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D 1.4 – Trends and challenges in the space/geospatial sector

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Work package / Task:

WP1- Preparing the Space/Geospatial Sector Skills Strategy
T1.3- Analysing trends, challenges and opportunities in the GI and EO sector: setting-up a technology and non-technology watch

Short Description:

This document describes the activities performed under Task 1.3 (*Analysing trends, challenges and opportunities in the GI and EO sector: setting-up a technology and non-technology watch*). One of the project objectives is to define a long-term and sustainable strategy to fill the gap between supply and demand for space/geospatial education and training taking into consideration the current and expected technological and non-technological developments in the space/geospatial related sectors (e.g. ICT). To reach this goal an extensive analysis of the most relevant trends in geospatial sector is required. Today the geospatial world is strongly connected to other technological sectors such as ICT but also to other non-geospatial sectors such as the economy, the communication sectors and the society at large.

Keywords:

Geospatial, Spatial, Trend, Technology Watch, Big Data, Internet of Things, Copernicus, Artificial Intelligence, cloud, Agenda 2030, SDG

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Acronyms

Acronym	Description
AI	Artificial Intelligence
AR	Augmented Reality
BoK	Body of Knowledge
CAPEX	CAPital EXpenditure
CE	Circular Economy
CRM	Customer Relationship Management
CS	Citizen Science
DEM	Digital Elevation Model
DIAS	Data and Information Access Services
EC	European Commission
EACEA	Education, Audio-visual, Culture Executive Agency
EARSC	European Association of Remote Sensing Companies
EARSeL	European Association of Remote Sensing Laboratories
ECOSOC	UN Economic and Social Council
ECTS	European Credit Transfer and Accumulation System
ECVET	European Credit System for Vocational Education and Training
EO	Earth Observation
EO/GI	EO and GI sectors
EQF	European Qualifications Framework
EU	European Union
ESA	European Space Agency
ESERO	European Space Education Resource Office
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
GDPR	General Data Protection Regulation
GEO	Group on Earth Observations
GeoBI	Geosoatial Business Intelligence
GEOSS	Global Earth Observation System of Systems
GI	Geographic Information
GISIG	Geographic Information System International Group
GIS&T BoK	Geographic Information Science & Technology Body of Knowledge
GLONASS	GLObal NAvigation Satellite System

GNSS	Global Navigation Satellite System
GPS	Global positioning System
ICT	Information Computer Technology
IEAG	Independent Expert Advisory Group
Info-aaS	Information as a service
INSPIRE	Infrastructure for Spatial Information in Europe
IoT	Internet of Thinks
ISPRS	International Society for Photogrammetry and Remote Sensing
ISWM	Integrated Solid Waste Management
IUCN	International Union for Conservation of Nature
UNSD	UN Sustainable Development
LRA	Local and Regional Authorities
MAEOS	Mall Earth Observation Services
MODIS	Moderate-resolution Imaging Spectroradiometer
MOOC	Massive Open Online Course
NEREUS	Network of European Regions Using Space Technologies
NOAA	National Oceanic and Atmospheric Administration
NSS	National Statistical Systems
OECD	Organisation for Economic Co-operation and Development
OGC	Open Geographical Consortium
OER	Open Educational Resources
OPEX	OPerating EXpense
PaaS	Platform as a service
PNT	Positioning, navigation and timing
POI	Points of Interest
RD	Reference Document
RS	Remote sensing
RUS	Research and User Support (for Sentinel Core products)
SAR	Synthetic Aperture Radar
SaaS	Software as a Service
SDG	Sustainable Development Goals
SME	Small and Medium Enterprises
SNAP	Sentinel Application Platform
TEP	Thematic Exploitation Platform

TW	Technology Watch
UAS	unmanned aircraft systems
UAV	Unmanned Aerial Vehicles
UN	United Nations
UNECE	United Nations Economic Commission for Europe
UNEP	United Nations Environmental Programme
UN-GGIM	UN Committee of Experts on Global Geospatial Information Management
VET	Vocational Education and Training
WP	Work Package

Glossary

- **Body of Knowledge (BoK)** is the complete set of concepts, terms, activities and relations between them, that make up a professional domain, (in this case EO/GI BOK) as defined by the relevant learned society or a professional association.
- **European Credit Transfer and Accumulation System (ECTS)** is a credit system designed to make it easier for students to move between different countries.
- **Education, Audiovisual and Culture Executive Agency (EACEA)** manages funding for education, culture, audiovisual, sport, citizenship and volunteering.
- **European Centre for the Development of Vocational Training (CEDEFOP)** is one of the EU's decentralised agencies. Founded in 1975 and based in Greece since 1995, it supports development of European vocational education and training (VET) policies and contributes to their implementation.
- **European Credit System for Vocational Education and Training (ECVET)** have common instruments helping individuals in transfer, recognition and accumulation of their assessed learning outcomes, to achieve a qualification or to take part in lifelong learning.
- **European Qualifications Framework (EQF)** is a common European reference framework whose purpose is to make qualifications more readable and understandable across different countries and systems.
- **Geographic Information (GI)** is the data of a geographic location spatial data, their combination with non-spatial information (e.g. statistical data) and their representation as a map.
- **Geographic information: Need to Know (GI-N2K)** is a project under the Lifelong Learning Programme Erasmus of the EU that aimed to improve the way in which future GI professionals are

prepared for the labour market so that the GI sector in general can evolve in a dynamic and innovative way.

- **Geographic Information System (GIS)** is a computerized tool designed for storing, analysing and consulting data where geographic location is an important characteristic or critical to the analysis.
- **Sector Skills Alliance** (SSAs) are designed to tackle skills, aligning vocational education and training (VET) systems with labour market needs. This is done by: (i) modernising VET by adapting to skills needs and integrating work-based learning, (ii) strengthening the exchange of knowledge and best practices, (iii) improving labour market mobility, (iv) increasing the recognition of qualifications. More info.
- **Skill** means the ability to apply knowledge and use know-how to complete tasks and solve problems. In the context of the European Qualifications Framework, skills are described as cognitive or practical skills.
- **Vocational Education and Training (VET)** is a key element of lifelong learning systems equipping people with knowledge, know-how, skills and/or competences required in particular occupations or more broadly on the labour market.

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1. Introduction

EO4GEO is an **Erasmus+ Sector Skills Alliance** gathering **26 partners from 13 EU countries,** most of which are part of the **Copernicus Academy Network.** Be they from academia, public or private sector, they are all active in the education and training fields of the space / geospatial sectors. The project is also supported by a strong group of Associated Partners mostly consisting of associations or networks active in space/geospatial ecosystem. The project started on January 1st, 2018, upon approval by the EU Education, Audiovisual and Culture Executive Agency (EACEA) and runs over four years.

EO4GEO **aims to help bridging the skills gap in the space/geospatial sector** by creating a strong alliance of players from the sector/community reinforcing the existing ecosystem and **fostering the uptake and integration of space/geospatial data and services**. EO4GEO will work in a **multi- and interdisciplinary** way and apply innovative solutions for its education and training actions including: case-based and collaborative learning scenarios; learning-while-doing in a living lab environment; on-the-job training; co-creation of knowledge, skills and competencies; etc.

EO4GEO will define a long-term and sustainable strategy to fill the gap between supply of and demand for space/geospatial education and training taking into account the current and expected technological and non-technological developments in the space/geospatial and related sectors (e.g. ICT). The strategy will be implemented by: creating and maintaining an ontology-based Body of Knowledge for the space/geospatial sector based on previous efforts; developing and integrating a dynamic collaborative platform with associated tools; designing and developing a series of curricula and a rich portfolio of training modules directly usable in the context of Copernicus and other relevant programmes and conducting a series of training actions for a selected set of scenario's in three sub-sectors - integrated applications, smart cities and climate change to test and validate the approach. Finally a long-term Action Plan will be developed and endorsed to roll-out and sustain the proposed solutions

For more information on the project please visit http://www.eo4geo.eu/about-eo4geo/.

1.1. Aim of the document

The aim of this document is to describe the activities performed under ***Task 1.3 Analysing trends, challenges and opportunities in the GI and EO sector: setting-up a technology and non-technology watch***.

