ESA SAR Missions - Status and Plans

Third Workshop on International Coordination for Spaceborne Synthetic Aperture Radar

6 November 2024

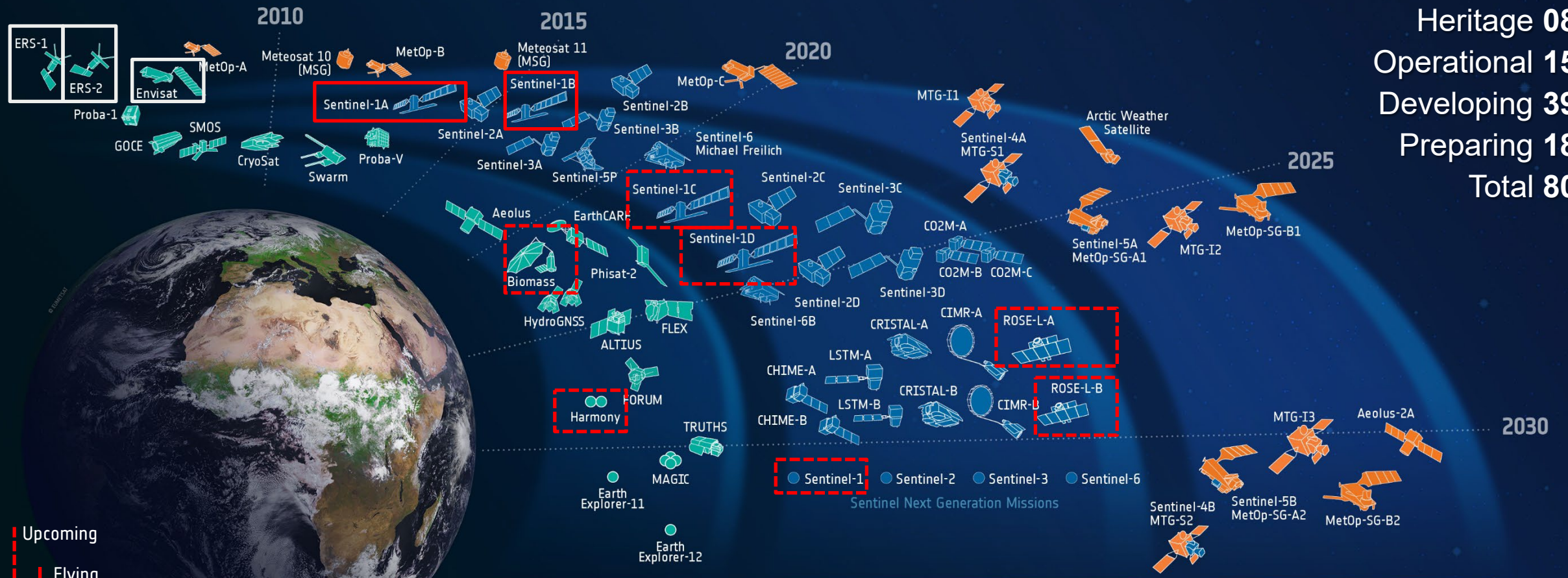
Martin Suess
Head of Microwave Instrument Section
Directorate of Earth Observation Programmes

ESA UNCLASSIFIED – For ESA Official Use

ESA Develops world-class EO systems with European and global partners to address Scientific & Societal challenges

Satellites

Heritage **08**
Operational **15**
Developing **39**
Preparing **18**
Total **80**



ESA-DEVELOPED EARTH OBSERVATION SAR MISSIONS



© ESA 2023

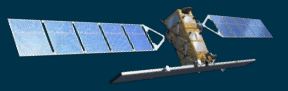
Sentinel-1



Copernicus
C-Band SAR
two satellite constellation
monitoring of geohazards,
land use,
agriculture and forestry,
soil moisture,
and the cryosphere

S1-C launch in December 2024
S1-D launch in 2025

Sentinel-1 in a nutshell



MISSION PROFILE

- Constellation of two identical SAR C-band satellites: (A & B → C & D units)
- Near-Polar, sun-synchronous (dawn-dusk) orbit at 698 km altitude
- 7.25 years lifetime (consumables for 12 years)
- 12-day repeat cycle (each satellite), 6 days for the constellation

PAYLOAD

- C-Band SAR
  - Centre frequency: 5.405 GHz
  - Polarizations: HH, VV, HH/HV, VV/VH
  - Incidence angle: 20º - 45º
  - Radiometric accuracy: 1 dB (3σ)
  - Radiometric stability: 0.55 dB (3σ), 0.45 (3σ) for S-1 C/D
  - NESZ: -22 dB
  - DTAR: -22 dB
- AIS Instrument marine surveillance (for S-1 C and D)

OPERATIONS

- Systematic SAR data acquisition using a predefined observation scenario
- Instrument duty cycle of max. 25 min/orbit in High Bit Rate modes (30 min outside eclipse) and 75 min/orbit in Low Bit Rate mode (Wave)

