Opportunities by the Copernicus Program for Archaeological Research and World Heritage Site Conservation

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Abstract In its aim to adapt Copernicus to user needs, the European Commission is currently in a phase in contemplating further areas and users to be served by Copernicus. One such area is the monitoring and preservation of Cultural Heritage. Several events in the recent years showed how observation techniques from space can help to monitor the destruction of historic sites through conflict and natural disasters. The process to potentially include Cultural Heritage Monitoring into Copernicus services may take a while and needs further programmatic and political decisions.

Keywords Copernicus program · Earth observation · Cultural heritage protection · European Commission · ESA

The Copernicus Program

European Member States and the European Space Agency (ESA) have been active in Earth observation since the early 1980s. National missions, such as the French Spot program with optical satellites, and international collaborations, such as the German/Italian cooperation with the US/NASA for radar imaging from the Space Shuttle cargo bay, have been international landmarks in technology and the provision of global data. They resulted in successful national follow-on missions (SPOT, Pleiades, TerraSAR-X, and Cosmo-Skymed) involving European companies and public private partnerships (PPP) to commercialize data and services. Next to pure science missions, ESA also started pan-European missions to generate global observation data. The "Earth Remote Sensing" Missions 1 and 2 (ERS-1/2; 1991, 1995) followed by the ENVISAT mission (2002) carried already sophisticated radar,

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optical, and atmospheric payloads, targeted to generate a sustainable supply of critical environmental information. However, it became evident that ESA in its status of a research and development agency cannot master alone the operational duties, the political challenges in data policy, and the long-term financing of a series of Earth observation missions. In a similar situation – the operational management of geostationary weather satellites – EUMETSAT was created in 1986. Hence, discussions started in the early 1990s about putting the European Commission in charge to define and manage a long-term pan-European Earth observation strategy. After initial studies (Churchill et al. 1995), the idea of a program for "Global Monitoring of Environment and Security" (GMES) was first initiated in a European conference in Baveno, Italy, in 1998 (Brachet 2004; Aschbacher and Milagro-Pérez 2012). The legal framework for the European Commission to get involved in Space missions was set with the treaty of Lisbon in 2007, where a new space strategy was adopted by all Member States. Therein, the European Commission was put in charge for defining and maintaining the European strategy for space science research and major space projects. Two of these large-scale projects have meanwhile been initiated and are now in an early operational phase. Next to an independent European global satellite navigation system (Galileo), the European Commission has taken over the governance of GMES, later christened Copernicus.

Copernicus shall make Europe independent in the supply of basic spaceborne Earth observation data. It shall deliver to European governmental agencies, but also to science, companies, and the citizen, critical and timely information on the state of environment and security in Europe and – where necessary – elsewhere.

To achieve this goal, Copernicus consists of several components and elements (see also Fig. 1).

Fig. 1 The segments and elements of the Copernicus program

Space Component

The space component ensures the provision, launch, and operations of dedicated Copernicus Earth observation missions, the Sentinels. Its operations include all ground facilities for mission control, payload data reception, processing, archiving, and delivery. Besides the Sentinels, also data from other national and commercial Earth observation satellites (contributing missions) is used to fulfill the Copernicus objectives. ESA is mandated to manage and control the space component. This is done in work-share with EUMETSAT, being responsible for those parts of the space component using EUMETSAT satellite facilities and within the mandate of EUMETSAT (i.e., specifically Sentinel-4/Sentinel-5/Sentinel-6 missions).

As of mid-2018, seven Sentinels are in orbit and in operations, delivering more than 10 terabyte of data every day, with this rate of data growing at a fast pace. The management, processing, and distribution of this amount of data constitute a specific challenge within Copernicus.

Service Component

The service component shall use the space component data and create information and services currently in six domains: atmosphere monitoring, marine environment monitoring, land monitoring, climate change, emergency management, and security. The Commission is coordinating the service component while leaving the concrete implementation and provision of services to European entrusted entities. The six domains of the service component are explained in more detail in the following paragraph.