One of the project aims is ***to define a long-term and sustainable strategy to fill the gap between supply of and demand for space/geospatial education and training taking into***

account the current and expected technological and non-technological developments in the space/geospatial and related sectors (e.g. ICT). To reach this goal an extensive analysis of the most relevant trends in the geospatial and related sectors is required. Moreover, also non-technological trends might influence developments in the sector. Indeed, Today the geospatial world is strongly connected to other technological sectors such as ICT but also to other non-geospatial sectors such as the economy, the communication sectors and the society at large. Geospatial trends could be used for updating academic programmes, government regulators, while professional organizations are attempting to develop appropriate methods for training their necessary skill sets, creating helpful credentials, i.e., licenses, degrees and certifications. For this reason the following chapters will analyse not only the geospatial trends but also all other relevant trends and opportunities having an impact on geospatial world.

1.2. Methodology

Task 1.3 is based on a desktop research of the most important trends. The methodology used for task implementation consists of an analysis of relevant documents on the addressed topic, direct contacts with sectors experts and internal knowledge and expertise of the Consortium. The analysis of the various information sources evidenced heterogeneous formats, styles and level of contents; for this reason, a synthesis was necessary outlining the most relevant information for the purposes of the task. Below are listed the main sources at the base of the document.

The sources for collecting the information synthetized in this document are many and different. First of all reports and documents listed in the section 9. Another fundamental source is the workshop in Castellon de la Plana held from 30 May to 1 June 2018 and the bilateral meeting with partners and experts. The workshop was very helpful for the task purposes. Here we especially mention Steven Ramage's presentation ***Global changes are local*** [RD 38], where the key elements for the future trends were addressed. The most relevant priority for the GEO related to the scope of this document is the priority of the UN 2030 Agenda for the future strategy. A general description of the UN Agenda 2030 is put in chapter 6. The Agenda 2030 defines the targets that the countries give themselves as priority and will address the public funds in the next years. The use of geospatial data can support the Goals implementation and in this sense, it will be constitute an important skill for future geospatial technicians.

Other points emerged during the round table dedicated to trends and challenges as drivers for the future geospatial applications and having an impact on the professional skills are: the environmental and anthropogenic changes (Climate Change, situation awareness, risk management), the economy indicators based on geospatial data, the innovation in the communication, the integration of data and technology, the awareness of location.

1.3. Structure of the document

The document is structured as follows. In chapter 2, the background in terms of geodata definitions and main actors is described. The term space/geospatial data refers mainly to EO data, but also includes the provision of value added services. A separate sub section is dedicated to the analysis of the geospatial market actors from the point of view of industries and public authorities since they represents the demand and the offer for geospatial data and the evolution of these pillars impacts on the typology and quantity of future professionals. In this context, the market actors, described in chapter 2 are manly the EO value added services industry and the public authorities at regional and local level. This analysis does not include the space manufacturing industry. This analysis does not consider national public authorities that generally demand to the regional and local level the provision of data and services responding to the national mandate. The chapter 3 is focused on the technological trends; this list includes the most relevant informatics technologies and the latest evolution of satellite systems. The micro satellites description does not focus on the engineering skills, but rather on the impact on the future generation of geospatial services and data. The chapter 3 ends with a description of the model of services, as Info-aaS and Analytics.
Chapter 4 describes not technological trends for what concern the economy.
Chapter 5 describes not technological trends for what concern the communication.
Chapter 6 is entirely dedicated to the Agenda 2030 and SDG that the most general trend for the next years.
Chapter 7 describes the Technology Watch starting from OGC work.
Chapter 8 concludes, Chapters 9 and 10 dedicated the bibliography close the document.

2. Geospatial Market actors

2.1. Introduction

The term geodata, computerised geographic data, used interchangeably with geospatial data, refers to data that has a direct association with a location on the Earth's surface. Although many applications for geospatial data strongly relate to Earth observation, in a general way the geospatial data make use of Geographic Information Systems (GIS), navigation and location based services and integration with in situ data.

The Geospatial or Geoinformation Industry is today aligned with the mainstream market and add the spatial dimension and the localization to the digital infrastructure, systems and business processes. The most relevant Technology innovation and trends are: Cloud, IoT, Artificial Intelligence, Big Data, Crowd sourcing and Blockchain. They contribute to the expansion of the traditional space services and to the transformation of the Geospatial Industry that today is linked to IT and engineering industry. In the EARSC stakeholder consultation for MAEOS study [URL 29], it is represented the increase of the market for the geospatial services provided through web portals.

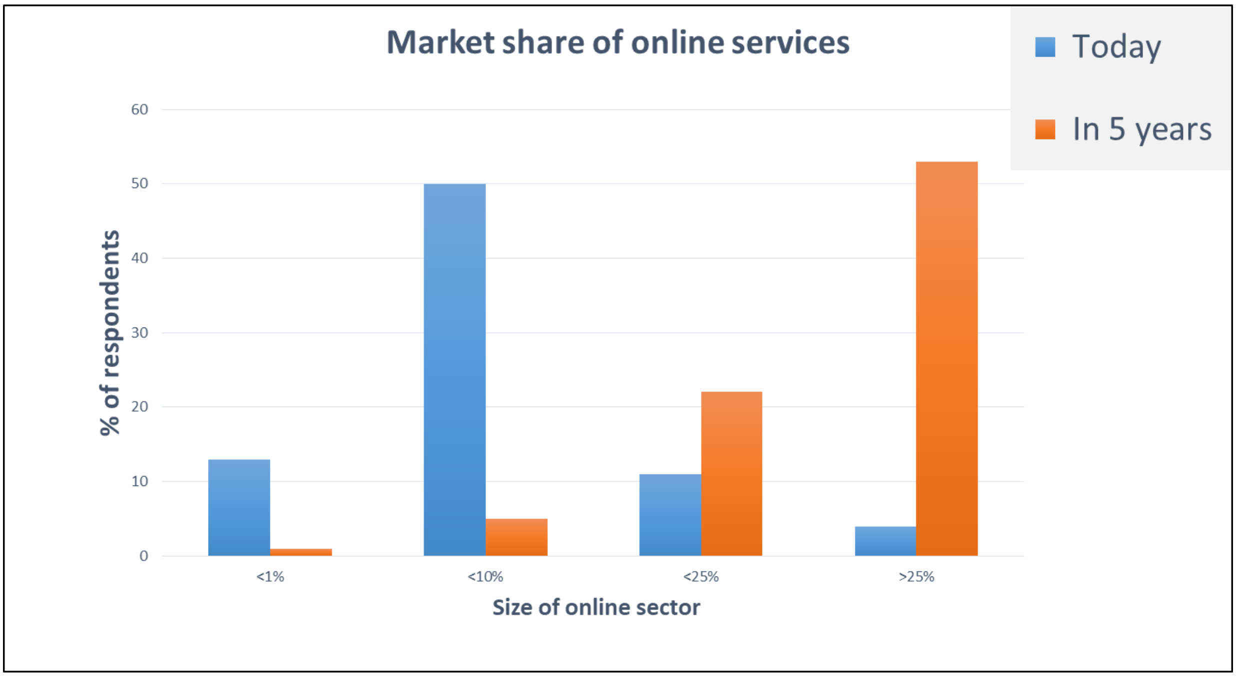

Figure 1: Increase of the market share for geospatial online services (EARSC stakeholder consultation for MAEOS study).

Mainstreaming of the geospatial market has created a big demand of geospatial services for business, government and consumer. This increasing demand is supported by the different way to access these services. Not only traditional information provides by data and services providers, but today customers can access to information, data, maps and analytics provided through web portals. Examples are the DIAS (Copernicus Data and Information Access Services) and the TEP (Thematic Exploitation Platform) for the provision of a collaborative, virtual work environment providing access to EO data and the tools, processors, and Information and Communication Technology resources required to work with them, through one coherent interface.

