THE COPERNICUS PROGRAMME

ESA Copernicus Space Office
What is Copernicus?

European response to global needs:
- to manage the environment,
- to mitigate the effects of climate change and
- to ensure civil security
What is Copernicus?
GMES/Copernicus Key Milestones

1998
- Initiation of Copernicus: ‘Baveno Manifesto’

2001
- ESA Ministerial Council in Edinburgh: first Copernicus services funded

2005
- ESA Ministerial Council in Berlin: first funds committed to the CSC

2008
- ESA Ministerial Council in The Hague provided next major funding contribution by ESA Member States; Signature of EU-ESA Delegation Agreement on GMES

2010
- Commission proposal for a Regulation on GMES initial operations (2011-2013)

2013
- EU Delegated Regulation for Copernicus data access

2014
- EU Regulation of the Copernicus programme

2014
- Revision of the ESA GSC Declaration

2014
- EU-ESA Copernicus Agreement for 2014-2020

2014+
- First Sentinel satellites launched
Copernicus Components & Competences

Overall Programme Coordination:

Space Component

Services Component

Coordinators:

Partners:

Industries

National Space Agencies

Private companies

EUMETSAT

EMCWF

Mercator Ocean

EEA

SatCen

JRC

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In-situ data are supporting the Space and Services Components
Copernicus Space Component: Role of ESA

- **Coordinator of overall Copernicus Space Component**
  - Definition of overall architecture and plan for future evolutions
  - Coordinating access to Copernicus missions from national, EUMETSAT and third party satellite owners

- **Development and procurement Agency for dedicated space infrastructure**
  - Development of first spacecraft and Ground Segment
  - Procurement of recurrent elements

- **Operator of Sentinel-1, Sentinel-2, Sentinel-3 (land) and Sentinel-5 precursor**
  - EUMETSAT is operator of Sentinel-3 (marine), Sentinel-4, Sentinel-5 and Sentinel-6
<table>
<thead>
<tr>
<th>Mission</th>
<th>Type</th>
<th>Launch Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1A/B:</td>
<td>Radar Mission</td>
<td>3 Apr 2014/25 Apr 2016</td>
</tr>
<tr>
<td>S2A/B:</td>
<td>High Resolution Optical Mission</td>
<td>23 June 2015/7 March 2017</td>
</tr>
<tr>
<td>S3A/B:</td>
<td>Medium Resolution Imaging and Altimetry Mission</td>
<td>16 Feb 2016/2017</td>
</tr>
<tr>
<td>S4A/B:</td>
<td>Geostationary Atmospheric Chemistry Mission</td>
<td>2021/2027</td>
</tr>
<tr>
<td>S5P:</td>
<td>Low Earth Orbit Atmospheric Chemistry Mission</td>
<td>2017</td>
</tr>
<tr>
<td>S5A/B/C:</td>
<td>Low Earth Orbit Atmospheric Chemistry Mission</td>
<td>2021/2027</td>
</tr>
<tr>
<td>S6A/B:</td>
<td>Altimetry Mission</td>
<td>2020/2025</td>
</tr>
</tbody>
</table>
... with a long-term operational perspective

Access to Contributing Missions

2011

S-1 A/B/C/D

S-2 A/B/C/D

S-3 A/B/C/D

S-4 A/B (on MTG)

S-5 Precursor

S-5 A/B/C (on MetOp-SG)

S-6 A/B

2014

2020

2030
Copernicus Contributing Missions

Optical MR and LR missions

SAR missions

Optical VHR and HR missions

Atmospheric missions

Altimetry missions

SPOT (VGT)
PROBA-V
DMC
Pléiades
Deimos-2
RapidEye
SPOT (HRS)
COSMO-Skymed
TerraSAR-X
Tandem-X
Radarsat
Cryosat
Jason
MetOp
Meteosat 2nd Generation

... and many more!
Launch Sentinel-1A

- 3 April 2014
- Kourou spaceport
- Soyuz-2 rocket
- New era of Earth observation
- B unit launched on 25 April 2016
Launch Sentinel-2 A

- 23 June 2015
- Kourou spaceport
- Vega rocket
- “Colour vision” of Copernicus
- B unit launched on 7 March 2017
Launch Sentinel-3 A