PROGRAMMATICS

- Sentinel-1C launch December 2024
- Sentinel-1D launch 2025



Full, Free and Open Data

Sentinel-1 is used in most Copernicus Services

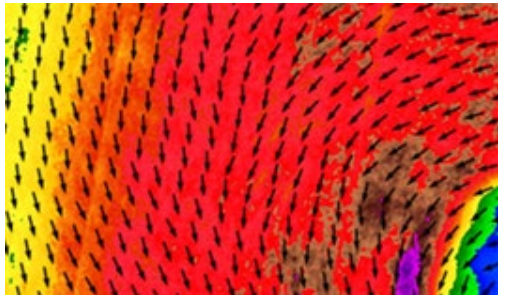
Emergency Management Service



- Rapid mapping (flood mainly)
- Risk recovery (e.g. ground deformation)
- Validation (e.g. flood, landslide)
- Automated global flood monitoring (in development)

Flooded area
Ground movement
Soil moisture
Abrupt surface elevation changes

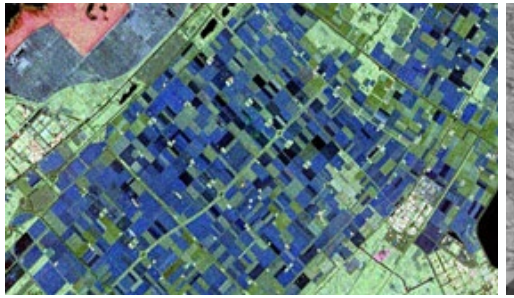
Marine Environment Monitoring Service



- Describe and analyse the physical and sea ice state of the ocean at the surface, on global scale or for a specific zone

Sea ice type, concentration and motion
Iceberg location, size and drift
Ocean surface currents
Ocean surface wind vectors
Swell properties

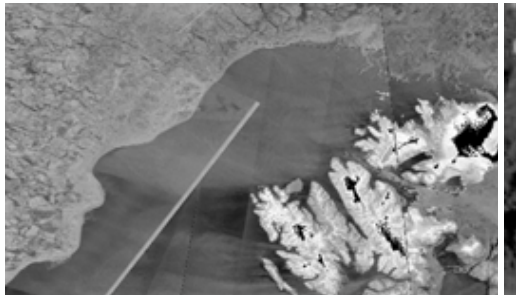
Land Monitoring Service



- Land Cover and Land Use Mapping (HRLs: Wetness and Water, Imperviousness, Tree cover & Forest, Grassland, Snow, River/Lake ice)
- Biogeophysical parameters
- European ground motion service

Land use and land use change, including agriculture and forestry
Ice sheets & glaciers velocity
Wet snow extent
Ground movement
Global Soil moisture

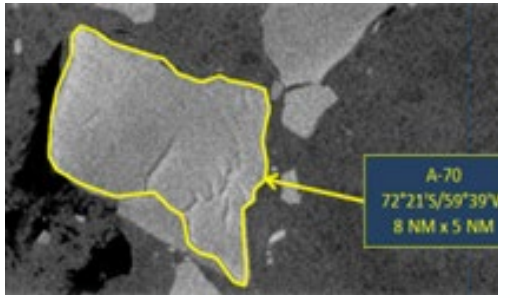
Climate Change Service



- Climate datasets and tools for science, policy and industry (e.g. for climate change impact assessment, risk assessment, sustainability)

- **Sea ice type, concentration and motion**
- **Ice sheets & glaciers velocity, Grounding line**
- **Ground movement**
- **Ice sheets margins and glacier surface height**
- **Ice sheet melt/freeze extent**