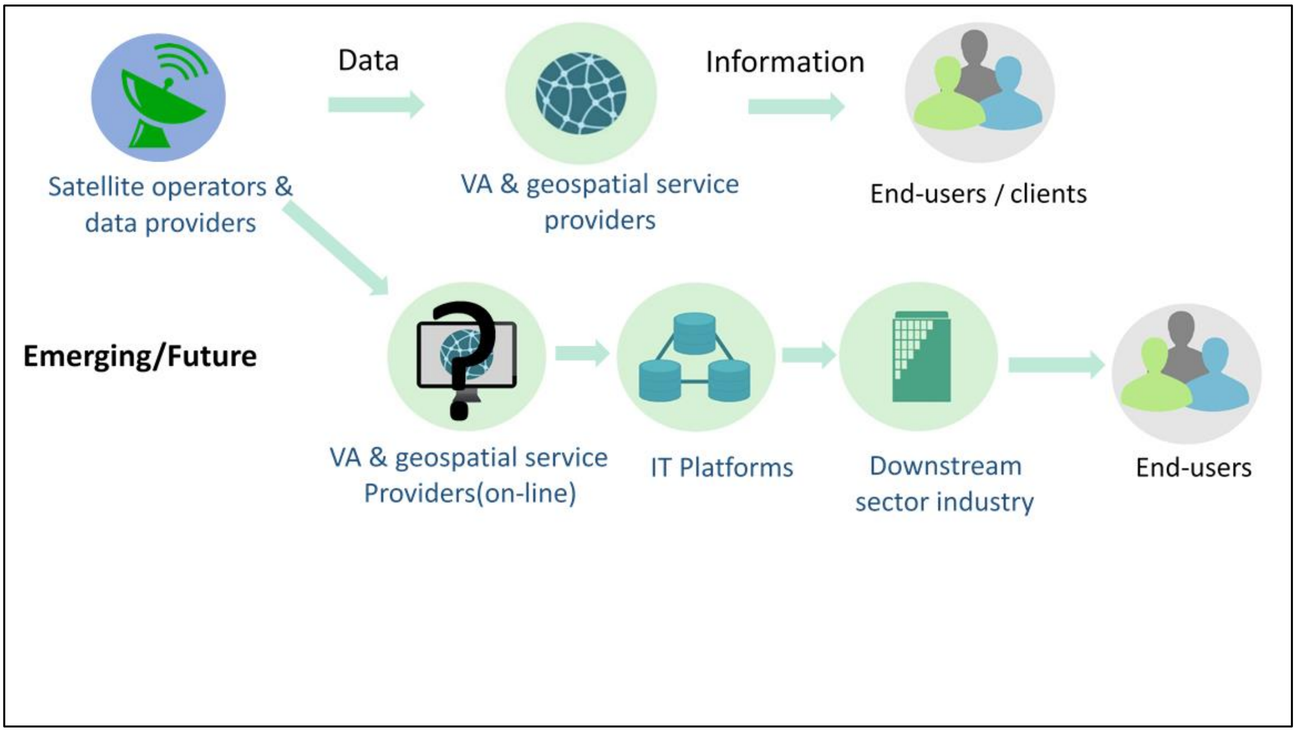

Figure 2: The emerging web portal for data and service provision having an impact on the demand

This transformation may have an impact also on the academic sector that shall be prepared to a transformation of the training to prepare and provide the future professionals for the geospatial industry but also on the training of the professionals that already works in the sector.

In the following chapters in sections 3, 4, **Errore. L'origine riferimento non è stata trovata.**, 6, the main relevant and innovative trends having an impact on the education skills, geospatial careers and relevant actors will be analysed. A focus on value added EO services Industry and the main customers that are Local and Regional Authorities as well as citizens that make use of the free Copernicus satellite data is presented below preceded an introduction on the geospatial technologies.

2.2. Geospatial technologies and professionals

Geospatial technology or Geo(infor)matics is a multidisciplinary field that includes disciplines such as surveying, photogrammetry, remote sensing, mapping, geographic information systems (GIS), geodesy and global navigation satellite system (GNSS). [RD 40].

Geospatial is the geographical data having locational information described in terms of coordinates (for instance latitude and longitude), address, city or ZIP code. Geospatial data may be gathered through satellite, global positioning system (GPS), geo tagging and remote sensing. Geographic Information System (GIS) is used for mapping and analysing geospatial data. Remote sensing is used to acquire geographical data without physical contact through sensors such as radars, radiometers and Lidar (a laser based light detection sensor).

Geospatial technologies is a term used to describe the range of modern tools contributing to the geographic mapping and analysis of the Earth and human societies. These technologies have been evolving in some form since the first maps were drawn in prehistoric times. In the 19th century, the long important schools of cartography and mapmaking were joined by aerial photography as early cameras were sent aloft on balloons and pigeons, and then on airplanes during the 20th century. The science and art of photographic interpretation and map making was accelerated during the Second World War and during the Cold War it took on new dimensions with the advent of satellites and computers. Satellites allowed images of the Earth's surface and human activities therein with certain limitations. Computers allowed storage and transfer of imagery together with the development of associated digital software, maps, and data sets on socioeconomic and environmental phenomena, collectively referredto GIS. An important aspect of a GIS is its ability to assemble the range of geospatial data into a layered set of maps which allow complex themes to be analysed and then communicated to wider audiences.

The fields and sectors deploying these technologies are currently growing at a rapid pace, informing decision makers on topics such as industrial engineering, biodiversity conservation, forest fire suppression, agricultural monitoring, humanitarian relief, and much more.

There are now a variety of geospatial technologies (www.aaas.org):

- **Remote Sensing**: imagery and data collected from space- or airborne camera and sensor platforms. Some commercial satellite image providers now offer images showing details of one-meter or smaller, making these images appropriate for monitoring humanitarian needs and human rights abuses. Lidar (Light Detection and Ranging), a remote sensing method using light pulses, combining with other data recorded by airborne systems, provide accurate three dimensional information about the shape of the Earth and its surface characteristics. These data can be used for inundation and storm surge modeling, hydrodynamic modeling, shoreline mapping, emergency response, hydrographic surveying, and vulnerability analysis of coastal zones (NOAA, 2018)

- **Geographic Information Systems (GIS)**: a suite of software tools for mapping and analyzing data that is georeferenced (assigned a specific location on the surface of the Earth, otherwise known as geospatial data). GIS can be used to detect geographic patterns in other data, such as disease clusters resulting from toxins, sub-optimal water access, etc.
- **Global Navigation Satellite Systems (GNSS)**: constellations of satellites, which provide positioning, navigation and timing (PNT) services to civilian and military users. Currently, besides the US Global Positioning System (GPS), already worldwide adopted in different market segments, similar systems have been developed (i.e. Russia’s GLONASS) or are currently in the deployment phase (EUs Galileo or China’s BEIDOU).
- **Internet Mapping Technologies**: software programs like Google Earth and other globe browsers like Microsoft Virtual Earth are changing the way geospatial data is viewed and shared. The developments of web user interfaces are also making such technologies available to a wider audience whereas traditional GIS has been reserved for specialists and those who invest time in learning complex software programs.

The geospatial value added services industry acquires, integrates, manages, analyses, maps, distributes, and uses geographic, temporal, and spatial information and knowledge.

Careers in geospatial technology disciplines are available in nearly all segments of the commercial, public, government and academic communities. Geographer, cartographer, physical scientist, computer scientist, GIS analyst, database administrator, applications specialist, project manager, remote sensing scientist, surveyor, photogrammetrist, earth observation scientist, are typical job titles. With the increased use of computers in imaging and geospatial technology careers, most jobs are in an office environment. However, certain careers may require extensive field work to verify results or to acquire data outdoors.

In the EO4GEO WP1 it was conducting a deep analysis of the existing offer and request of professional profiles. The results are well addressed in D1.1 and D1.3 reports. In this document the point of view of the value added services providers and public authorities demand is detailed in the following sections to have a clear picture of the status and the future projection of the geomatics in terms of careers.

