Imaging

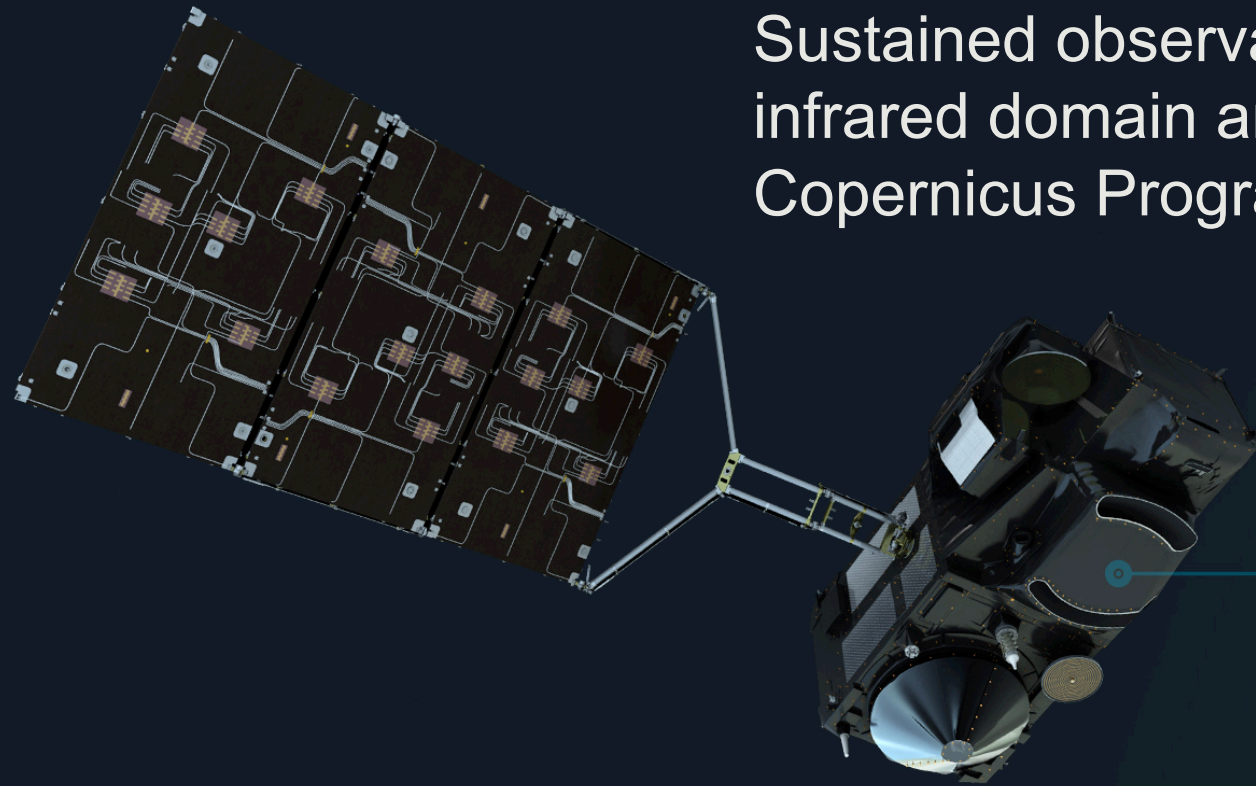
### LSTM

Land Surface Temperature

### CIMR

Imaging Microwave Radiometer





Sustained observations in the visible and infrared domain are one of the pillars of the Copernicus Programme.



**SLSTR**  
Sea and Land Surface  
Temperature Radiometer

Vast amount of data from SLSTR provide crucial input to a number of Services including the Copernicus Marine Environment Monitoring Service (CMEMS) and Land Monitoring Service (CLMS)

Figure: EUMETSAT









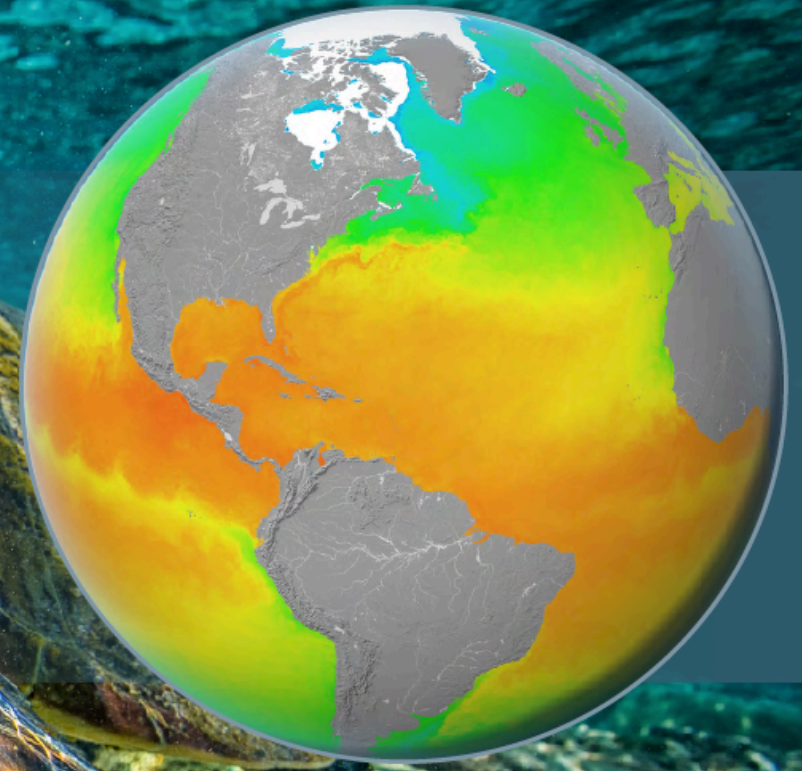
# SEA-SURFACE TEMPERATURE

Sea-surface temperature measurements improve weather prediction and the study of marine ecosystems but also provide fundamental information on the global climate, helping to understand how the oceans exchange heat and gases with the atmosphere.