Security Service



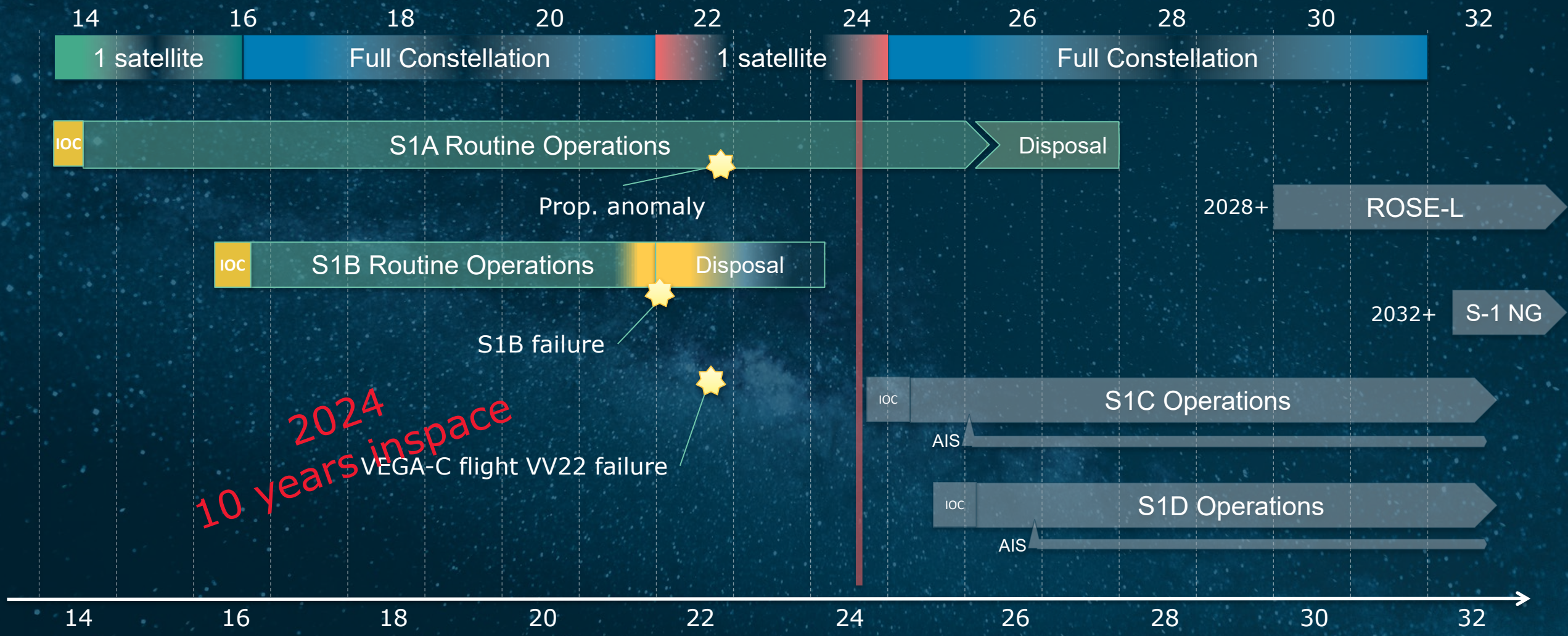
- Oil spill detection and polluter identification (CleanSeaNet)
- Maritime surveillance (detection, search and rescue, anti-piracy)
- Border surveillance;
- Support to EU External and Security Actions
- R&D for EO Security

- **Iceberg location, size and drift**
- **Vessel location, size and velocity**
- **Oil spill location and morphology**
- **Feature identification**
- **Change Detection**

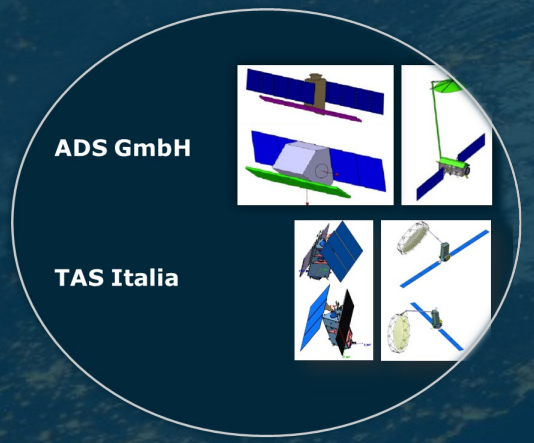
Enhanced continuity by Sentinel-1 Next Generation

… as well as in national services, and the scientific and commercial domain

Sentinel-1 Timeline



Sentinel-1 NG Highlights



OBJECTIVES

- *Ensure continuity* and expansion of services and applications relying on Sentinel-1
- *Enhance* existing services and applications
- *Enable* new application developments building on improved performance and observation gaps (e.g. resolution, revisit and others)
- Launch in 2032

MISSION PERFORMANCE REQUIREMENTS

- Performance shall be equal or better than Sentinel-1 FG
- Revisit: 3 days Global, 0.5 days Arctic and sea ice
- Resolution ≤ 25 m^2
- NESZ ≤ -26 dB
- Dual-Pol and Quad-Pol capability
- Large swath 400km or greater

Sentinel-1NG vs. Sentinel-1FG

Performance Requirements	Sentinel-1NG	Sentinel-1FG
Latitude coverage	**-80 to +90 deg**	North-pole gap
Revisit Goal	Goal: **3 days** Global Goal: **0.5 days** Arctic and Sea Ice	Up to 12 days
Latency	**10 min** European Waters **120 min** Global	10 min RT, 1 h NRT emergency, > 3 h Global
Repeat pass InSAR	**6 / 12 days** (S1 & ROSE-L orbit)	6 / 12 days
Incidence angle access	**Better than 20 – 45 deg**	20 – 45 deg
Swath width	**Larger than 400 km**	250 IW – 400 EW
Resolution	**25 m2**	~100m2 IW - ~800m2 EW
NESZ	**-26 dB**	-22 dB
Polarization capability	**SP, DP and QP**	SP and DP
Duty cycle	**43% (˜43 min/orbit) with 53min any orbit**	25min/orbit