2.4. EO service sector

The EO services sector is evolving very rapidly. An example of EO service is the reference maps. They are cartographic maps produced by satellite data integrated with in situ data. New and innovative satellite operators are entering the market, new data sources are emerging - including unmanned aircraft systems (UAS) and crowd or citizen sources using mobile technologies - and large IT companies are seeking to establish global, geospatial, businesses. All this is leading to more data and many more potential opportunities to exploit them.

Europe has a strong and diversified EO services industry[1] capable of providing many products and services derived from satellite observations across a wide range of applications[2]. These include satellite imagery as well as geospatial information and their applications often referred to as value-added products. They are mainly products developed for a single client, tailored to their needs and requiring specific expertise in processing and interpreting satellite data as well as domain knowledge relevant to the client. In this respect, selling into new markets requires a personal approach more like a physical good than a digital service which can be marketed broadly over the internet.

Europe boasts an active and vibrant EO services sector, with over 500 companies generating nearly €1.2b of sales and generating nearly 8000 highly skilled jobs. Over 95%, of the companies are small (<50 employees) or micro (<10 employees) in size [RD 39]. The sector is growing steadily at 8-10% per annum over the last 10 years and this is anticipated to continue supported significantly by the Copernicus Programme for which more than €7b [RD 39] investment have already been made available by EU Member States. Further investments are planned for the next Multi-Annual Financial Framework [URL 15] [URL 16] as foreseen in the recently published EU Space Programme proposal [URL 17]. The industry is welcoming the strong commitment being shown by the EC and calls upon the European Parliament and EU Council to endorse this budget proposal ensuring that a sufficient part is earmarked and dedicated to the development of Copernicus, especially to promote user uptake and to stimulate the development and exploitation of the data being generated.

The Copernicus programme has been designed to enable European decision makers' non-dependence on strategic geospatial information coming from anywhere else in the world, including data and information for climate change negotiations and actions, for security and humanitarian operations and for peacekeeping. It has now become the world's leading satellite Earth Observation programme and is playing a strong role to help develop the EO services sector in Europe helping to create new jobs and new businesses in Europe as part of the digital "big data" age.

[1] EO products and services are intermediate products and are mainly used by government (B2G) and businesses (B2B). They are referred to extensively throughout this paper. The focus in promoting them shall be on their use rather than the fact that they are derived from satellite observations or EO. Nevertheless, the specialist industry which generates them is referred to as the EO services industry and is the sector represented by EARSC.

[2] The European industry is active right along the value chain of EO services; from companies supplying data, value-added services to geo-spatial information as well as software and equipment to produce them. A profile of the industry is produced by EARSC every 2 years with the latest covering 2016 (published in 2017) showing over 500 companies generating nearly €1.2b of sales and generating nearly 8000 highly skilled jobs. Over 95%, of the companies are small (<50 employees) or micro (<10 employees) in size.

Continuity of data supply and the confidence that this will be maintained in the future is fundamental for businesses to develop. It is not just satellites that feature in these considerations but the whole value-chain covering all types of data sources and value-adding capabilities together with the technology necessary to handle and deliver these products into the hands of the policy makers. New technologies and business models have opened the way to more private investment and space- derived imagery is becoming a commodity. By reducing the cost of the imagery, the market is being opened to new players in the downstream sector and especially data coming from the Sentinel satellites [URL 23] which will be made available for free.

For the EO services industry, whilst EO data is the primary “raw material” they work with, they depend on its combination with other data sources, e.g. from other European initiatives such as INSPIRE or from Open Data developments, to generate commercial geospatial products and services. As new technologies become available to support the delivery of geospatial information to meet policy needs, security of the supply of satellite data is still of fundamental importance but diversity of sources is making this of less concern. Information services are likely to emerge as a major market sector in its own right, serving both commercial / industrial sectors and governmental and citizens needs alike. These disruptions to the marketplace are causing public and private sector to rethink and innovate. Consequently, the sector is also boarding in a strategy able to upskill their current or future employees as the agility in the market is key and it is recommended that public and private sector as well the academic sector work together in a close and effective way hence the skills strategy for the sector is cemented.

2.5. Local and Regional Authorities

Local and Regional Authorities (LRAs)[3] are recognised as being among the key potential customers of products and services based on information derived from the European Copernicus Programme. This is stated in the EU Regulation establishing the Copernicus Programme: “Copernicus users’ means (a) Copernicus core users: Union institutions & bodies, European, national, regional or local authorities entrusted with the definition, implementation, enforcement or monitoring of a public service or policy in the areas [atmosphere monitoring, marine environment monitoring, land monitoring, climate change, emergency management and security]” Regulation (EU) No. 377/2014, Article 3 Definitions §(9).

[3] LRAs are officially defined as “Public institutions with legal personality, component of the State structure, below the level of central government and accountable to citizens. Local Authorities are usually composed of a deliberative or policy-making body (council or assembly) and an executive body (the Mayor or other executive officer), directly or indirectly elected or selected at local level. The term encompasses different tiers of government, e.g. villages, municipalities, districts, counties, provinces, regions, etc. Local and regional authorities are also responsible bodies in charge of certain public policies of managerial tasks of territory management e.g. Port Authorities, Environment agencies etc.)” COM (2013) 280 final

As voice of regions for matters of space uses, NEREUS [URL 31] has become a reference in terms of advocating for a stronger regional dimension of EU space policies and programmes. The regional dimension is fundamental for bringing the added value of space to the citizens, and regions – intended as public administrations as well as ecosystems including local agencies, clusters, companies, universities and research centres - play an important role in this sense. The story of European space-based innovation is increasingly a story of regional ecosystems – regions constantly refining and developing their innovation fabric to both foster home-grown companies and attract others from across the continent.

- Regions are close to the public and have therefore broad outreach capabilities;
- Regions are a privileged scale to identify societal needs and growth capabilities for space;
- Regions are themselves a key user group of space-based services and products, in vicinity to diverse professional user communities;
- Regions are close to service providers and business communities, in particular SMEs; thus, an ideal level for measures targeting the commercialization of space.

The bulk of public spending / investment in Europe is done at the regional level (55%), making regional administrations key authorities in terms of public procurement, funding for the implementation of smart specialization strategies.

The reason for this is that LRAs can draw significant benefits from using products and services tailored to their specific needs. However, the use of space-based Earth Observation (EO) services is still not common amongst European LRAs and: to ensure that LRAs take up future services, a strategic deployment of Copernicus is needed. As stated in the Copernicus Regulation "...their [users] input should be actively sought through regular consultation with end-users from the public and private sectors" Regulation (EU) No. 377/2014, §(45).

In the frame of a collaborative project between NEREUS and the European Space Agency, an in-depth analysis was delivered to understand LRAs' needs (demand) and the potential for service provision at the local and regional level (supply) as well as identify the LRAs' experience with EO and potential roadblocks for deployment. The use of EO/Copernicus data and services by LRAs varies according to expertise and capacity in the region and the management or organisational structures that have been put into place (or lack of them). An emerging infrastructure that will impact on the Copernicus diffusion among the public authorities is DIAS. LRAs typically employ EO/Copernicus data/services in one or a combination of the following ways:

- LRA uses EO/Copernicus data and develops applications in-house,
- LRA procures a commercial service which employs EO/Copernicus data, or

- ➢ LRA appoints a public body or technical institute, which may develop applications or use services involving EO/Copernicus data to provide information supporting the work of the LRA.

Such trends depend from a series of framework conditions, such as:

- In the first case, using EO/Copernicus data to develop applications and create information in-house requires a sufficient amount of high level of technical expertise in the LRA as well as the capacity to receive and process EO data.
- In the second case, the use of EO/Copernicus data through commercial services requires a high level of commitment by the LRA as well as financial and human resources. There might also be the need for some technical expertise although the level depends on the relationship with the service provider and the type of service to be offered.
- In the last case, if public institutes provide high quality value added information, then relatively little EO technical knowledge is required by government department officials. However, these public institutes also act as facilitators and bridge between the public authorities and private service providers who can often provide an operational service more efficiently. To increase the uptake of operational EO/Copernicus based services, awareness raising in the public sector and capacity building in the private sector is necessary.

The same analysis of the LRA's needs looked into the roadblocks to the uptake of Copernicus data within LRAs, using the PEST business analysis tool [URL 30].