In Situ Component

Space data is complemented by data gathered through airborne, seaborne, and ground-based installations, in order to support the abovementioned geo-information services. The European Environmental Agency (EEA) is mandated to manage the in situ component. Cartographic and geographic digital information shall – in general – be treated according to the European INSPIRE (Infrastructure for Spatial Information in the European Community) directive.

These three components define the operational core of the Copernicus program. Additional measures have been implemented to guarantee the adaptation of Copernicus data and information to national user needs, to ensure the acceptance of Copernicus to European users, and to face the challenges in managing the enormous amount of data Copernicus is generating.

Collaborative Ground Segment

Copernicus participating states (i.e., members of the European Union and countries having signed a special agreement (currently Norway and Iceland)) may implement special measures to allow their citizens an improved access to all Copernicus Sentinel data and information. This may be done either by the direct reception of Sentinel-1 data with national data acquisition stations (possible over most of the continental and marine European territory) or the replication of Sentinel data holdings on the national Internet-based user portals. By early 2017 12 of these national portals mirror Sentinel data and partly offer enhanced cloud-based online computing (ESA 2017a, b; 2018).

User Segment and Big Data

The European Commission and ESA take several measures to spread the knowledge about Copernicus, to support the implementation of new space-based applications, and to increase the competitiveness of European industry in dealing with the massive amount of Copernicus Sentinel data. These supportive measures include the stimulation of science using Earth observation thru the European Horizon2020 research program contests for new ideas (Copernicus Masters (https://www.copernicus-masters.com), Hackathons, etc.) and contracts to the European Information Technology industry to implement a Copernicus Data and Information Access System (DIAS).

Four such DIAS have been implemented by European industrial consortia, primed by Serco Europe; Creotech, Poland; ATOS France; and Airbus Defence and Space, France.

In addition, EUMETSAT has launched its own DIAS Service primarily targeting its own user community.

A regulation of the European Parliament (European Commission 2014) defines the concrete roles and responsibilities of the Commission as the owner and main financing organization of Copernicus, as well as the role of its European partners, specifically the European Space Agency (ESA) and the European Meteorological Satellite Organization (EUMETSAT), for implementing Copernicus.

A particular breakthrough in the definition and implementation of Copernicus is the data policy, declaring all Sentinel mission data and all Copernicus Service information free and open. This decision is reflecting the experience made with similar programs in the United States (e.g., Landsat) and the new and easy access to digital data provided by the Internet. This Copernicus data policy is aimed to stimulate the use of Earth observation data, including the implementation of new commercial services and businesses (Schreier 2016). The Copernicus data policy is also driven by the European INSPIRE (Infrastructure for Spatial Information in the European Community) directive (INSPIRE 2007), which harmonizes the policy, electronic access, and formats to geographic information within Europe.

The free and open policy does not apply for data from the contributing missions. These data from often higher resolution and commercial missions are purchased by the Copernicus Data Warehouse mechanism from the mission operators. The supply of this contribution mission data is regulated by the demand of the Copernicus Core Services and other Commission- and Member States-related activities. These have free access to the Data Warehouse.

The entire costs of the Copernicus program starting on European Commission side in the initial investment in the Framework 6 and 7 Research Programs and with ESA on GMES service evolution and the Copernicus Space Component up to the end of the first operational phase in 2020 are estimated about 8,8 billion Euro. This amount is complemented by various national activities and R&D budgets in the Horizon 2020 research program of the European Union. The first financial framework (until 2020) financed the procurement of current series of Sentinel satellites up to the D-units (four satellites for most Sentinel series). The European Commission is regularity evaluating the benefit of Copernicus for its policy, for economy, and the European citizen (PWC 2017). Although by mid-2018 still ongoing discussions on the BREXIT cast a slight shadow on the budget of the European Commission, it is assumed that the Copernicus program will be further financed and even be enlarged in satellites and services within the next Multiannual Financial Framework (MFF; 2021–2027).