Harmony



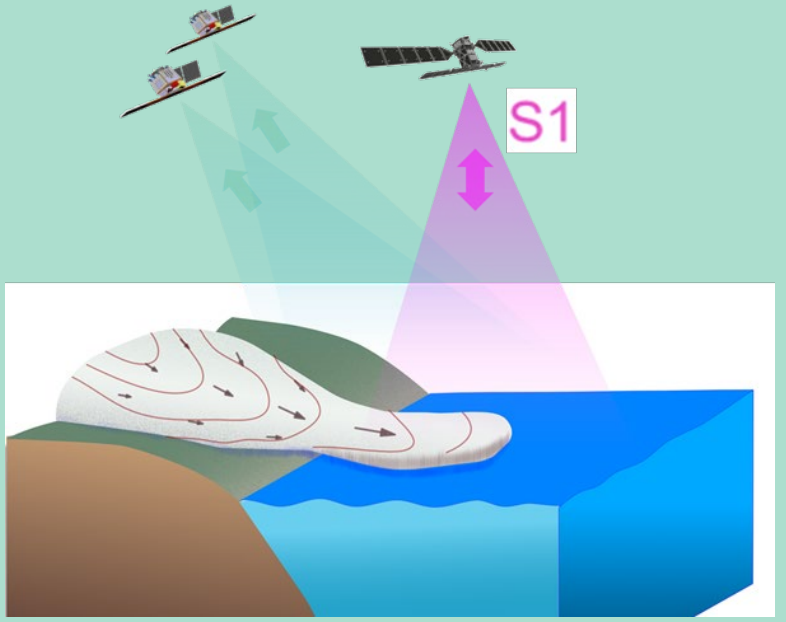
Earth Explorer 10
two receive only SAR satellites
as companions to Sentinel-1D
measuring motion vectors
and dynamic processes
on sea, land and ice
Launch in 2029

→ THE EUROPEAN SPACE AGENCY

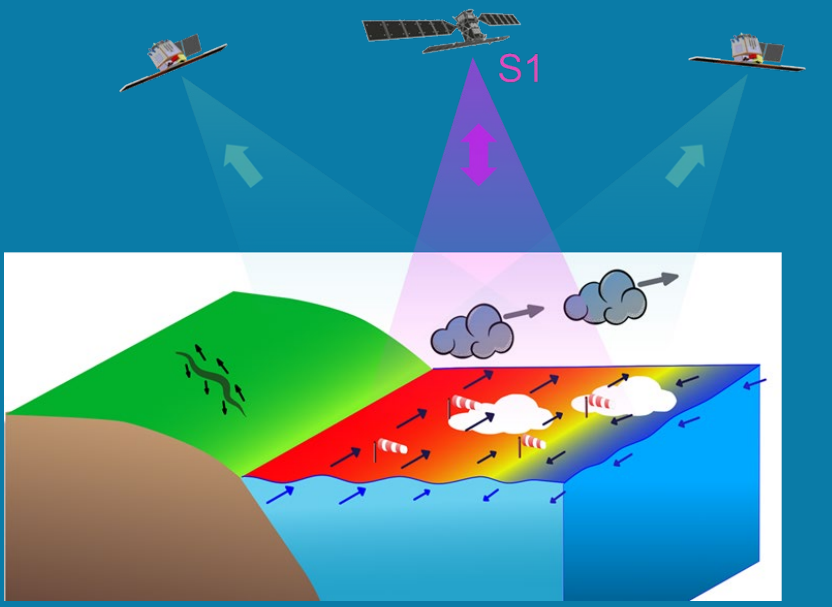
Image courtesy of OHB

Harmony in a nutshell

Harmony is ESA's Earth Explorer 10 mission, comprised of two companion satellites in a loose convoy with Sentinel-1D (along-track separation ~350 km)
Its payload suite consists of a **passive SAR** and a **multi-view TIR instrument**



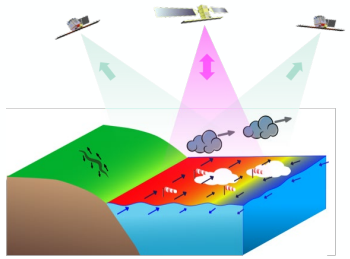
Cross-track Interferometric phase covering land applications like glaciers, permafrost, volcanoes.

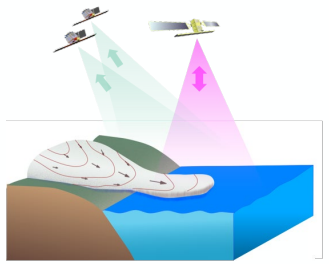


Stereo phase covering 3-D surface deformation ocean applications: surface motion, surface winds, sea surface temperature, cloud motion.

Year 1 | Year 2 | Year 3 | Year 4 | Year 5

Harmony Science Products





Simultaneous,
O(1 km) scale

SST

Cloud-top Motion

Directional roughness

Directional Doppler

C-band = all weather

3-D repeat pass InSAR

Dense DSM time-series

Simultaneous,
O(50m) scale

- Data driven ocean-atmosphere couplings and statistical characterization of vertical fluxes in ESM 2.0.
- Understanding of air-sea interactions within extremes.
- Sea-ice dynamics.
- Global strain maps.
- Understand cycles of topographic change at volcanoes.
- Global and temporally consistent map of ice volume change (loss).
- Improved understanding of glacier dynamics.