Heat and moisture released from the sea are the dominant drivers of atmospheric circulation and weather patterns. Sea-surface temperature influences the rate of this energy transfer to the atmosphere, as evaporation increases in line with temperature. Long-term, accurate measurements that are stable over time are fundamental for climate-change research.

**Copernicus Sentinel-3** maintains and extends the high-quality sea-surface temperature measurements required for climate change research.

The average temperature of the sea surface across ice-free oceans has increased by 0.6°C in the 40-year record of satellite observations. Marine heatwaves are increasingly common, with negative consequences such as mass coral bleaching events.



Sea-Surface Temperature - ESA CCI  
-5 0 5 10 15 20 25 30 35 °C









# ASLSTR Key requirements

The ASLSTR should provide sampling along- and across-track at the sub satellite point of **500m at least**

Table 2 ASLSTR spectral channels and characteristics.

ASLSTR									
Band	Resolution	Center Wavelength	Bandwidth	$L_{min}/T_{min}$	$L_{ref}/T_{ref}$		$L_{max}/T_{max}$	SNR/NEDT <sup>(1)</sup>	
					Low	High		@ $L_{ref}$ Low	@ $L_{ref}$ High
	@ SSP [m]	$\lambda$ [ $\mu m$ ]	$\Delta\lambda$ [nm]	$mWm^{-2}sr^{-1}nm^{-1}/K^{(2)}$				@Ref SSD	
1a (G)	500	0.440	20	TBD	TBD	TBD	TBD	20	n/a
1 (T)	500	0.555	20	2.92	2.92	n/a	585.0	20	n/a
2 (T)	500	0.659	20	2.43	2.43	n/a	475.0	20	n/a
3 (T)	500	0.865	20	1.53	1.53	n/a	295.0	20	n/a
4 (T)	500	1.375	20	0.58	0.58	6.0	113.1	20	75
5 (T)	500	1.610	60	0.39	0.39	3.8	74.0	20	250
6 (T)	500	2.250	50	0.13	0.13	1.0	24.3	20	110
7 (T)	500	3.740	380	200K	270K	n/a	323K	0.08 (T)/(50mK (G))	n/a
7a (G)	500	3.900	200	200K	270K	n/a	321K	50mK	n/a
7b (G)	500	4.090	200	200K	270K	n/a	321K	50mK	n/a
7c (G)	500	8.700	1000	200K	270K	n/a	323	30mk	n/a
8 (T)	500	10.850	900	200K	270K	n/a	321K	0.05 (T)/(30mK (G))	n/a
9 (T)	500	12.000	1000	200K	270K	n/a	318K	0.05 (T)/(30mK (G))	n/a

<sup>(1)</sup> SNR for solar channels, NEDT (K) for IR channels

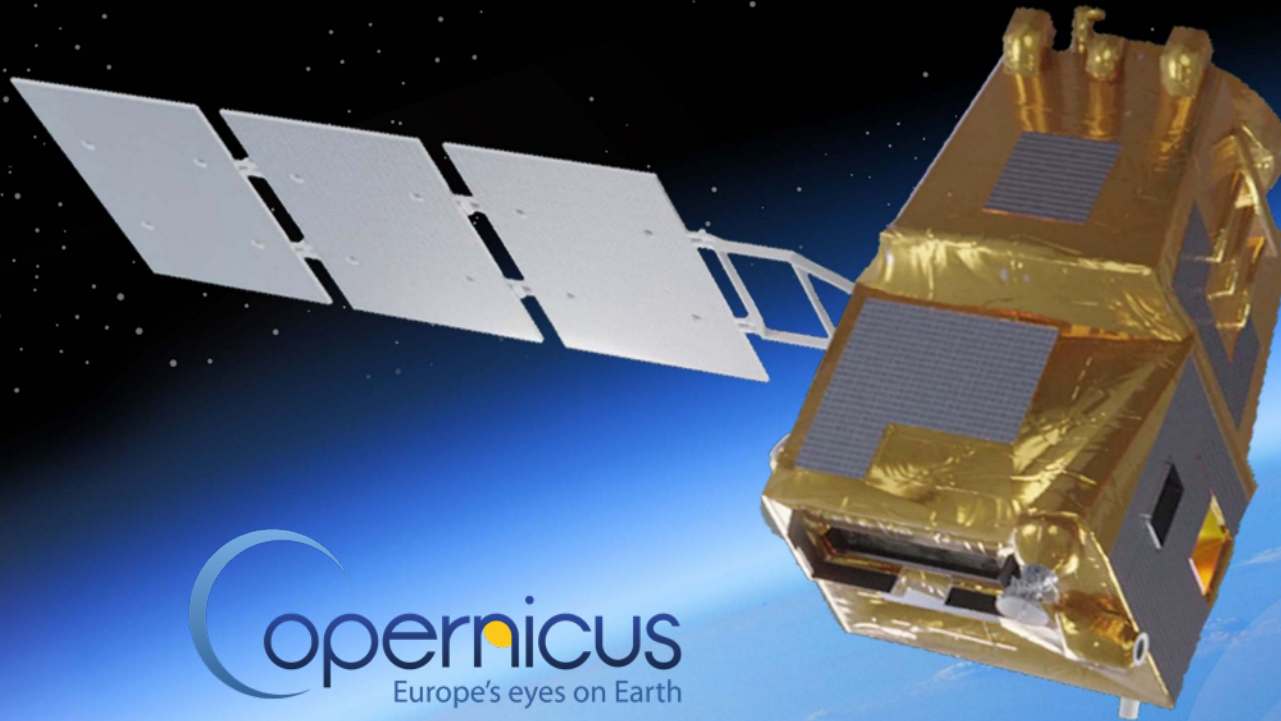
<sup>(2)</sup> TOA radiance for solar channels, brightness temperature for thermal channels