The Copernicus Space Segment

The Copernicus Space Segment provides Europe with an autonomous access to spaceborne Earth observation data. The characteristics of the dedicated Sentinels have been defined following a process of recognizing European observation needs and the continuity of past ESA missions on one side and avoiding any conflict of interest with other European national and commercial missions, on the other side. The Sentinel observation data therefore refrain from delivering a better geometric resolution than 10 m (pan channel of Sentinel-2). Any geometric resolution better than 10 m is left to the Copernicus contributing missions. Whereas Copernicus Sentinel data is available at no cost, the contributing missions are available only via individual license fee mechanisms. For the various Copernicus Services, using contributing mission data, these licenses are organized in the Copernicus Data Warehouse and paid from the Copernicus budget.

In order to increase the frequency of observations and to guarantee redundancy in case of failures, two Sentinels of each series shall always be in orbit. The first series of Sentinels will have four spacecraft (A-, B-, C-, and D-unit) of about at least 7 years orbital lifetime. This would give this series of Sentinels an operation lifetime until the early 2030s.

Currently, six series of Sentinels constitute the operational Copernicus constellation. They deliver global Earth observation data in the optical and microwave domain, as well as information about the atmosphere and the oceans. The characteristics of the current Sentinel mission series are depicted in Fig. 2.

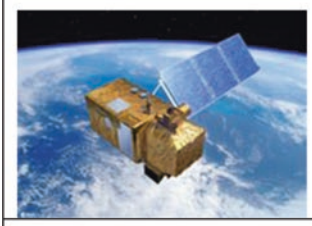
Sentinel/ first launch	main instruments	application examples
Sentinel-1/ 2014 	C-Band Synthetic Aperture Radar (SAR); 5m – 40 m resolution	Ocean and ice monitoring, martime awareness; ship and oil detection; land surface moisture and topography, land/ soil motion (interferometry)
Sentinel-2/ 2015 	MSI (Multi Spectral Instrument) 13 spectral bands Spatial resolution: 10 m, 20 m and 60 m	European wide-swath high-resolution super-spectral imaging mission designed for data continuity for operational land and security services
Sentinel-3/ 2016 	OLCI (Ocean and Land Colour Instrument); Spatial sampling: 300 m @21 bands SLSTR (Sea and Land Surface Temperature Radiometer)	European global land and ocean monitoring mission. 2 day global coverage Earth observation data for sea and land applications
Sentinel-4/ 2022 	UVN instrument: high resolution spectrometer (305-400 nm) (400-500 nm) (750-775 nm) spatial sampling: 8 km	Covers the needs for continuous monitoring of the atmospheric chemistry from the geostationary orbit. The main data products will be O3, NO2, SO2, HCHO and aerosol optical depth, generated with high temporal resolution (~ 1 hour).
Sentinel-5 Precursor/ 2017 	UV-VIS-NIR-SWIR push-broom grating: TROPOMI Spectral Range: 270-495 nm, 710-775 nm, 2305-2385 nm ground pixel 7x3,5 km^2	Dedicated to monitoring our atmosphere. The satellite carries the state-of-the-art Tropomi instrument to map a multitude of trace gases such as nitrogen dioxide, ozone, formaldehyde, sulphur dioxide, methane, carbon monoxide and aerosols – all of which affect the air we breathe and therefore our health, and our climate.

Fig. 2 The Copernicus Sentinel missions overview

Sentinel/ first launch	main instruments	application examples
Sentinel-5/ 2021 	high resolution spectrometer Spectral Range: 270-370 nm, 370-500, 685-773 nm, 1590-1675 & 2305-2385 nm ground pixel 7x3,5 km^2	Continuous monitoring of the atmospheric chemistry at high temporal and spatial resolution from a low-Earth orbit. The mission will provide coherent and long-term information on atmospheric variables in support of European policies
Sentinel-6/ 2020 	Poseidon-4 (SAR Radar Altimeter) AMR-C (Climate-quality microwave radiometer)	To provide continuity of the reference, high-precision ocean topography service after Jason-3

Fig. 2 (continued)