ROSE-L



Copernicus
L-Band SAR
two satellite constellation
monitoring of geohazards,
land use,
agriculture and forestry,
soil moisture,
and the cryosphere
Ready to launch in 2028 / 2030

→ THE EUROPEAN SPACE AGENCY

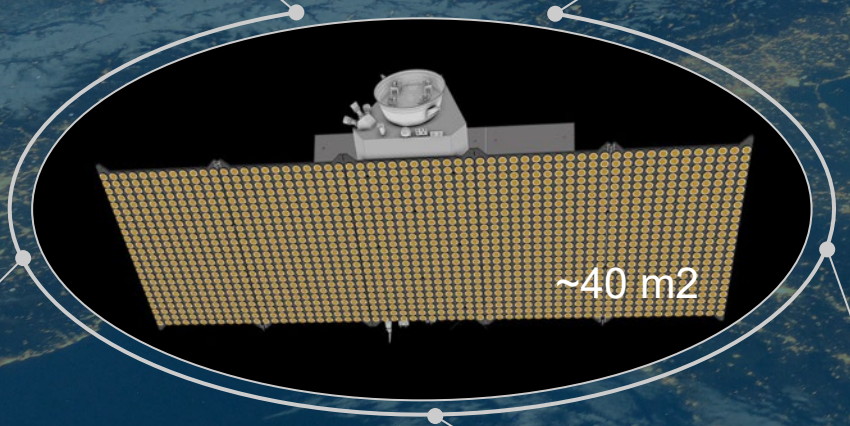
ROSE-L Mission in Brief

GENERAL

- Constellation of 2 satellites (PFM & FM2)
- Consortium led by Thales Alenia Space Italy (TAS-I), involving 29 companies from 15 countries
- Service continuity with Sentinel-1 FG and NG

COVERAGE

- Coverage of Global Land (excl. Antarctica) and Arctic
- Revisit with 2 satellites :
  - 6 days Global Land
  - 3 days Europe
  - 1 day Arctic
- Repeat cycle of 6 days over Global Land (2 satellites)



PROGRAMMATICS

- **Currently in Phase C (CDR KO March 2025)**
- Science Plan activities start in 2023
- QAR of PFM expected in 2028
- FM2 delivery expected in 2030

IMAGING

- L-Band – 85 MHz ITU allocated band (1.215-1.300 GHz)
- Dual-Pol mode: RIWS (ROSE-L Interferometric Wide Swath)
- Support to Quad-Pol mode: QWS (Quad-Pol Wide Swath)
- Wave mode capability
- Resolution < 50 m2 (RIWS mode)
- NESZ < -28 dB
- DTAR < -23 dB
- Swath width > 250 km

SYNERGIC ASPECTS

- Synergic acquisitions with Sentinel-1: co-located swaths and support to convoy configuration
- Companion friendliness for Single-Pass Interferometry

ROSE-L Objectives and Services

CLMS

C3S

CMEMS

EMS

Security

Meteorology and Hydrology Services

National and Local Authorities



Geohazards Monitoring

- **Deformation**
- **Landslides**
- **Urban subsidence**
- **Flooding**

EU-GMS



Land Use, Agriculture and Forestry

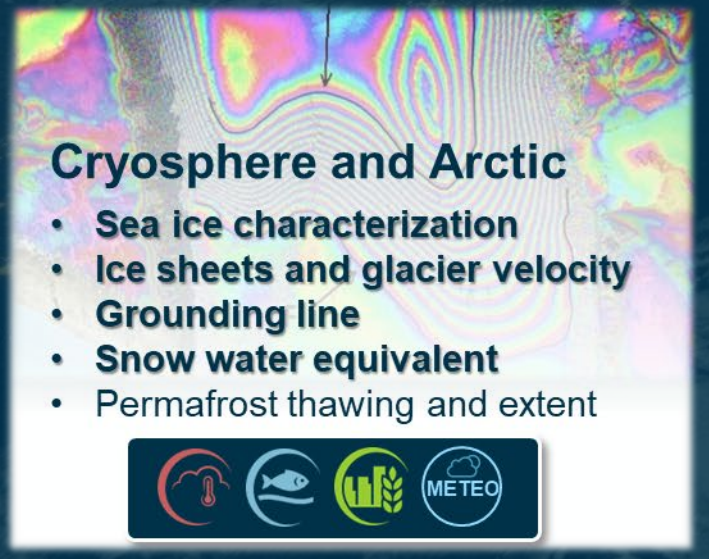
- **Forest biomass and structure**
- Land cover and land cover change
- Agriculture



Soil Moisture

- **High-resolution soil moisture**

METEO



Cryosphere and Arctic

- **Sea ice characterization**
- **Ice sheets and glacier velocity**
- **Grounding line**
- **Snow water equivalent**
- Permafrost thawing and extent