- 16 February 2016
- From Plesetsk cosmodrome, Russia
- Rockot rocket
- "A bigger picture" for Copernicus
- B unit to be launched at the end of 2017
Sentinels Operations Strategy

Main objectives of the Sentinels operations strategy:

- Reliable provision of data to Copernicus users
- Ensure systematic and routine operational activities

Sentinels operations approach:

- Sentinels are operated via a pre-defined background observation and downlink plan
  - Scenario is updated on a regular basis (e.g. 6 to 12 months) taking into account evolution of user needs
- All Sentinels acquired data is systematically downlinked and processed to generate a predefined list of core products within specific timeliness
  - Typically within 3h after sensing for Near-Real Time, and within 24h after sensing for Non-Time Critical
Sentinels Products dissemination: data hubs

Large and small private companies are re-distributing Sentinel products via free and pay-per-use schemes.

As of spring 2016, international partners mirror sites have started disseminating towards own national communities.

Collaborative mirror sites directly serve more than 600 users (status end 2015).

Copernicus Services are providing their higher level products to approx 10,000 users (status Q1-2016).
## Sentinel Data Hubs – Latest Configuration (Feb 17)

<table>
<thead>
<tr>
<th>Open Data Hub</th>
<th>Collaborative Data Hub</th>
<th>International Access Hub</th>
<th>Copernicus Services Data Hub</th>
</tr>
</thead>
<tbody>
<tr>
<td>Self Registration</td>
<td>13 Collaborative GS 5 Data Hub Relays</td>
<td>4 Intl. Agreements</td>
<td></td>
</tr>
<tr>
<td>&gt; 63,000 Users</td>
<td>Node 1: 30 days Node 2: 9 days</td>
<td>30 Days</td>
<td>180 Users</td>
</tr>
<tr>
<td>No Rolling Policy</td>
<td>Sentinel-1 NTC Sentinel-2 L1C Sentinel-3 (pre-Ops)</td>
<td>Sentinel-1 NTC Sentinel-2 L1C</td>
<td>No Rolling Policy</td>
</tr>
<tr>
<td>Max 2 Concurrent Downloads</td>
<td>Node 1: Max 10 downloads Node 2: No limits</td>
<td>Max 10 concurrent downloads</td>
<td>Sentinel-1 NTC Sentinel-2 L1C</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Max 10 concurrent downloads</td>
</tr>
</tbody>
</table>
Copernicus Sentinel Data Policy

Sentinel Data Policy = FREE and OPEN access

- Joint COM/ESA Sentinel Data Policy Principles have been prepared in 2009 - adopted by ESA MSs in Sep 2009

- EU Delegated Act on Copernicus Data and Information Policy has been published on 12 July 2013 (C(2013)4311, final)

- ESA will table a Sentinel Data Policy for approval by PB-EO in Sep 2013. Main principles of Sentinel data policy:
  
  - Open access to Sentinel data by anybody and for any use:
    
    - Free of charge data licenses
    
    - Restrictions possible due to technical limitations or security constraints
 Sentinel-1 C-band SAR mission

Mission profile:

- **C-Band SAR** at 5.4 GHz, multi-polarisation
- Sun synchronous orbit at **693 km** mean altitude
- **250 km** swath width (Interferometric Wide-swath mode)
- **6 days** repeat cycle at Equator with 2 satellites
- **7 years** design life time, consumables for 12 years
- 4 nominal mutually exclusive operation modes

Mission objectives:

- Ice and marine, land monitoring
- Mapping for humanitarian aid and crisis management
Sentinel-1 Operational Modes

Operational Modes

<table>
<thead>
<tr>
<th>Resolution</th>
<th>Swath Width</th>
<th>Polarisation</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 x 40 m²</td>
<td>&gt; 400 km</td>
<td>HH+HV or VV+VH</td>
</tr>
<tr>
<td>5 x 20 m²</td>
<td>&gt; 250 km</td>
<td>HH+HV or VV+VH</td>
</tr>
<tr>
<td>5 x 5 m²</td>
<td>&gt; 80 km</td>
<td>HH+HV or VV+VH</td>
</tr>
<tr>
<td>5 x 5 m²</td>
<td>20 x 20 km² at 100 km spacing</td>
<td>HH or VV</td>
</tr>
</tbody>
</table>