The early success and acceptance of the Sentinel data created a demand to consider even an extension of the current Sentinel observational capabilities. These resulted in considerations for the timely expansion of the Sentinel fleet (potentially from Sentinel 7 to 10). The following additional key observational requirements for the expansion missions are stated (as of end 2017):

Sentinel Exp.	Objective
Sentinel-7	Multi-satellite mission to measure the anthropogenic contribution to the CO2 cycle
Sentinel-8	Observations at high spatiotemporal resolution in the thermal infrared region of the optical spectrum in order to complement and expand the current Sentinel-2 measurements
Sentinel-9	New measurements on critical parameters of interest for the polar regions, such as sea ice/floating ice concentrations and surface elevation
Sentinel-10	Optical observations with hyper-spectral imaging capabilities to expand the current Sentinel-2 measurements

In parallel, analysis has started for a long-term scenario of Copernicus. Herein, the strategy of the next generation of Sentinels, operational beyond 2030, is defined. This strategy calls for an extension of the current Sentinel capabilities, e.g., potentially with an additional L-Band SAR and thermal components on the optical facilities.

Both Sentinel Expansion and Sentinel Extension mission are currently being discussed and will be turned into concrete plans and projects, pending on the appropriate budget from the European Commission and ESA.

The management of all Sentinel data from satellite data downlink to the distribution of Application Ready Products (ARD) to Copernicus Services and general

users is performed by the Copernicus Core Ground Segment. Likewise the Sentinels, it is managed by ESA and operated by European companies and aerospace entities, contracted by ESA.

The downlink of Sentinel data is performed via X-Band, received via four main core ground stations in Europe and in Northern Canada. An alternative downlink – only for Sentinel-1 and -2 series– is via a Laser Communication Terminal (LCT) mounted on board these Sentinels. Via a Laser beam, captured data is transmitted with up to 1.8 Gb/sec to currently one European Data Relay Satellite (EDRS-A). From there, the data is transmitted via Ka-Band to few European EDRS stations (Weilheim, DE, Redu, BE, Harwell, UK). EDRS increases the amount of data available especially with Sentinel-1 and therewith the global coverage. EDRS allows getting data faster from areas outside the reception of the core ground stations.

The X-Band and Ka-Band stations are connected via redundant high-capacity fiber links with the Processing and Archiving Centers (PACs). There, all the raw data is transformed into user products, all raw data and products are archived, and all products are disseminated to the Copernicus Core Services and dedicated Internet hubs. From these hubs, general users and European and international partners can grab the free and open Sentinel product data for their own use (Fig. 3).

As of mid-2018, the "open access hub" keeps all Sentinel product data from the beginning of operations (i.e., 2014). Meanwhile, the volume of data has reached several petabytes, and the science hub is overloaded with international data requests. From the beginning of operations to end of September 2018, about 89,52 PB of data have been downloaded by more than 170.000 users from the ESA Internet hubs (ESA 2018).