METEO



Marine Monitoring

- Ocean surface wind vectors
- Swell properties

METEO

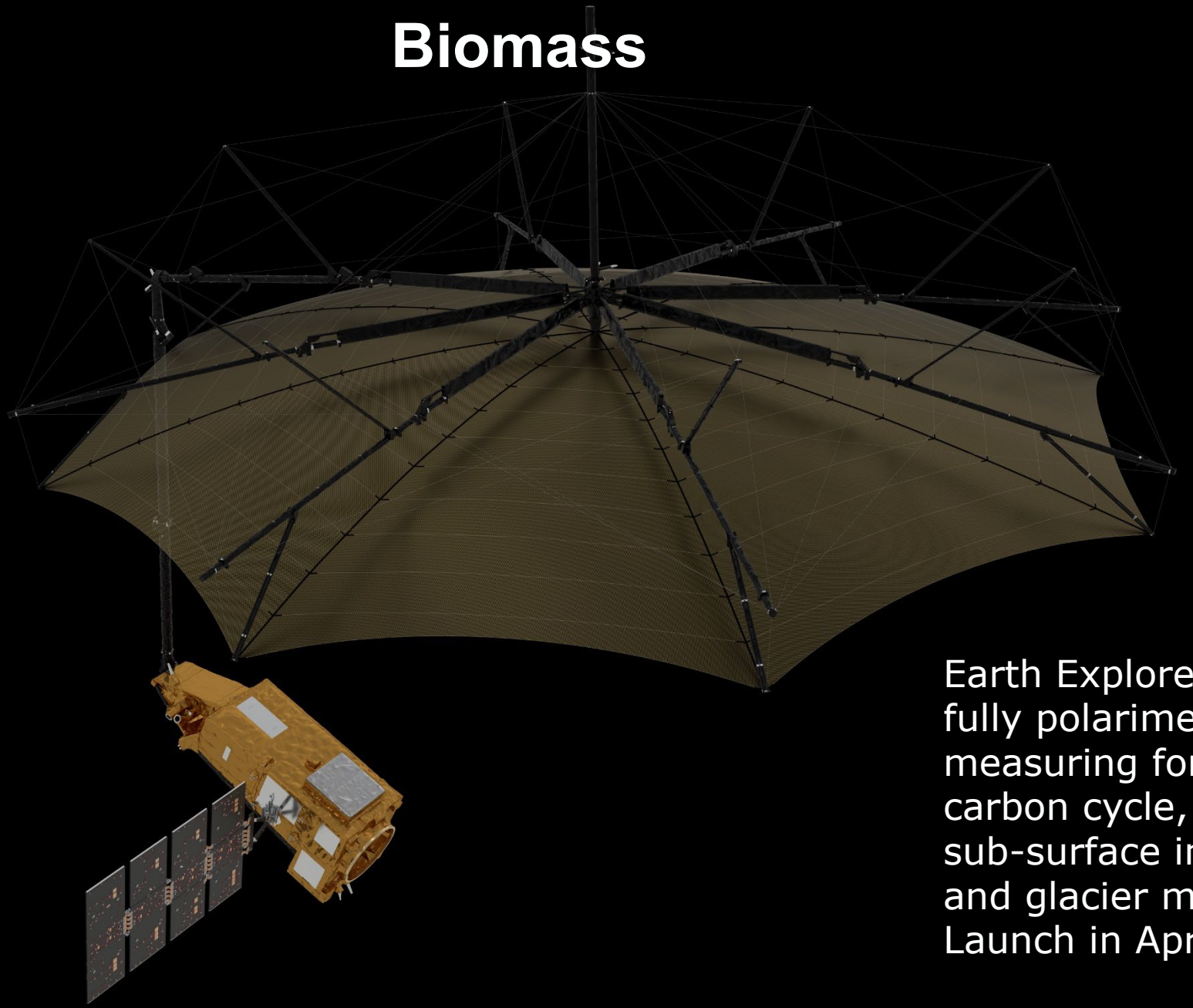


Maritime Monitoring

- **Iceberg location, size and drift**
- Vessel location, size and velocity
- Oil spill location and morphology