## LSTM Mission Objective:

Provide high spatio-temporal resolution Thermal Infra-Red observations over land and coastal regions *in support of agriculture management services*, and a range of additional applications *including coastal zone management*





# LSTM Key Features



## Key requirement\*

Geometrical revisit	2 days/2 satellites
Local time	13:00 (Europe) & night observations
SSD	50 m (37m at nadir)
Spectral Bands	5 TIR, 4 VNIR, 2 SWIR
Nominal swath	687 km, at 651 km altitude
Acquisition system	Whiskbroom scanner
Geo-location L1c	0.5 SSD (GCP) / 1 SSD (without GCP)
MTF	0.2-0.3
Data latency (L2)	6-12 hours
NeDT	< 0.15 K
ARA	< 0.5 K

## User requirement\*\*

### Evapotranspiration (goal)

- Accuracy 15% [mm/day]
- Precision 5%
- Field scale [0.5 ha]
- Daily observations

### LST observations\*\*

- 50 meters resolution
- 1-3 days revisit
- 1-1.5 K LST accuracy

\* Copernicus LSTM Phase B2/C/D/E1 System Requirements Document

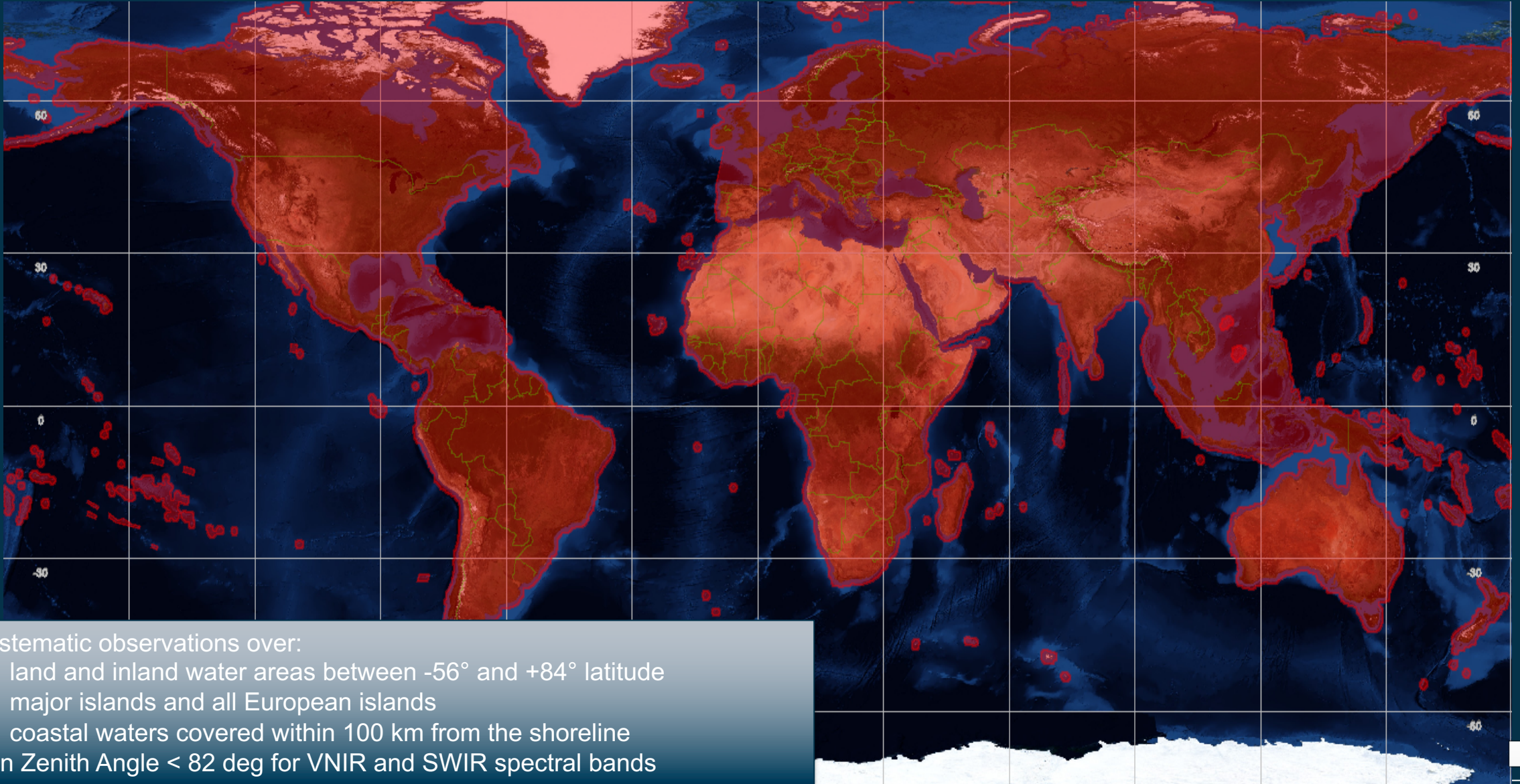
\*\*Mission Requirement Document V3

[https://www.esa.int/Applications/Observing\\_the\\_Earth/Copernicus/Copernicus\\_Sentinel\\_Expansion\\_mission](https://www.esa.int/Applications/Observing_the_Earth/Copernicus/Copernicus_Sentinel_Expansion_mission)





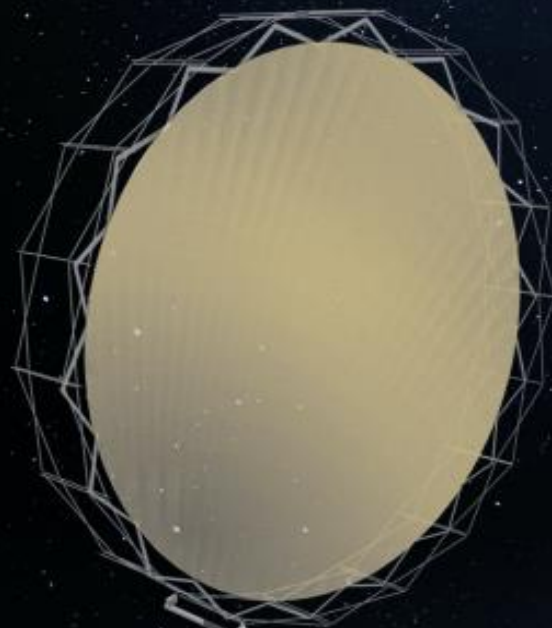
# LSTM Acquisition and Coverage



## Systematic observations over:

- land and inland water areas between  $-56^{\circ}$  and  $+84^{\circ}$  latitude
  - major islands and all European islands
  - coastal waters covered within 100 km from the shoreline
- Sun Zenith Angle  $< 82$  deg for VNIR and SWIR spectral bands





# CIMR

COPERNICUS IMAGING  
MICROWAVE RADIOMETER

Multichannel:

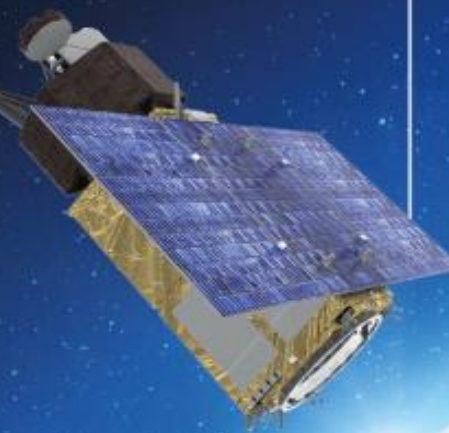
1.4 GHz (L)

6.9 GHz (C)

10.6 GHz (X)

18.7 GHz (K)

36.5 GHz (Ka)





# CIMR Mission Aim and Objectives

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## 3 CIMR MISSION AIM AND OBJECTIVES

### 3.1 CIMR Mission Aim

Considering the User needs expressed in [AD-1], [AD-2], [AD-3] and [AD-4] and concisely articulated in the previous sections, the **aim** of a Copernicus Imaging Microwave Radiometry (CIMR) Mission is to:

***Provide high-spatial resolution microwave imaging radiometry measurements and derived products with global coverage and sub-daily revisit in the polar regions and adjacent seas to address Copernicus user needs.***

### 3.2 CIMR Mission Objectives

**PRI-OBJ-1.** Measure **Sea Ice Concentration (SIC)** and **Sea Ice Extent (SIE)** in non-precipitating atmospheres at a spatial resolution of  $\leq 5^4$  km (goal 4 km), with a total standard uncertainty of  $\leq 5\%^{5,7}$ , and **sub-daily coverage** of the Polar Regions<sup>6</sup> and daily coverage of Adjacent Seas<sup>7</sup> [AD-1], [AD-2], [AD-3] and [AD-4].

**PRI-OBJ-2.** Measure **Sea Surface Temperature (SST)** in non-precipitating atmospheres at an effective spatial resolution of  $\leq 15$  km, with a total standard uncertainty of  $\leq 0.3^8$  K with a focus on **sub-daily coverage** of Polar Regions and daily coverage of Adjacent Seas [AD-1], [AD-2], [AD-3] and [AD-4].

**PRI-OBJ-3.** Ensure European operational continuity of **L-band** (e.g. SMOS/SMAP) and **enhanced AMSR type capability** in synergy with other missions [AD-2] (e.g. MetOp-SG(B)) to enhance monitoring of the Polar Regions and Adjacent Seas.