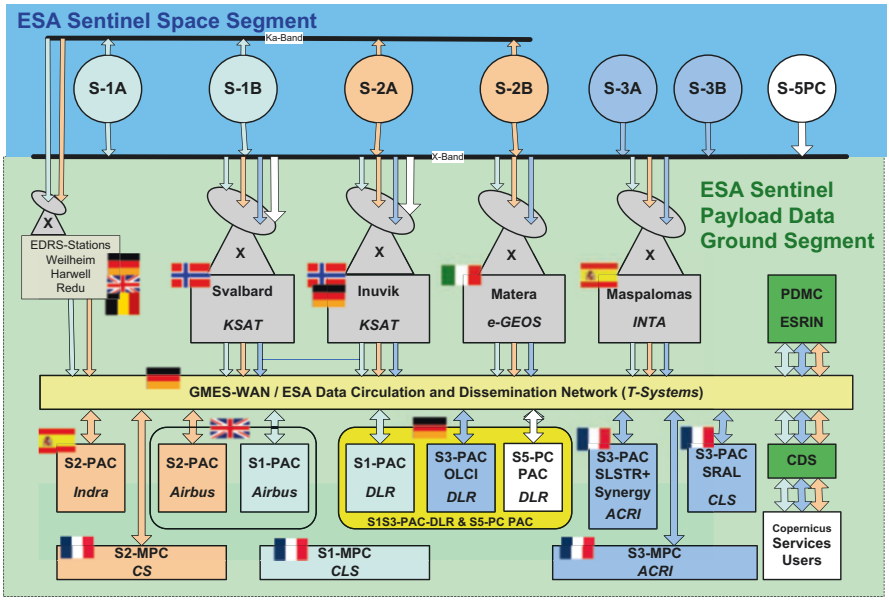


Fig. 3 Copernicus Sentinel Core Ground Segment in Europe and its functions. (Graphics: DLR)

The Copernicus Collaborative Ground Segment and Big Data

In order to satisfy all user requests for Sentinel data, ESA has opened alternative means to have access to data, among them, encouraging Member States to open their own national data distribution portals, eventually supported by further functions to make value out of the data. Next to the general "open access hub," a dedicated hub serves the Copernicus Core Services. International partners, such as USGS, NASA, NOAA, and the Australian CSIRO, get Sentinel products via an "international hub." European states are served via a "collaborative hub" (Fig. 4).

The purpose of the "international" and the "collaborative" hubs is to allow European and international partners to get most recent Sentinel data from this server and replicate these on Internet platforms for their national users. These Internet platforms offer regional or global data, and some offer additional capabilities such as processing of the Sentinel data directly with processors attached to the platform. By 2018 14 such national European platforms are in operations, all with slightly different data holdings and additional services (ESA, Serco, 2017a, b). For instance, the German national platform CODE-DE offers global Sentinel-1 and Sentinel-2 data, various preprocessed geo-information products, and a cloud space for user remote processing (Kiemle et al. 2016; Keuck et al. 2017).

Early in the operations of the Sentinel hubs, the Internet companies Amazon and Google uploaded the free and open data from Sentinel-1 and Sentinel-2 on their global data storage and processing systems. The Slovenian company Synergize was supported by Amazon to offer all Sentinel-2 data for download from Amazon servers (http://www.sentinel-hub.com). Google is offering this data on its Google Earth Engine (https://earthengine.google.com), offering free computing space for scientific and noncommercial purposes.

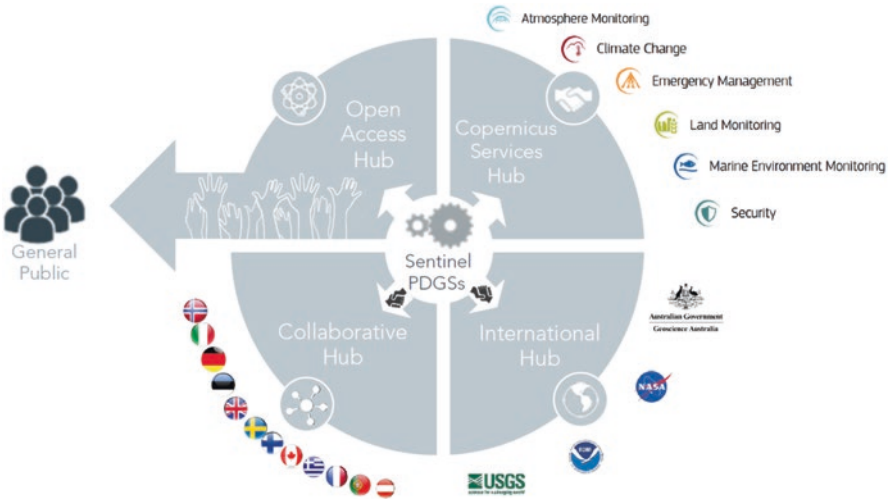


Fig. 4 The Sentinel Data Access System configuration by end Y2016. (ESA, Serco, 2017a, b)

The overwhelming demand for Sentinel satellite data and the pressure from the commercial Internet providers motivated the European Commission to take special actions in order to have all Sentinel data and information ready for online computing and therewith to support new scientific approaches and innovative Internet-based businesses. Together with ESA, the European Commission launched the creation of Copernicus Data and Information Access Systems (DIAS), to be implemented by European consortia. DIAS platforms shall have all Sentinel data (and more information) available online, shall enable remote cloud processing and moreover, and shall allow third-party users to establish their own – science, governmental, and commercial – offers based on these resources. End of 2017 contracts with four DIAS providers have been signed.