EMSA FRONTEX

Biomass

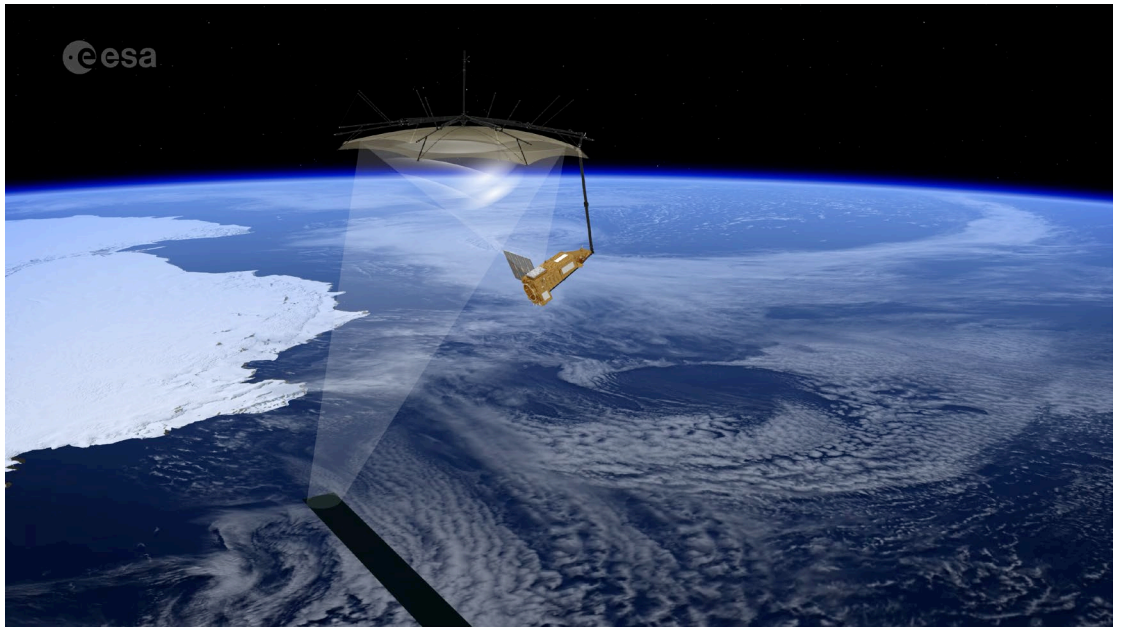


Earth Explorer 7
fully polarimetric P-Band SAR
measuring forest biomass,
carbon cycle,
sub-surface in arid regions,
and glacier movement
Launch in April 2025

Key Mission Characteristics

Fully polarimetric P-band SAR

- Operating at 435 MHz with 6MHz bandwidth
- Highest sensitivity to biomass compared to other wavelengths
- High temporal coherence over repeat passes
- P-band signals are highly susceptible to ionospheric distortions
- Quad-pol mode acquisition of all linear polarisation combinations, i.e. HH, VV, HV & VH (in transmit and receive).
- Large wavelength and large antenna diameter requires to rely on a dedicated antenna pattern characterisation in orbit
  - Dedicated development: Biomass Calibration Transponder
- High accuracy polarimetric and radiometric accuracy
- Single antenna beam steered mechanically by satellite orientation