Political

Political obstacles concern the lack of support which could arise from a given mandate, regional strategy and/or legislation. Even if EO/Copernicus data may be useful for implementing certain EU directives or complying with legislation, the use of this data is not mandatory and often not investigated. The lack of a mandate or political support to employ EO/Copernicus data and services for the tasks of LRAs was often voiced as one of the main obstacles to:

(i) creating an interest in the LRAs about the possibilities of using this technology and
(ii) using EO/Copernicus technology to either replace existing techniques or to enhance the work of the LRA.

The lack of a mandate or political support contributes to a lack of interest within departments and institutes of LRAs and therefore the willingness to explore and adopt new working practices. Even if there is knowledge and an interest in using EO/Copernicus data/services by technical staff, proposals may be blocked at higher levels of the hierarchy. Low awareness concerning the social value of EO/Copernicus among high level regional government directors is the root of the problem.

Economic

Economics concerns the efficient allocation of resources (financial, human and time) to perform the mandated tasks and given that these are scarce in most LRAs, they can cause hindrances in the uptake of EO/Copernicus data. In the past, and for some applications still today, the data cost is a high proportion of the cost of using EO and in the end prevents many LRAs from pursuing applications of EO for their work. A number of LRA departments and service providers who had demonstrated services to potential LRA users stated this. The fact that Copernicus data is available free of charge will change this. However, many LRAs stated that there are still significant costs involved for processing, adding value to the data and turning it into useful information.

The lack of qualified human resources is a major obstacle. Most LRAs do not have sufficient qualified staff that can either procure EO services or interpret EO data themselves.

On the other hand, the high costs appear also as the result of the way in which the use of EO has developed in many LRAs. The scattered distribution of individuals in LRAs that either have an interest, experience or use EO/Copernicus data/services is problematic for commercial service providers but could also create inefficiencies for the regions themselves when it comes to coordinating infrastructure and data acquisition, which may be duplicated. In order to explore the use of new technologies for routine work by LRAs there is also an investment in time needed, a resource, which is also limited. The time needed to define their needs and to assess the relevance of EO/Copernicus data is something that most LRAs are unable to invest in. Even if the LRA outsources the work to a commercial service provider there is still a lot of time and energy needed to define and develop the services with the service provider. Furthermore, the typically long procurement processes associated with public authorities cost time, labour and money.

Social

Social obstacles concern the reluctance to accept a (new) technology and change working practices. The social acceptance of a new technology and changing working practices is low, especially amongst civil servants working in LRAs. The possible efficiency gains, overall cost savings or improvement in public services of using a new technology are rarely investigated in some LRAs.

The willingness to use EO data and services is not only hampered by a general reluctance to new technology but also unfortunate experiences in the past. From the Walloon Region there is the example of how government departments had in the past turned to universities for EO data and were supplied with relatively raw data (little processing) which could not be used by the LRAs. Experiences have also led to worries about the cost, reliability, frequent availability and continuity of data sources. An LRA from Bavaria explained that EO data cannot be fully implemented in internal information systems if at least continuity of data supply is not guaranteed. The fact that the Copernicus programme is a public commitment for the provision of EO data by the EU/ESA is still not clear to many potential users.

Technological

Technological obstacles concern the lack of infrastructure for processing, storage and transfer, data access and the need to build competencies for operational service provision. Problems of infrastructure for data processing, storage and transfer were raised at the Azores workshop [URL 27] where the integration of EO data is performed in-house and the technical capabilities are within the departments. Currently, GIS infrastructure is development by government departments separately and there is little technology transfer between the departments. Presently, a centralised GIS is under development and will serve all government departments eliminating duplication of efforts. However, concern was raised about the large bandwidth required to receive Sentinel satellite data, the high storage capabilities needed and the communication costs associated with data transfer between government departments. When some workshop participants from the private sector recommended the use of cloud technology and increased use of private sector services this was not so easily acceptable for the LRAs present. As mentioned in the "Social" obstacles section earlier, it is difficult for LRAs to change working practices by using new technology. ***Data access was mentioned a couple of times at all workshops. There were varying degrees of knowledge on how to access sentinel data and the type of data (formats) that can be accessed***.

Other technological obstacles concern the structure of the EO landscape in a particular region. A problem mentioned at the Lombardy workshop [URL 28] is the lack of inexpensive user-friendly software for working with EO data. LRAs that have few trained staff do not have the opportunities to experiment and use data. This also has an implication for the use of EO in schools where future LRA staff could have had their first introduction to EO. Where there are very few service providers able to provide EO based products and services in a region like the Azores, outsourcing is not an option even though private companies in the business of geo-information may be in a better position to adopt the necessary new technologies and automated techniques for a cheaper, more efficient solution. Discussions during both the Lombardy and Bavaria workshops confirmed that pilot projects, demonstrations or other first experiences of EO for the LRAs were usually in collaboration with a research institute but for the use of EO based information to become routine and operational, a service provider has to provide it. Although some research institutes do provide EO based services to public authorities on a regular basis, most are not in a position to be able to do this and need a commercial service provider to make a project operational. However, if commercial service providers are not involved or it is not known whether the service in question is commercially viable, the initial demonstration project will end with no follow up as is so often the case. Recently the Pre-Commercial Procurement has been started also in space project as a good practise to let also the LRA to acquire research till the operation solution.

The roadblocks to EO/Copernicus take up were summarised as follows:

Political
• There is a lack of political mandate / support to using EO data
• There is low awareness at political level concerning the social value of EO data
Economic
• The cost / effort of processing satellite data to turn it into useful information is high
• The cost / effort to procure space-based services from providers is high
• There is a lack of awareness within LRAs on the potential uses of satellite data
Social
• There is resistance / difficulty with changing working practices within LRAs
• There are doubts about the continuity and reliability of the data
• There are doubts about the real gains and benefits of using EO data
Technological
• There is insufficient technical infrastructure in LRAs
• There are problems with accessing Sentinel data
• There are technical problems in processing Sentinel data to transform it into useful information
• There is a lack of available solutions fitting the needs of LRAs

In this sense, the Space Strategy for Europe, published by the European Commission in October 2016, includes specific mentions to the regional level, namely:

- With the European Structural Investment Funds, the Commission will **support research and innovation in Regions which have identified "space" as a priority in their Smart Specialization Strategies**, and will facilitate cross-border cooperation among research and innovation actors.
- **Awareness-raising campaigns** will be organised at regional level, including the set-up of support networks such as the Copernicus Relays and the Copernicus Academy network.
- The Commission will provide technical support in using **innovative and cross-border procurement for space solutions**, specifically targeted to the public sector.
- The Commission will explore **alternative business models** (public-public, public-private partnerships or buying services) where this may be more efficient and would leverage available funding. This will provide manifold opportunities for SMEs and networks of entrepreneurs.
- As part of the New Skills Agenda for Europe, the Commission launched a **dedicated Sector Skills Alliance for Space/Earth Observation**. Key stakeholders from public authorities, university, research and industry can gather to tackle new skills requirements in the sector.

The Commission will **upgrade user consultation processes and set up dedicated user platforms** to ensure that developments are driven by user needs.

2.6. Geospatial Data Use in new sectors

Geospatial EO data was traditionally used by the military, intelligence agencies, maritime or aeronautical organizations, etc. Most frequent applications are in the fields of precision farming, urban planning, facilities management, disaster and geohazard, security, automated mapping, , environmental management, land administration, marine and coastal monitoring.

Today, the use of geospatial information has expanded into almost every market and institution around the globe, with the discovery that it can provide new levels of insight and information. In the following we provide some illustrative examples:

Geospatial data has become an integral element in how companies and organizations conduct business throughout the world. **Geospatial data in Retail** can provide retailers data on income, housing/rent prices, surrounding business performance, population, and age. Another illustration is, weather pattern visualizations allow grocery stores to know when they should stock up on non-perishable items. Although storms are not predictable long time before they take place, the times and trends year after year are, and the ability to forecast at least a few weeks ahead can increase profits and better serve customers in times of need. Socioeconomic data as well as information like traffic patterns, and the number of residences in the area can be helpful when choosing a location.