**SEC-OBJ-1.** Measure **Sea Surface Temperature (SST)** in non-precipitating atmospheres at an effective **spatial resolution of  $<15$  km**, with a total standard uncertainty of  $\leq 0.2^{10}$  K with daily coverage of the **global ocean and inland seas** [AD-1], [AD-2], [AD-3] and [AD-4].

**SEC-OBJ-2.** Measure **Thin Sea Ice ( $<0.5$  m depth)** in non-precipitating atmospheres and freezing conditions at an effective spatial resolution of  $<60$  km, with a total standard **uncertainty of  $<20\%$ <sup>11</sup>** (goal:  $<10\%$ ) with **daily coverage** of the marginal ice zone in the Polar Regions and Adjacent Seas [AD-1], [AD-2], [AD-3] and [AD-4].

**SEC-OBJ-3.** Measure **Sea Ice Drift** in non-precipitating atmospheres at an effective spatial resolution of  $\leq 25$  km with a standard uncertainty of  $\leq 3^{12}$  cm s<sup>-1</sup> [AD-1], [AD-2] with daily coverage in the Polar Regions and Adjacent Seas [AD-1], [AD-2], [AD-3] and [AD-4].

**SEC-OBJ-4.** Measure **Ice type/Stage of development** in non-precipitating atmospheres and freezing conditions [AD-1], [AD-2] in combination with other satellite data including scatterometer and SAR measurements with daily coverage in the Polar Regions and Adjacent Seas [AD-1], [AD-2] and [AD-3].

**SEC-OBJ-5.** Measure **Snow depth on sea ice** in non-precipitating atmospheres and freezing conditions with an effective spatial resolution of  $\leq 15$  km and standard uncertainty of  $\leq 10$  cm [AD-1], [AD-2] with daily coverage in the Polar Regions and Adjacent Seas [AD-1], [AD-2] and [AD-3].

**SEC-OBJ-6.** Measure terrestrial **Total Snow Area** with an effective spatial resolution of  $\leq 15$  km and standard uncertainty of  $\leq 10\%$  with daily coverage in the Polar Regions [AD-1], [AD-2], [AD-3] and [AD-4].

**SEC-OBJ-7.** Measure terrestrial **Snow Water Equivalent (SWE)** with an effective spatial resolution of  $\leq 15$  km and standard uncertainty of  $\leq 40$  mm with daily coverage in the Polar Regions [AD-1], [AD-2], [AD-3] and [AD-4].

**SEC-OBJ-8.** Measure **Sea Ice Surface Temperature (SIST)** in freezing conditions with an effective spatial resolution of  $\leq 15$  km standard uncertainty of  $\leq 1.0$  K [AD-1], [AD-2] and [AD-3] in combination with other satellite data including thermal infrared imagery in the Polar Regions and Adjacent Seas [AD-1], [AD-2] and [AD-3].

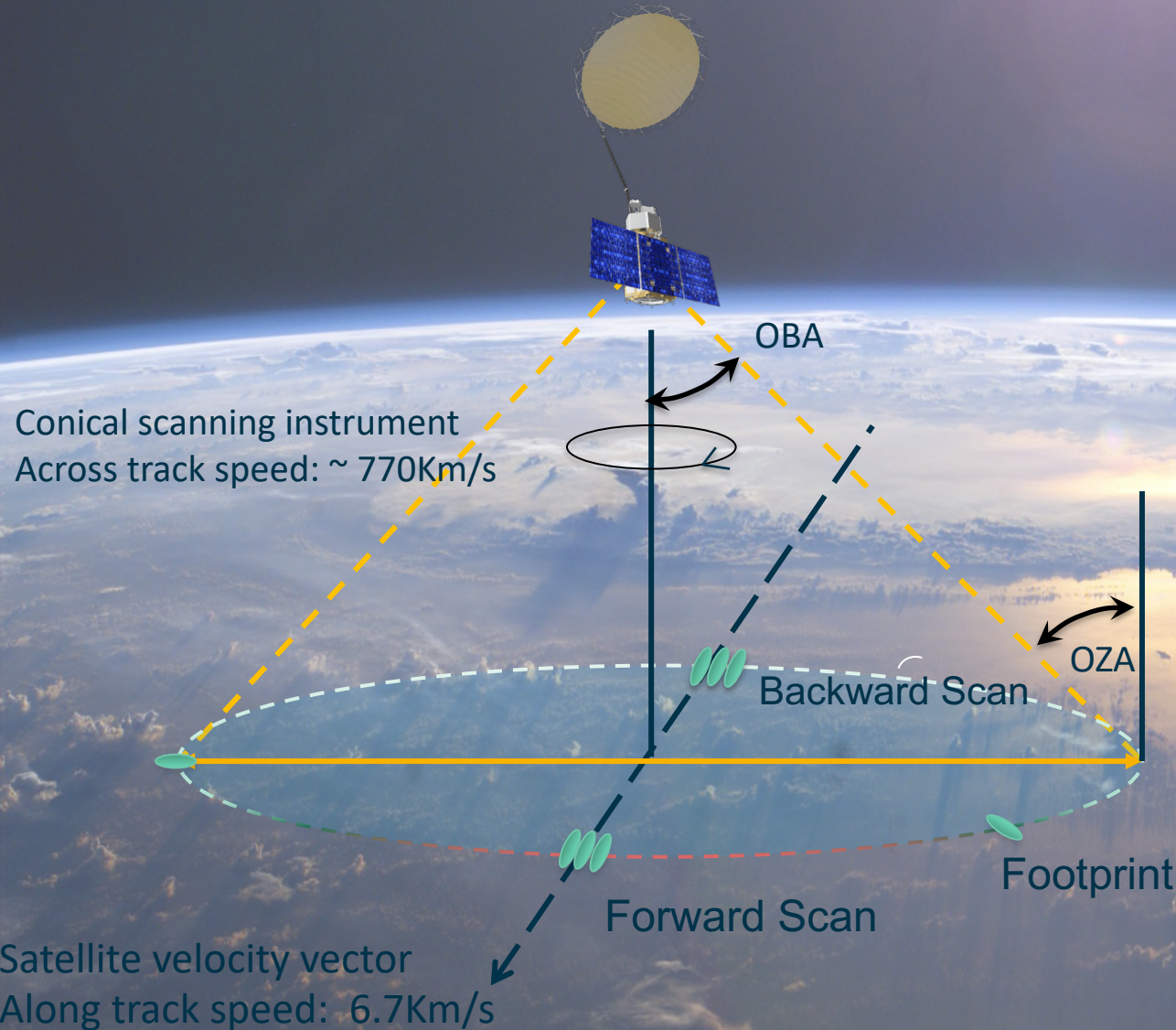
**SEC-OBJ-9.** Measure **Sea Surface Salinity (SSS)** over the global ocean from space [AD-3], [AD-4] with a target gridded spatial resolution of 40 km and uncertainty  $\leq 0.3$  pss<sup>13</sup> over monthly time-scales [AD-3].