In any case, the avalanche of Earth observation data coming from Copernicus, national missions, and those operated by new commercial start-ups (New Space) is creating a new Big Data ecosystem. For Europe, it is estimated that Internet-based Earth observation online services will increase from about 10% today (2017) to about 25% in the next few years (EARSC 2017).

The online availability of global coverage long-term time series together with large-scale computing facilities also allows unprecedented advances in the understanding of global processes such as vegetation, global change, and urbanization (Hansen et al. 2013; Esch et al. 2016). Online availability of data is also a basis for new companies being created in the Earth observation value-added sector and big industrial players getting interested in adding Earth observation data in their business processes (Linz 2017).

The Copernicus Service Segment

Created as a program, where the data from satellites shall satisfy the needs of European policymakers, economy, and the citizen for geo-information, the Copernicus program has as a key element the Core Services. These services have been defined in comprehensive requirements process with many governmental and institutional stakeholders in Europe. Nearly all of them have been tested and prototyped during European Commission Framework 6 and 7 projects and have used the Earth observation data available before the Sentinels. The operational execution for most of the services has been entrusted by the European Commission to European agencies, involved by its mission statement in environmental, planning, and security topics. Further on, these entrusted entities implement the generation of the geo-information services through contracts to European consortia, selected in a competitive tendering process. With a few restrictions in the Emergency Management and Security Services, all products and information from these Core Services are – according to the general Copernicus data policy – free and openly available via Internet portals.

Currently, the following six Copernicus Core Services exists (adopted from the description on http://copernicus.eu/main/services):

The *Copernicus Atmosphere Monitoring Service* provides the capacity to continuously monitor the composition of the Earth's atmosphere at global and regional scales. This service capacity encompasses the description of the current situation (analysis), the prediction of the situation a few days ahead (forecast), and the provision of consistent retrospective data records for recent years (reanalysis). The service generates geophysical products which require further technical processing and various forms of high-level information to support decisionmakers. The main areas the Copernicus Atmosphere Monitoring Service focuses on are:

- Air quality and atmospheric composition
- Ozone layer and ultra-violet radiation
- Emissions and surface fluxes
- Solar radiation
- Climate forcing

The Copernicus Atmosphere Monitoring Service is entrusted to the European Centre for Medium-Range Weather Forecast (ECMWF), Reading, UK.

The *Copernicus Marine Environment Monitoring Service* provides regular and systematic information about the physical state and dynamics of the ocean and marine ecosystems for the global ocean and the European regional seas. This data covers analysis of the current situation, forecasts of the situation a few days in advance, and the provision of retrospective data records (reanalysis). The Copernicus Marine Environment Monitoring Service calculates and provides products describing currents, temperature, wind, salinity, sea level, sea ice, and biogeochemistry. These factors support marine and maritime applications and related EU policies, e.g., in the fields of:

- Marine safety
- Marine and coastal environment
- Marine resources
- Weather, seasonal forecasting, and climate

The Copernicus Marine Environment Monitoring Service is entrusted to Mercator Océan, Ramonville Saint-Agne, France.

The *Copernicus Land Monitoring Service* provides geographical information on land cover, land use, land cover-use changes over the years, vegetation state, or water cycle. Applications that are built upon and integrate the information supplied by the service can provide support in areas such as spatial planning, forest management, water management, agriculture and food security, and emergency management, among others. Service priorities and their relevance to users are defined and validated by the European Commission and the Member States. The three main components of the Copernicus Land Monitoring Service are currently:

- A Global component
- A pan-European component
- A local component

The Copernicus Land Monitoring Service is entrusted to the European Environmental Agency (EEA), Copenhagen, Denmark. The global component of the Land Service is coordinated by the European Commission DG Joint Research Centre (JRC), Ispra, Italy.