Health geography and the application of geospatial data and techniques continues to expand its influence and use to support more accurate and timely decision-making in the healthcare market. Geospatial data is essential for both the study of epidemiology and the geography of health care. Geospatial tools are able to visualize and inform service providers about changes in patterns, environmental impacts, identification of and changes within high-risk areas, and where the greatest need for resources providing the greatest benefit should be deployed.

By using **Geospatial Data in Financial Services** and employing experts in geospatial analysis, companies can access new elements of knowledge, including the visualization of geographic and demographic data of investments and the regions of the globe they occupy and the real estate or land holdings tied to a particular investment.

2.7. Geospatial Technologies in Education

The starting point in building a successful career in geospatial technologies is a solid education. This involves taking classes in cartography, GIS, spatial analysis, database management, web technologies, and programming.

The importance of geospatial technology in education is obvious from its multidisciplinary areas of application. As it was presented before, the need for geospatial technology in the marketplace, increase the demand for researchers and students to have geospatial skills.

Geospatial technologies require skills of spatial thinking that too often have been neglected in schools. The spatial thinking skills that are vital for understanding the world can be taught and strengthened in the geospatial area. Students and teachers around the globe are using geospatial technologies to investigate our changing world, studying social and scientific concepts and processes, engage in problem-solving and decision-making about local and global issues, and broaden their skills in using this emerging technology [RD 41].

Spatial thinking/literacy in education should be a fixed component of school curricula and treated in a similar fashion to linguistic and mathematical thinking. It is an important part of everyday life.

Academic programs, government regulators and professional organizations are attempting to develop appropriate methods of training in necessary skill sets, while creating helpful credentials, i.e., licenses, degrees and certifications.

3. Technology Trends

3.1. Disruptive technologies in the Geospatial sector

The availability of EO data and geospatial information has increased dramatically in the last 5 years with Google Earth and – Maps being the most well-known examples for most people. The data is still mostly used as background images for navigation and for route planning and search for business locations or Points of Interest (POI).

Large datasets have become freely available during the last ten years, starting with the release of Landsat and MODIS data in 2008, with ESA following as data from the Copernicus program were made freely available. National Survey Organizations release their data for free use, e.g. Digital Elevation Models (DEM) in Finland and Norway. Adding to this trend towards open and freely accessible data, several crowd sourced projects such as Open Street Map and Mapillary have allowed anyone to freely map the world and contribute to the expanding geodata infrastructure.

The computing power and storage capacity available to any organization has at the same time increased enormously giving supercomputer power to almost anyone. Devices are connected and Internet of Things (IoT) is exploding and smart devices are controlling more and more of our daily lives. The combined effect and the market opportunities of this development is not that easy to grasp. However, with reasonable probability, a few statements can be made:

1. Digital geodata has become part of everyone's daily life.
2. Open and free geodata will be available to everyone.
3. The amount of geodata is rapidly growing.
4. More processing power is becoming available.

This puts certain demands on the actual and future capability to use these enormous amount of data and on the role of the academic institutions and providers of Vocational Education and Training (VET) in preparing the future generations of professionals and final users of geospatial information. On one side, new professionals are needed to handle and provide information based on geospatial data, on the other also the final users should be aware of the use of the geospatial information in a lot of sectors. Moreover, there is a need to continuously upgrade the skills of current professionals active in the GI/EO field.

The space market is in rapid expansion and, more and more, EO derived products and services will be part of value chains different from their original ones. Whereas a data value chain in the space market is a framework through which people can view the flow of geospatial data from the instant it is collected throughout its entire lifecycle. Each vertical industry has its own flow (and needs) of data, but eventually, that data intersects with analytics that can turn individual points of

information into all different kinds of actionable intelligence. It means that each single step of the space services value chain could be integrated in different market sectors. The more it happens, the more space market needs to improve its maturity. Today the geospatial market is influenced by other emerging technologies.
The chart below shows the most relevant emerging technologies having an impact on the geospatial data.

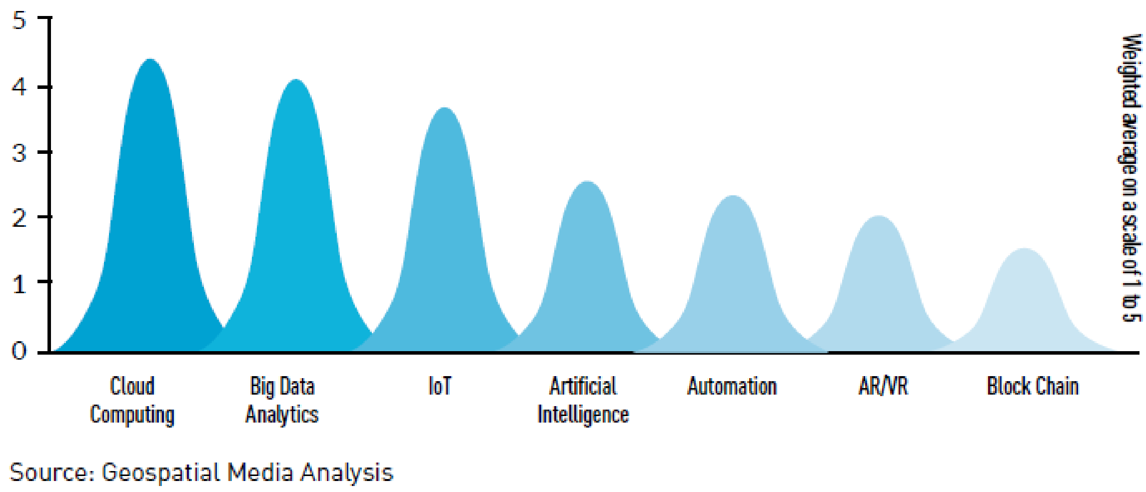

Figure 3: Emerging technologies having an impact on geospatial data

Interestingly, all of those technologies are closely associated with geospatial data developments – either they benefit from location data or technologies, or directly empower the geospatial sector. Global mega trends like the growing population, urbanisation and expanding middle class combined with the ever-increasing digitalisation of the world around us are contributing to changes that impact us all [RD 42]. In some cases, some of these technologies converge with geospatial technologies to deliver solutions and have long-lasting impacts. These technologies are at varying degrees of maturity; some have been around for years but are finally hitting their stride, while others are maturing rapidly. While listing the technologies, we also describe how they are connected with the geospatial sector and the future prospects in the industry. One of the greatest opportunities with digitalisation is improved productivity in almost all industries, though, for example, artificial intelligence (AI). By connecting the real and the virtual worlds, a machine can perceive and analyse its environment and correct deviations in real time, which reduces the risk of delays and cost overruns. Demands for higher productivity have also led to increased automation of time-consuming and resource-intensive tasks. The more digitalisation and automation achieved, the more intelligent machines and systems that can be created that learn, adapt, make decisions and act without human control [RD 42].

Cloud computing is an emerging technology that will have maximum impact in the next years. Big Data Analytics came up as the next biggest technology driver for future market growth. A detailed description of each technology is out of the scope of this document, so we focus on their in relationships with the geospatial market.

3.1.1. Cloud computing

Cloud applications are challenging traditional thinking about information technology (IT) infrastructure performance, as well as the availability and accessibility of information for key data management and delivery mechanisms. Cloud computing is designed to treat IT as a scalable service rather than an institutional infrastructure. Scalable services have the ability to dynamically increase or decrease capacity to match user demands, leverage shared technologies and hardware, and ultimately realize economies of scale. Service-oriented architecture is adopted in Cloud Computing and enables "everything as a service", including Infrastructure as a Service (IaaS), Platform as a Service (PaaS) and Software as a Service (SaaS). While redefining the possibilities of geospatial science and Digital Earth [RD 42] (Yang et al., 2013), Cloud Computing engaging Big Data enlightens potential solutions for big geospatial data problems in various geosciences and relevant domains.