➢ Daily coverage of high priority areas, e.g. Europe, Canada, shipping routes

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Sentinel-2 Superspectral imaging mission

Mission profile

- Multispectral instrument with 13 spectral bands (VIS, NIR & SWIR)
- Sun synchronous orbit at 786 km mean altitude
- 290 km swath width
- 5 days repeat cycle at Equator (cloud free) with 2 satellites
- 7 years design life time, consumables for 12 years
- 10, 20 and 60 m spatial resolution

Mission objectives:
- Generic land cover maps
- Risk mapping and disaster relief
Sentinel-2: 13 Spectral Bands

**Spectral bands versus spatial resolution**

- **VIS**
  - B1: Aerosols
  - B2, B3, B4: Vegetation
  - B5, B7, B8a: Red-edge

- **NIR**
  - B6: Vegetation
  - B9: Water-vapour

- **SWIR**
  - B10: Cirrus
  - B11, B12: Snow / ice / cloud discrimination

**Continuity with SPOT5 multispectral**

**LANDSAT 7**

**SPOT-5**

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Sentinel-3 Ocean & Global Land Mission

Mission profile

- **3** main instrument sets: OLCI, SLSTR and RA
- Sun synchronous orbit at **814.5 km** mean altitude over geoid
- **1270 km** swath width for OLCI and **750 km** for SLSTR
- **< 1 day** repeat cycle for OLCI/SLSTR with 2 satellites, **27 days** for the topography package
- **7 years** design life time, consumables for 12 years

Mission objectives:
- Sea/land colour data
- Sea/land Surface temperature
- Sea surface and land ice topography
Sentinel-3 Payload

**Optical Mission Payload**
- Ocean and Land Colour Instrument (OLCI)
- Sea and Land Surface Temperature Radiometer (SLSTR)

**Topography Mission Payload**
- Ku-/C-band Synthetic Aperture Radar Altimeter (SRAL)
- MicroWave Radiometer (Bi-frequency)
- Precise Orbit Determination (POD) including:
  - GNSS Receiver
  - DORIS
  - Laser Retro-Reflector
Sentinel-3 Main Components

- Ocean and Land Colour Instrument (OLCI)
- Microwave Radiometer
- X-band Antenna
- DORIS Antenna
- SAR Radar Altimeter
- S-band Antenna
- Laser Retro-Reflector
- Sea and Land Surface Temperature Radiometer (SLSTR)
- Solar Panel
Sentinel-3 Revisit Time & Coverage: Topography Mission

- **Ground tracks after 1 complete cycle (27 days)**

- **Ground track repeatability**

- **Dense spatial sampling**
### Sentinel-3 Revisit Time & Coverage: Optical Mission

#### Short Revisit times for optical payload

<table>
<thead>
<tr>
<th></th>
<th>Number of Satellites</th>
<th>Revisit at Equator</th>
<th>Revisit for latitude &gt;30°</th>
<th>Spec.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ocean Colour</td>
<td>2 Satellites</td>
<td>&lt; 1.9 days</td>
<td>&lt; 1.4 days</td>
<td>&lt; 2 days</td>
</tr>
<tr>
<td>(Sun-glint free, day only)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Land Colour</td>
<td>2 Satellites</td>
<td>&lt; 1.1 day</td>
<td>&lt; 0.9 day</td>
<td>&lt; 2 days</td>
</tr>
<tr>
<td>(day only)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SLSTR dual view</td>
<td>2 Satellites</td>
<td>&lt; 0.9 day</td>
<td>&lt; 0.8 day</td>
<td>&lt; 4 days</td>
</tr>
<tr>
<td>(day and night)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Simulated OLCI products
Sentinel-4 GEO atmospheric mission

Mission profile

- UV-VIS-NIR spectrometer instrument
- Geostationary orbit at about 0° longitude
- Spatial sampling of $8 \times 8 \text{ km}^2$ at 45° north latitude
- **30 min** repeat cycle over Europe and North Africa

Mission objectives:
- Air quality monitoring, climate forcing and tropospheric composition
Sentinel-4 UVN instrument