The *Copernicus Climate Change Service* is designed to respond to changes in the environment and society associated with climate change. The service will provide information for monitoring and predicting climate change and help to support adaptation and mitigation strategies. It will provide access to several climate indicators (e.g., temperature increase, sea level rise, ice sheet melting, ocean warming) and climate indices (e.g., based on records of temperature, precipitation, drought events) for both the identified climate drivers and the expected climate impacts. The Copernicus Climate Change Service will enter a pre-operational stage by the end of 2017. The operational phase will start before the end of 2018. This pre-operational phase is also supported by a series of projects funded by the EU research framework program related to climate modeling and observation analyses.

The Copernicus Climate Change Service is entrusted to the European Centre for Medium-Range Weather Forecast (ECMWF), Reading, UK.

The *Copernicus Emergency Management Service* delivers warnings and risk assessments of floods and forest fires and provides geospatial information derived from satellite images on the impact of natural and man-made disasters all over the world (before, during, or after a crisis). Through these, it supports crisis managers, civil protection, and hydrometeorological authorities, humanitarian aid actors dealing with natural disasters, man-made emergency situations, and humanitarian crises, as well as those involved in recovery, disaster risk reduction, and preparedness activities. As an EU service, the emergency management's first priority is responding to EU needs and interests, whether within the EU or abroad. The Emergency Management Service is provided free of charge to authorized users. The service has two main components:

- Early warning
- Mapping

The Copernicus Emergency Management Service is implemented by the European Commission DG Joint Research Centre (JRC), Ispra, Italy.

The *Copernicus Security Service* is one part of the Copernicus program. It aims to support related European Union policies by providing information in response to the security challenges Europe is facing, namely, improving crisis prevention, preparedness, and response capacities in the following key areas:

- Support to EU External Actions (implemented in partnership with the
- European Union Satellite Centre and the Emergency Management Service)
- Maritime surveillance (implemented in partnership with the European Maritime Safety Agency, EMSA)
- Border surveillance (implemented in partnership with FRONTEX) (Fig. 5)

Besides these Copernicus managed and funded Core Services, several European and national agencies and entities are already using Sentinel data for their services.

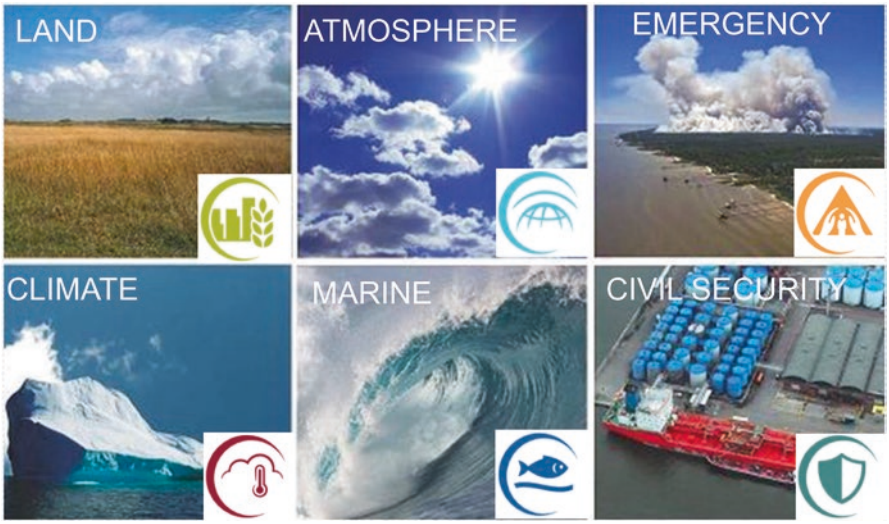


Fig. 5 The six Copernicus Core Services, delivering geo-information and decision support