An increasing amount of data is today stored in cloud services. There are several advantages, including the opportunity to access, adjust and share information more efficiently. This means there is only one source of information and the risk is eliminated that old, locally stored, data is used in work processes. Storing and using data in the cloud enables everyone to work under the same conditions, with exactly the same information available. Another efficient type of data processing is edge computing or edge data processing and analysis, which accelerates the response time by analysing data in real time, where the data is collected, rather than first allowing the data into the cloud. This is particularly important in time-critical situations, such as smart traffic systems and autonomous vehicle systems. This type of information flow, which is updated in real time, will and has already, changed a multitude of industries and is an important element in everything from smart cities to smart factories.

At this point it is important to mention the rise of new technologies that are developed in parallel with Cloud applications and they are strongly connected with the world of IoT. In particular, **Fog and Edge** computing are both extensions of cloud networks, which are a collection of servers comprising a distributed network.

Fog computing, also known as fog networking or fogging, is a decentralized computing infrastructure in which data, computers, storage and applications are distributed in the most logical, efficient place between the data source and the cloud. Fog computing essentially extends cloud computing and services to the edge of the network, bringing the advantages and power of the cloud closer to where data is created and acted upon. The goal of fogging is to improve efficiency and reduce the amount of data transported to the cloud for processing, analysis and storage. This is often done to improve efficiency, though it may also be used for security and compliance reasons. Popular fog computing applications include smart grid, smart city, smart buildings, vehicle networks and software-defined networks.

Edge computing is a distributed information technology (IT) architecture in which client data is processed at the periphery of the network, as close to the originating source as possible. The move toward edge computing is driven by mobile networks, the decreasing cost of computer components and the sheer number of networked devices in the internet of things (IoT). Depending on the implementation, time-sensitive data in an edge computing architecture may be processed at the point of origin by an intelligent device or sent to an intermediary server located in close geographical proximity to the client. Data that is less time sensitive is sent to the cloud for historical analysis, big data analytics and long-term storage.

Similar to the emergence of cloud computing, edge and fog computing will shift the economics of the "computing on demand" marketplace. The implications of the fog, edge and cloud computing and vice versa, the role geospatial could play in these technologies have been described in an OGC White Paper [URL 32].

3.1.2. Big Data

"Big data" refers to datasets whose size is beyond the ability of typical database software tools to capture, store, manage, and analyse. This definition is intentionally subjective and incorporates a moving definition of how big a dataset needs to be in order to be considered big data—i.e., we don't define big data in terms of being larger than a certain number of terabytes (thousands of gigabytes). We assume that, as technology advances over time, the size of datasets that qualify as big data will also increase. Also note that the definition can vary by sector, depending on what kinds of software tools are commonly available and what sizes of datasets are common in a particular industry.

Digital data is now everywhere—in every sector, in every economy, in every organization and user of digital technology. While this topic might once have concerned only a few data geeks, big data is now relevant for leaders across every sector, and consumers of products and services stand to benefit from its application.

The ability to store, aggregate, and combine data and then use the results to perform deep analyses has become ever more accessible as trends such as Moore's Law in computing, its equivalent in digital storage, and cloud computing continue to lower costs and other technology barriers.

The means to extract insight from data are also markedly improving as software available to apply increasingly sophisticated techniques combines with growing computing horsepower. Further, the ability to generate, communicate, share, and access data has been revolutionized by the increasing number of people, devices, and sensors that are now connected by digital networks. In 2010, more than 4 billion people, or 60 percent of the world's population, were using mobile phones, and about 12 percent of those people had smartphones, whose penetration is growing at more than 20 percent a year. More than 30 million networked sensor nodes are now present in the transportation, automotive, industrial, utilities, and retail sectors. The number of these sensors is increasing at a rate of more than 30 percent a year.

Simply making big data more easily accessible to relevant stakeholders in a timely manner can create tremendous value. In the public sector, for example, making relevant data more readily accessible across otherwise separated departments can sharply reduce search and processing time. In manufacturing, integrating data from R&D, engineering, and manufacturing units to enable concurrent engineering can significantly cut time to market and improve quality.

Big data enables companies to create new products and services, enhance existing ones, and invent entirely new business models. Manufacturers are using data obtained from the use of actual products to improve the development of the next generation of products and to create innovative after-sales service offerings. The emergence of real-time location data has created an entirely new set of location based services from navigation to pricing property and casualty insurance.

Big Data has emerged with new opportunities for research, development, innovation and business. It is characterized by the so-called four V's: volume, velocity, veracity and variety and may bring significant value (commonly referred to as the fifth V) through the processing of Big Data.

It already shows the important increase of data to be archived, processed and distributed in the years to come, coming principally from Sentinel missions. The potential behind this "Big EO Data" exploitation needs to be unlocked via the adoption of Big Data technologies and functionalities. Besides the amount of data, it is worth recalling also the diversity of the Sentinel missions in terms of purposes but also in terms of payloads and therefore the typology of data to be delivered. Besides Sentinel missions, the amount of available data has drastically increased in recent years also due to the increased number of institutional and commercial satellite missions and the improvement in their performances. At the same time, there is an increasing volume of exogenous data produced by non-space systems (mainly in situ data collected by sensors) and for which there is a clear potential in terms of integration and complementarity with space based-images. The challenge is to successfully transform and integrate these data into real added-value applications while dealing with the inherent difficulties related to the data: high volume, high frequency of update (revisit), high heterogeneity (multi-sensors) and different exploitation needs.

3.1.3. IoT

IoT enables devices to be connected and remotely monitored or controlled. The term IoT has come to represent any device that is now "connected" and accessible via a network connection. Information and communication technologies (ICT), mobile devices location-aware sensors have triggered a new paradigm of the IoT. A decade ago, the number of devices on the Internet exceeded the number of people on the planet, and, in 2008, the U.S. National Intelligence Council projected that IoT would be one of six disruptive civil technologies—as in "by 2025 Internet nodes might reside in everyday things – food packages, furniture, paper documents, and more". More recently, the proliferation of low-cost sensors, reduced costs of cloud-computing resources and increasing accessibility of artificial intelligence (AI) and open-source machine learning platforms have combined to propel advancements and applications of IoT. The geospatial applications of the IoT, (e.g., state-of-art in sensors network and integration) are based on semantics (e.g., representing, storing, sharing, interconnecting, searching, and organizing geo-information generated by the IoT), in order to provide the most innovative and effective solutions (e.g., smart and connected communities, ecological and agricultural applications, etc.).

3.1.4. Artificial Intelligence

Artificial Intelligence (AI) has become a buzzword that symbolizes the next stage of innovative technological transformations and how the industry in the future would be driven. Using intelligent algorithms, data classification and smart predictive analysis, AI has its utility in a large number of sectors. AI is an “umbrella” concept that is made up of numerous subfields such as computer vision, and in particular machine learning and deep learning, which focuses on the development of programs that can teach themselves to learn, understand, reason, plan, and act (i.e., become more “intelligent”) when exposed to new data in the right quantities.

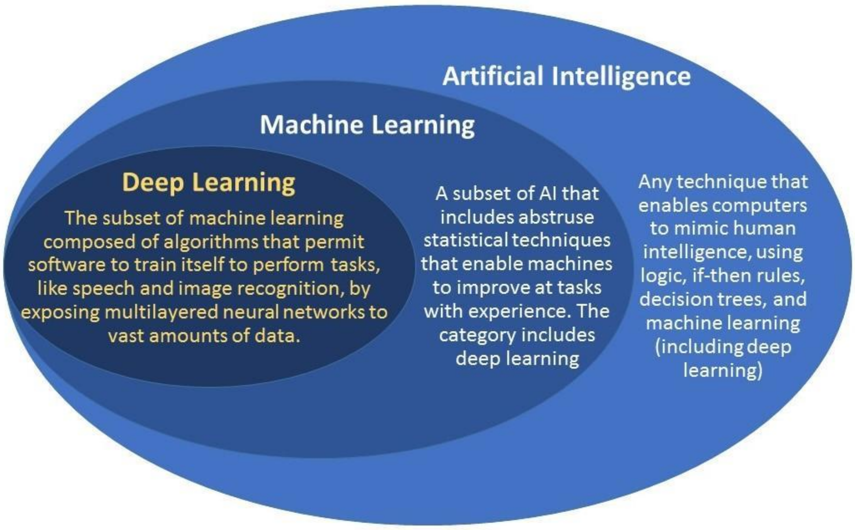

Figure 4: AI is the technique that enables computers to mimic human intelligence. It includes Machine Learning and Deep Learning.