**SEC-OBJ-10.** Measure **wind speed over ocean** [AD-4], **soil moisture** [AD-4], **land surface temperature** [AD-4], **cloud liquid water over ocean** [AD-4], **precipitation over ocean**, **terrestrial surface water extent** [AD-4] and **vegetation indices**.





# CIMR general architecture



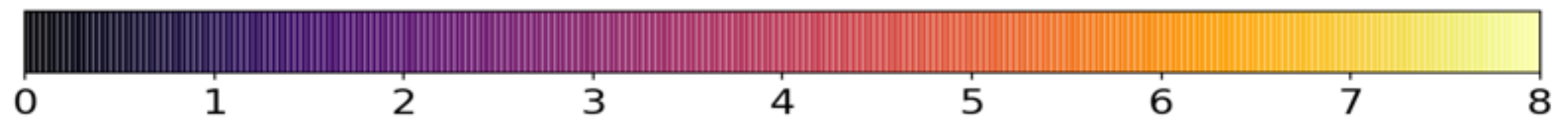
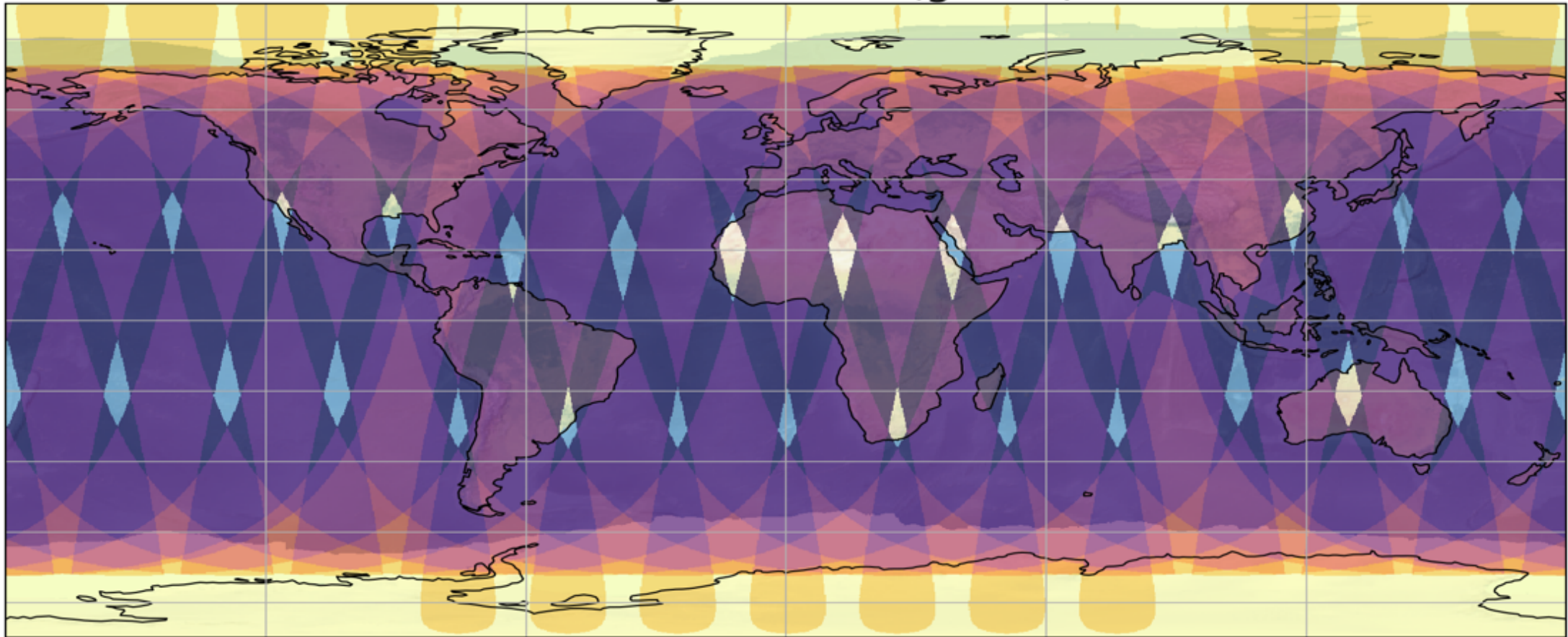
- Mean spacecraft altitude 832.2km
- OZA  $55 \pm 1.5$  degrees
  - Provides required swath and coverage
- Instrument conically scanning
  - Rotation speed 7.8rpm (=7.7 sec per revolution)
  - Dictated by radiometric sensitivity requirements
- Antenna aperture diameter 7.13 m
  - Dictated by spatial resolution requirements