Instrument Coverage: Europe and Sahara
Repeat Cycle: 30 minutes

Sentinel-4/UVN Instrument embarked on the MTG-S platforms

Instrument Performance Requirements
1. Spatial resolution: 8 km at 45°N
2. Low sensitivity to polarization (1%)
3. Low level of spectral features (0.05%)
4. High radiometric accuracy: < 3%
Sentinel-5/5P LEO atmospheric mission

Mission profile

- **UV-VIS-NIR-SWIR** spectrometer instrument
- Sun-synchronous LEO platform at **824 km** mean altitude
- **7 years** design life time
- Global daily coverage with **7 x 7 km²** sampling

Mission objectives:

- Monitoring air quality, climate forcing and stratospheric ozone
The Sentinel-5P instrument data is **acquired systematically** during the complete orbit according to a simple **baseline observation scenario**.

The TROPOMI/SENTINEL-5P instrument has **a swath of 2600 km on the ground**. It provides a full daily surface coverage for latitudes $>+7^\circ$ and $<-7^\circ$, and better than 95% coverage for latitudes in the interval $[-7,7]$. 
### Sentinel-5P: products overview

<table>
<thead>
<tr>
<th>Product</th>
<th>Description</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 0</td>
<td>Unprocessed instrument measurement, HK &amp; engineering data</td>
<td>internal use only</td>
</tr>
<tr>
<td>Level 1B</td>
<td>Calibrated, geo-located Earth radiance &amp; solar irradiance spectra in all bands</td>
<td>Systematic processing</td>
</tr>
<tr>
<td><strong>Level 2</strong></td>
<td><strong>Column densities/profiles for S5P primary species:</strong></td>
<td>Non Time Critical: All products; Near Real-Time: All species except CH₄ &amp; tropospheric O₃</td>
</tr>
<tr>
<td><strong>UVN channel products</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>O₃</td>
<td>total &amp; tropospheric columns, profiles</td>
<td></td>
</tr>
<tr>
<td>NO₂</td>
<td>total &amp; tropospheric columns</td>
<td></td>
</tr>
<tr>
<td>SO₂, HCHO</td>
<td>total columns</td>
<td></td>
</tr>
<tr>
<td>aerosols</td>
<td>aerosol index &amp; aerosol layer height</td>
<td></td>
</tr>
<tr>
<td>clouds</td>
<td>cloud fraction, top height, optical thickness</td>
<td></td>
</tr>
<tr>
<td><strong>SWIR channel products</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CO, CH₄</td>
<td>total columns</td>
<td></td>
</tr>
</tbody>
</table>

**Near real-time delivery:** 3 hours after sensing

**Non time critical:** 14 days after sensing

**Level 1b and Level 2 will be provided to all users by ESA**
Sentinel-6 topography mission

Mission profile

- SAR Radar altimeter, microwave radiometer and precise orbit determination instruments
- LEO non-sun-synchronous orbit, 1336 km mean altitude
- 10 days repeat cycle with 66° inclination
- 5.5 y lifetime

Mission objectives:

- To provide continuity of the reference, high-precision ocean topography service after Jason-3
Advantages of Sentinel Satellites

- Fully operational system
- Most comprehensive EO system in the world
- Complementary to Contributing Missions
- Free Sentinel data
- Long-term observations
1st Generation Copernicus Space Component

- In 2005 ESA decided to invest in the build-up of the necessary space infrastructure, complementary to the capacity available in its MSs
- After iteration with thematic Implementation Groups a preliminary system architecture was consolidated:

<table>
<thead>
<tr>
<th>GMES initial services</th>
<th>Sent-1</th>
<th>Sent-2</th>
<th>Sent-3</th>
<th>Sent-4</th>
<th>Sent-5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marine &amp; Coastal Environment</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td></td>
<td></td>
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<tr>
<td>Land Cover state &amp; changes</td>
<td>*</td>
<td>*</td>
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<tr>
<td>Global Change Issues</td>
<td>*</td>
<td>*</td>
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<td>*</td>
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<tr>
<td>Atmos. Pollution Management</td>
<td></td>
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<td>*</td>
<td>*</td>
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<tr>
<td>Risk Management</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td></td>
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<tr>
<td>Forest Monitoring</td>
<td>*</td>
<td>*</td>
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<tr>
<td>Food Security</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td></td>
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<tr>
<td>Marine Security</td>
<td>*</td>
<td></td>
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<tr>
<td>Humanitarian Aid</td>
<td>*</td>
<td>*</td>
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</tr>
</tbody>
</table>