For instance, the European Maritime Safety Agency (EMSA) in Lisbon, Portugal, is using, next to other spaceborne SAR data, also the data from Sentinel-1 for its trans-European oil-spill detection program CleanSeaNet (EMSA 2017). In the framework of the International Charter on Space and major Disasters (www.diasterscharter.org), the DLR Center for Satellite Based Crisis Information (ZKI) and several international partners are using Sentinel-1 and Sentinel-2 data for monitoring of global natural and humanitarian crisis situations (Voigt et al. 2016).

World Cultural Heritage and the Copernicus Program

Copernicus has to respond to emerging needs on critical geo-information for European interest. The Copernicus Core Services are therefore under regular review to consider new services and new user groups to be included in their free and open portfolio. After the first years of service operations, the European Commission has started a series of workshops to review needs in new services and listen to the demands of new user groups. Besides "polar applications," "agriculture," and "energy" (to name a few), a special workshop was also conducted on April 24, 2017, in Brussels (Copernicus Support Office 2017). The workshop covered the following aspects:

- Intermediate and end-users' needs in the Cultural Heritage domain
- An overview of space-based applications in support of Cultural Heritage at EU and global level

- An outline of requirements for Copernicus-based products/services in support of Cultural Heritage
- Potential implementation scenarios for a structured Copernicus-based approach for Cultural Heritage support

About 100 participants of the workshop discussed these issues with the European Commission Copernicus Office. Stakeholders, such as the UNESCO, NEREUS, EARSEL, and national institutions, such as the German Archaeological Institute (DAI), presented their needs and capabilities in this area. Several European research framework and ESA projects on the matter have been presented.

The discussion and analysis yielded that Cultural Heritage applications range from long-term monitoring of various environmental conditions up to very fast crisis support in case of conflicts and natural disasters. For the latter, the need for fast access to very high-resolution optical and SAR data is evident. This need is shared with already existing Copernicus Core Services such as the emergency management and the civil security services.

The Copernicus civil security service already has a diverse spectrum of applications (e.g., border monitoring, maritime surveillance, external relations) and therewith is working with several European entities. The case of the destruction of the antiquities of Palmyra in Syria showed that conservation of Cultural Heritage and fast reaction in military conflicts seems to have similar needs. Therefore, some stakeholders would like to have the Copernicus security service have closer connections to European military, such as the European Defense Agency (EDA). It needs to be contemplated, however, whether such proximity of "culture" to "military intelligence" and therewith "classified information" would be appropriate. On the other site, organizations such as UNESCO have to rely on national police and military expertise on dealing with issues such as illegal trade of antiquities. For this purpose, UNESCO has signed an agreement with Italy to ask for support from a special task force of the Italian Carabinieri (UNESCO 2016).

National Space Agencies and aerospace research centers, such as DLR, support the use of Earth observation to preserve cultural heritage. DLR has supported the German Archaeological Institute (DAI) in various observations of its international sites. Likewise, DLR was active to monitor the destructions of the "Islamic State" in Palmyra (Cerra et al. 2016, 2017; Jung et al. 2016; and other chapters in this book).

Supporting the needs of European institutions and those of European citizens is the primary objective of the Copernicus program. Safeguarding the European Cultural Heritage by using spaceborne reconnaissance information from the Sentinels and very high-resolution contributing missions therefore would perfectly fit to launch a new service within the Core Services. More analysis and prototyping and improved dialogues with stakeholder and users are required to take place before defining cultural heritage preservation as an integral part of the Commission-financed services within Copernicus. Therefore, the European Commission has contracted Price Waterhouse Coopers of France with an analysis and developing options for such an implementation. At the time of writing (September 2018), this analysis was presented to the Copernicus boards, and further decisions are pending.

In any case, Earth observation satellite data – most of them available by Copernicus for free and open to all – is an unquestionable tool for the global societal goal to preserve cultural sites and monuments, in Europe and all over the globe.

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