# Coverage and Revisit

(~95%/day Global coverage, 1 satellite; 99% coverage after 1.5 days)

## Coverage of CIMR (global)

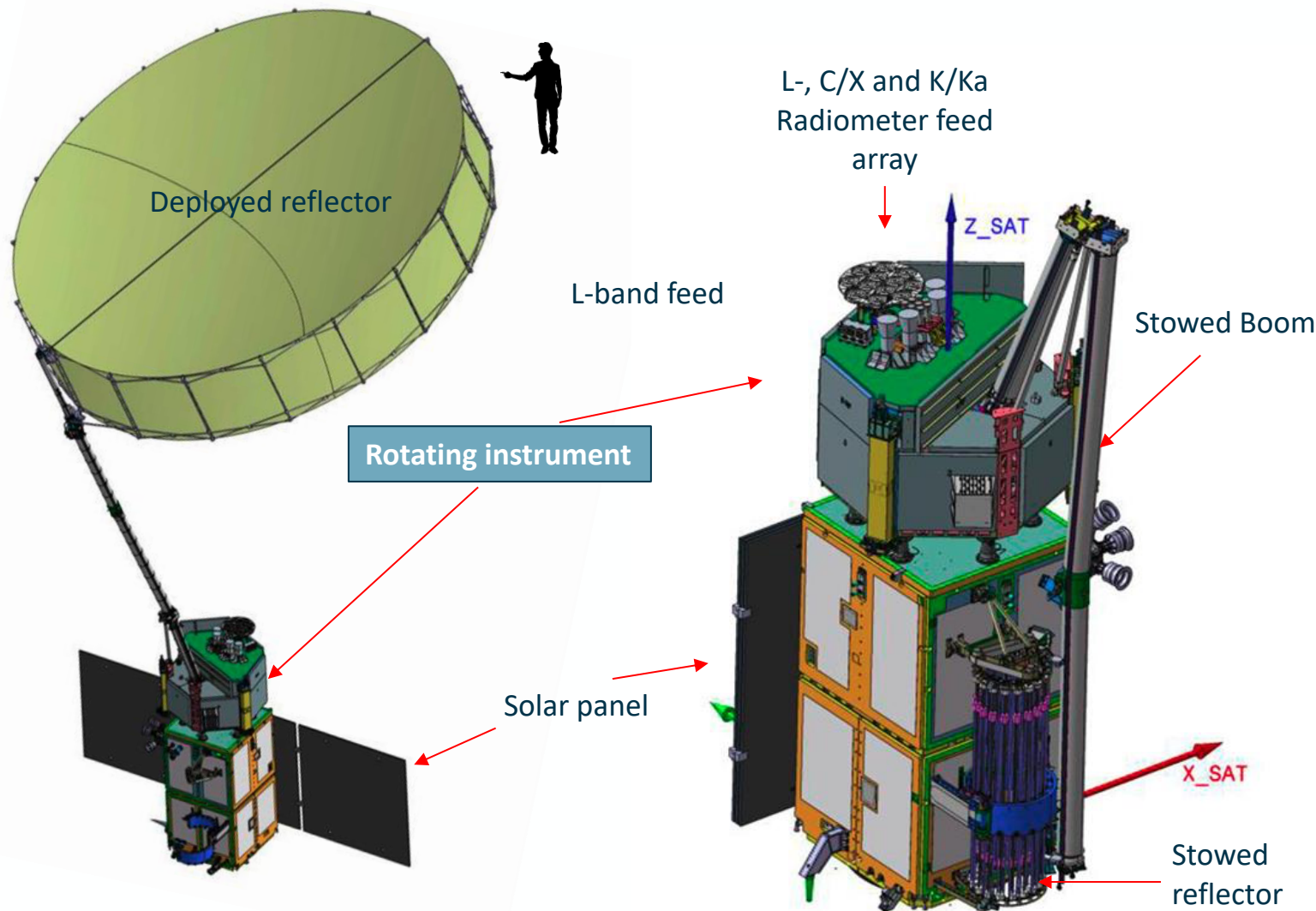


Number of revisits in 24 hours





# The CIMR Payload



## Rotating instrument

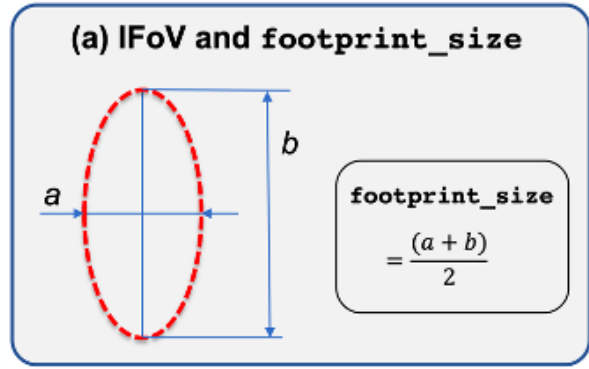
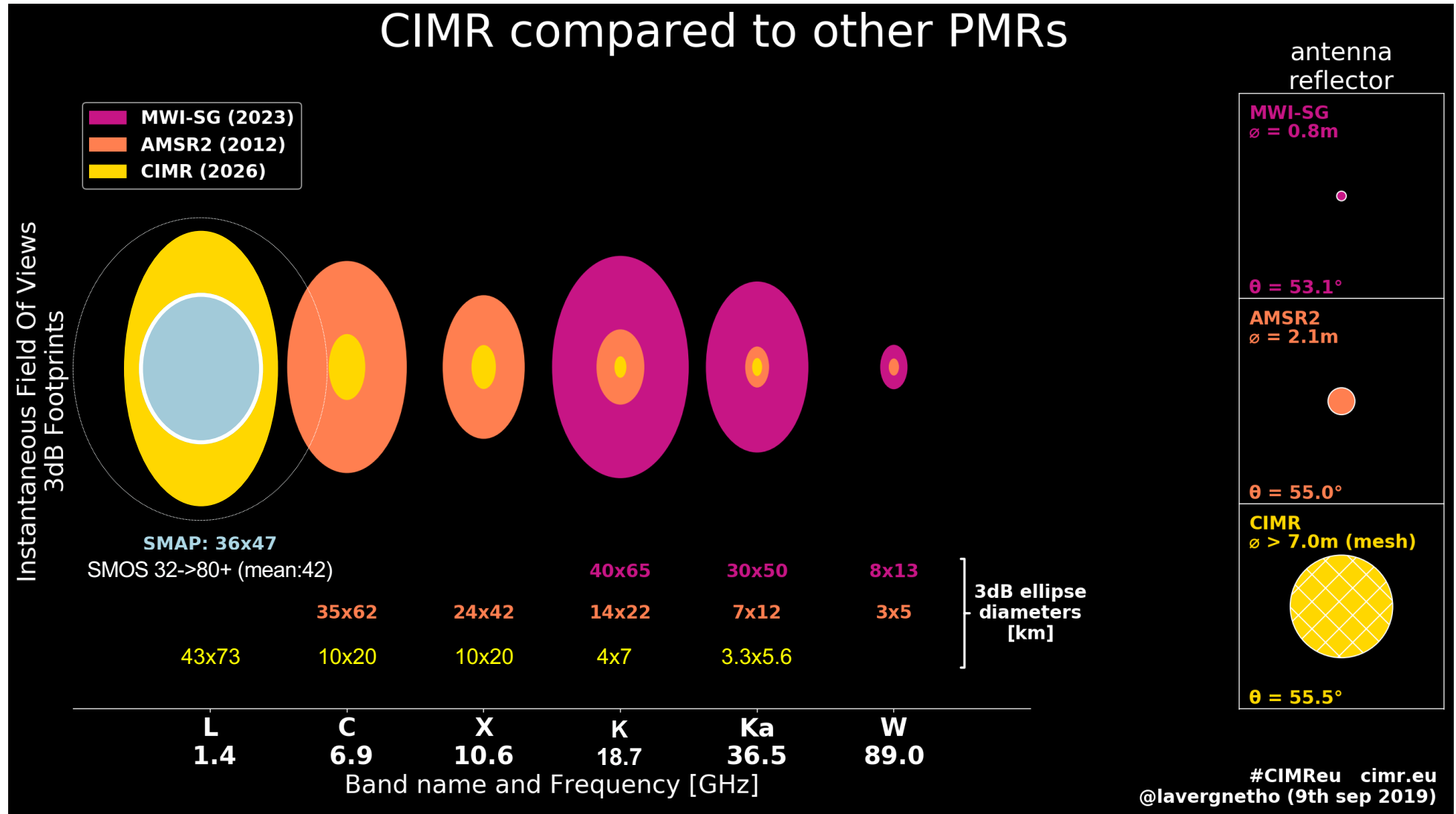
- 50 receiver channels in total (~11GHz total bandwidth), including dual linear polarisation.
- Full Modified Stokes parameters provided.
- Each channel uses **internal calibration**.
  - Hot and Active Cold Load (ACL).
- Detection is done in digital domain.
- All channels have **onboard RFI processor**.
  - To identify interference and remove it from the measurement.
- All the above done in rotating part of the satellite (due to limitation in data transfer through the rotary joint to the fixed part).





# CIMR -3dB projected IFoV and footprint\_size

## CIMR compared to other PMRs



footprint\_size:

- L: <60 km
- C: ≤15 km
- X: ≤15 km
- K: ≤ 5.5 km
- Ka: ≤5 (g:4) km





The legacy of Sentinel-3 SLSTR for operational and climate-quality SST is being continued and enhanced:

- S3-NGO ASLSTR: 500 m resolution
- LSTM: high resolution, for coastal applications
- CIMR: all-weather SST from passive microwave

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