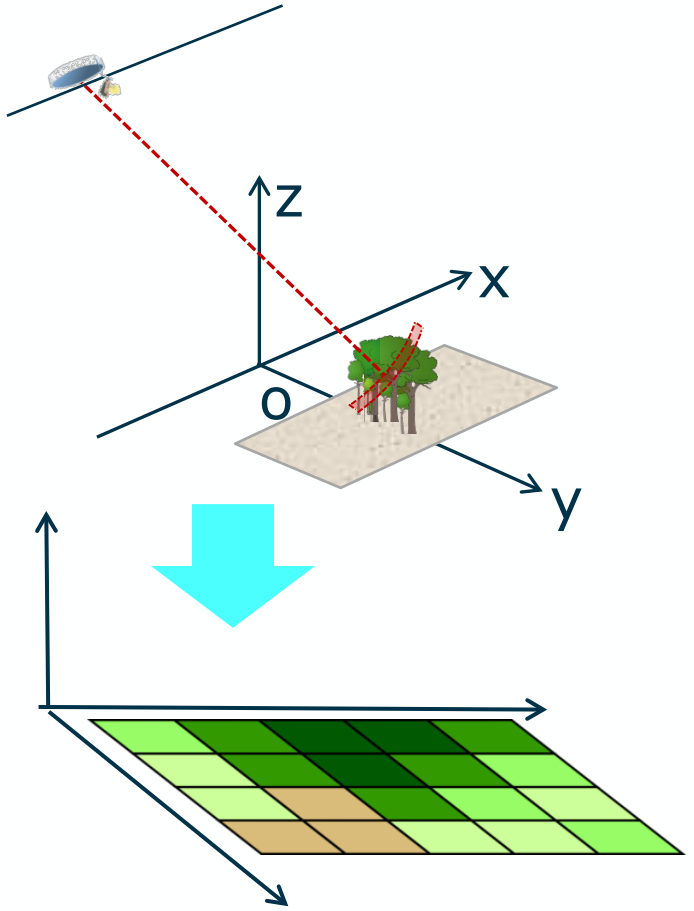


Two mission phases employing multi-pass tomography and interferometry

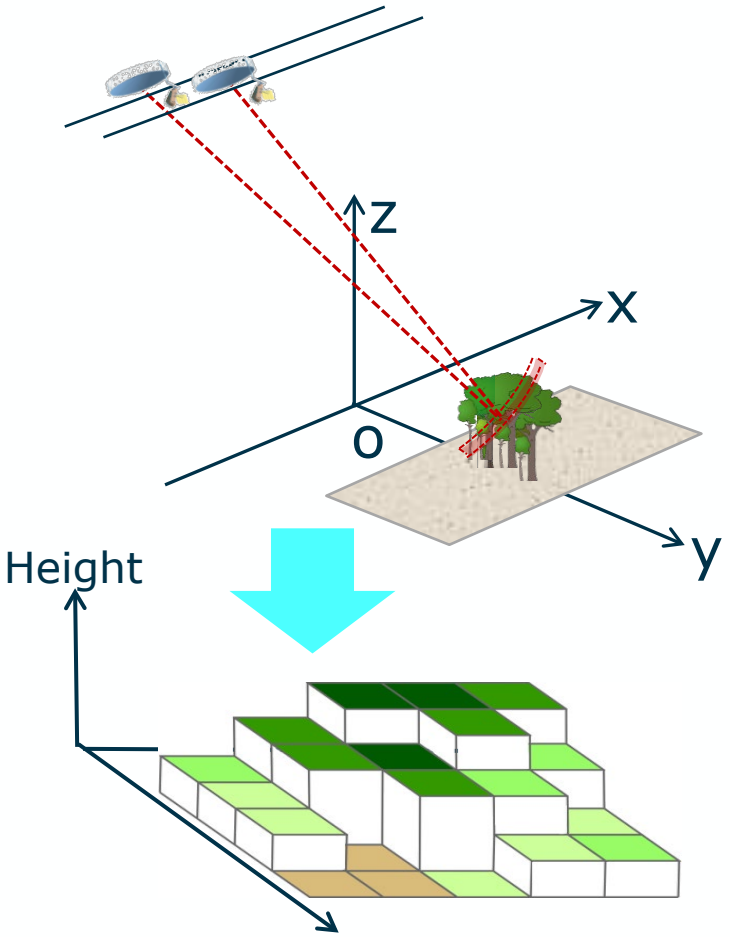
- controlled inter-orbit baselines between successive revisits to the same site
- Tomographic phase: observations with 6 3-day baselines (7 acquisitions) for 18 months for global coverage
- Interferometric phase: observations with 2 3-day baselines (3 acquisitions) for 9 months per global coverage

Biomass SAR observation capability

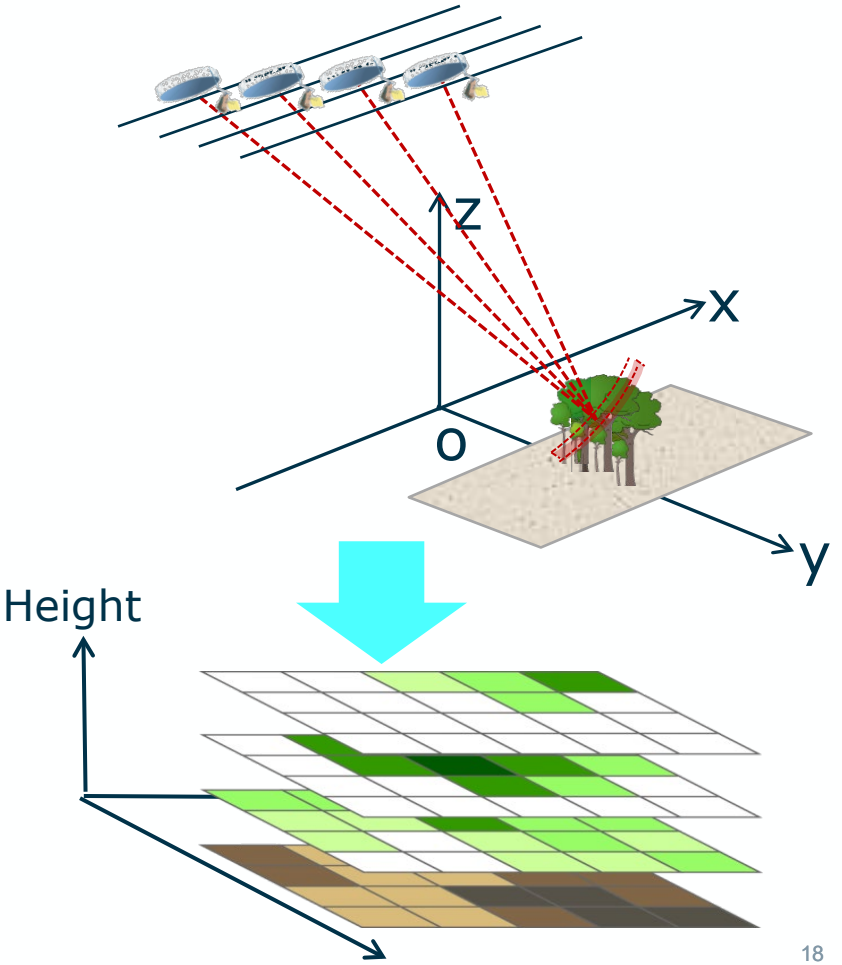
PolSAR
(SAR Polarimetry)



PolInSAR
(Polarimetric SAR Interferometry)



TomoSAR
(SAR Tomography)



Thank you for your attention!

www.esa.int

ESA UNCLASSIFIED – For ESA Official Use