Sentinel-5p and 6 were added later to avoid data gaps for atmospheric composition and to continue Jason-1/2/3 reference altimetry.
The evolution of the Copernicus Space Component is a joint EC-ESA endeavour that must be defined together. It is divided into two different sets of activities:

- The current Sentinel families need to be complemented to fill some gaps in environmental monitoring caused by emerging European policy priorities (first missions to be launched around 2024) → **Sentinels expansion**

- Also, the current Sentinel generation will have to be replaced by a next generation of satellites before the end of the last units’ lifetimes (first missions to be launched before 2030) → **Next Gen Sentinels**
Copernicus Space Component expansion

The Mission Concepts and Thematic Areas proposed as high priority are:

- CO₂ Monitoring
- Polar ice/ocean interfer. altimetry
- Other polar (Arctic) observations
- Land thermal imaging
- Soil moisture, ocean salinity
- Hyperspectral land imaging

**climate change**

**marine & polar envir. monitoring**

**land monitoring** (agriculture, food security)

**emergency management** (geohazards)

**marine envir. monitoring**
Copernicus Services Component

Marine

Climate Change

Land

Security

Atmosphere

Emergency Management
Example of Land Monitoring

Devastating earthquake in central Italy on 24th August 2016 (Magnitude: 6.2)

Vertical ground subsidence (~20 cm) and lateral movement (~16 cm) around Accumoli

Credits: Panorama & AP Images
Example of Land monitoring

Sentinel-1 constellation study: INSARAP
San Francisco area InSAR Results

Contains modified Copernicus Sentinel data (2015–16) / ESA SEOM INSARAP study / PPO.Labs / Norut / NGU
Example of Marine Monitoring

2006 Sea Surface Temperature
over the Mediterranean Sea

Credits: Medspiration
Example of Marine Monitoring

Global Sea Level Rise from several satellite radar altimeters
Example of Atmospheric Monitoring

- European Air Quality forecasts produced daily using models with EO and *in situ* data as input
- Local Air Quality forecasts use European-scale forecasts plus additional *in situ* input data
- City and street-level forecasts communicated to individuals
  - physicians now exploring its use in predictive medicine
Example of Atmospheric Monitoring

Ash Cloud Monitoring During Volcanic Eruption in Iceland, April 2010

Credits: ESA, ENVISAT & Norwegian Institute for Air Research

39 April 2010
Example of Climate Change Monitoring

Pacific Sea Surface Height between April and September 2010
The sea surface is higher (warmer) than normal (yellow and red) in the West; and lower (cooler) than normal (blue and purple) in the East due to La Niña effects on Pacific coasts.
Example of Climate Change Monitoring

Rice crop evolution in the Mekong delta

Credits: contains modified Copernicus Sentinel data (2015–16)/CESBIO/ESA DUE GEO-Rice Innovator project
Example of Emergency Management

Fire map at La Palma, Canary Islands (Aug 2016)

Credits: Sentinel-2 and Pléaides-1A
Example of Emergency Management

Flooding in Passau, Germany, June 2013

Credits: DLR
Example of Security Monitoring

Hijacked Italian ‘Savina Caylyn’ Oil Tanker monitored by COSMO-Skymed

Credits: e-GEOS
Example of Security Monitoring

WEBGIS Coastline
SAR Image L1B
EO Plot
EO Plot and AIS Tracks
EO Plot Correlated with AIS Tracks
EO not Associated Plot

Service Timeline
Copernicus For Everyone: Socio-Economic Benefits

2026-2030 potential Copernicus benefits =

€ 130 B or around € 6.9 B / year =

0.2% of the EU current annual GDP

- “Money where it matters – how the EU budget delivers value to you”
  EC, MEMO/11/469, Brussels, 29 June 2011

1 € spent by European tax payer on Copernicus → public return of 10€ can be expected

- “The Socio-Economic Benefits of GMES”
  ESPI report 39, November 2011
Copernicus For Everyone: Educational Benefits & Development

www.copernicus-masters.com

www.app-camp.eu
Interested in more?

ESA Copernicus website
http://www.esa.int/copernicus

EC Copernicus website
http://copernicus.eu