A more specific subset of AI that combines GIS technologies with the razor-sharp analysis and solution-based approach of AI is termed Geospatial AI, or simply Geo.AI. Geospatial AI is a new form of machine learning [URL 22] that is based on a geographic component.

The biggest opportunity for geospatial industry in AI is its core asset, which is geospatial data. It is widely acknowledged that 80% of all data that is generated are spatial in nature. Therefore, data exploiting using automation through AI and deep learning comes naturally to creating solutions for all of the basic sectors.

In particular, AI has great potential for image analysis. With the world regularly monitored by satellite image acquisitions and distributed in-situ sensors, AI-driven applications can provide previously inaccessible insights on global-scale economic, social and industrial processes. For example, land cover classification using remote sensing has become an important tool for analysis land cover distribution and dynamics for areas all around the world. Monitoring and mapping the natural resources land in order to construct land cover maps at the present time is a costly and time-consuming operation and this currently limits how frequently such maps can be produced. Therefore it is promising to implement automatic segmentation routines and classification techniques in order to automatically create land cover mapping from high-frequent imagery provided e.g. by Sentinel-2 (up to 5 days intervals). Physical-model based expert systems or deep neural networks and other machine learning algorithms can be implemented in order to meticulously assign each square meter a land cover label such as water, grass/herbaceous, tree/forest, or barren/impervious surface. In addition, AI can also be used to monitor and cover change which are regarded as the single most important variable of global change.

In addition, the applications of Geo.AI can converge to deliver solutions for improving precision farming, disease prediction, and predictive policing. For the businesses, they can help in planning, predicting demand spikes, identifying high-margin prospects, adding efficiency to the supply chain, and optimizing service delivery.

3.1.5. Blockchain

The blockchain was created to support Bitcoin, but now the blockchain concept can be defined regardless of the Bitcoin ecosystem.

Its most common definition on Internet is:

"***A blockchain is a ledger of facts***, *replicated across several computers assembled in a peer-to-peer network. Facts can be anything from monetary transactions to* ***content signature*** *or even real objects equipped with IoT devices. Members of the network are anonymous individuals called nodes. All communication inside the network takes advantage of cryptography to securely identify the sender and the receiver. When a node wants to add a fact to the ledger, a consensus forms in the network to determine where this fact should appear in the ledger; this consensus is called a block.*"

The geospatial market is in a rapid expansion and geospatial derived products and services will be part of value chains different from their original ones. It means that each single step of the geospatial services value chain could be integrated in different market sectors. The geospatial market needs to improve its maturity and reliability and some fundamental steps towards the aforementioned targets are to ensure the authenticity of the managed information and data and the integrity of each processing step applied to them, from their acquisition to their delivery to the customer or to the Service Provider.

One area where Blockchain will find major use along with geospatial technologies is the Internet of Things. Today, IoT conjures up a mental image of a complex network of humans and objects all passing data to each other. For example, could an autonomous delivery van, which depends on sensors be hijacked and driven to a wrong location? Consider the data carrying the instructions as transactions. If the network were on a Blockchain, then the process of consensus would help validate the transactions and weed out the wrong instructions because the illegal transactions would be trapped. Other domains where Blockchain could play a role in geospatial terms are land transactions and data repositories.

The aforementioned problems can be addressed in different ways, but a promising technology like Blockchain seems the best fitting solution to that. In fact, the blockchain is for sure the right solution to guarantee:

- Identity (the source and destination endpoints of the data),
- Integrity (the data was not counterfeit),
- Freshness (the data was processed and the time-relation between original and resulting data was stored and certified).

Moreover, from a technical point of view, the blockchain is a database relying on three fundamental concepts:

- Peer-to-peer networks,
- Public-key cryptography,
- Distributed consensus.

By exploiting those characteristics, the geospatial market could go out its protected shell and be integrated inside more complex and complete refactored value chains without the need of setting up intermediation or centralized trusted authorities. In fact, in the context of the blockchain, data can be anything, but most interesting use cases concern information that currently require a trusted third-party to exchange.

Examples include money (requires a bank), a proof or property (requires a lawyer), a loan certificate, a swarm of drones, etc. In essence, **the blockchain removes the need for a trusted third party, but guarantees the possibility to identify the inputs, the outputs and the transaction of each processing step**.

3.1.6. Drones

Also popularly known as UAVs (Unmanned Aerial Vehicles), drones are vehicles that fly or move without an on-board human pilot. Drones can operate autonomously (via on-board computers) on a predefined flight plan or be controlled remotely, and are different from the land-based automated vehicles.

Until a few years back the use of UAVs was always associated with surveillance and war. However, with the demand for timely, accurate, high-resolution and hyperspectral data for mapping, exploring, investigating and monitoring increasing, the pilotless flying machines have today become an integral part of geospatial industry. The very fact that this flying data collection platform can be managed by a single person and carried in the field has drastically reduced the geospatial industry’s dependence on (classical) airphoto campaigns or satellite imagery.

A UAV technically becomes a UAS (unnamed aerial system) once the payload is added, which in the present context are cameras, sensors and detectors — both imaging and non-imaging. The hardware development has been rapid and sensors with very high resolution (both spatial and radiometric) are in the market. The parallel development of software to accept high data throughput, analyze, and deliver usable products is in place.

3.1.7. Augmented Reality

Augmented reality (AR) involves augmenting the real physical world with visuals via computer-generated or extracted real-world sensory input such as sound, video, graphics or GPS data to improve the user experience. Simply speaking, AR supplements your world with digital objects of any sort. In particular, AR heads and overlays data such as 3D objects and video into your vision in some way or another. All this while continuing to let you see the world around you. Airline pilot helmets that display data within the pilot's view as they fly are AR headsets.

Then there are Spatial Augmented Reality (SAR) systems, which are capable of augmenting real-world objects and scenes without the use of special displays such as monitors or head mounted displays.

A quickly growing area of location-centric technology concerns the development of AR systems that can present digital information to users based on what they are looking at in reality. For example, using AR glasses, you could look at a building on the street and the system could overlay details about who owns the building, the number of occupants, and when it was built. While AR has already made a mark in consumer application areas in geospatial, there is a huge scope of uptake in areas like construction and infrastructure management, or disaster risk analysis and mining etc.

3.1.8. SmallSats

In the few past years, a new trend emerged in space, and namely in Earth Observation, of a new class of small satellites.

This approach is disruptive of the traditional space value chain and put a strong competitive hedge to traditional Large System Integrators.

Smaller satellite first means lower launch cost, shorter time of deployment means lower cost of deployment, numerous constellation (mainly in Low Earth Orbit) means better resolution in revisit time and geometry.
In the OCG Technology Watch, in the New Geo Sources branch, it is indicated the SmallSats. SmallSats is a family of satellites with a mass less than 180 kilograms. Even with small spacecraft, there is a large variety of size and mass that can be differentiated.

- Minisatellite, 100-180 kilograms
- Microsatellite, 10-100 kilograms

- Nanosatellite, 1-10 kilograms
- Picosatellite, 0.01-1 kilograms
- Femtosatellite, 0.001-0.01 kilograms

Small satellites have become a competitor to large satellites with a mass of over 1000 kg. This development has come about through the technological advances in micro-electronics. Small satellites are obviously less expensive to launch. Small satellites usually require innovative propulsion, attitude control, communication and computation systems. Larger satellites usually use monopropellants or bipropellant combustion systems for propulsion and attitude control; these systems are complex and require a minimal amount of volume to surface area to dissipate heat. These systems may be used on larger small satellites, while other micro/nanosats have to use electric propulsion, compressed gas, vaporizable liquids such as butane or carbon dioxide or other innovative propulsion systems that are simple, cheap and scalable. Small satellites can use conventional radio systems in UHF, VHF, S-band and X-band, although often miniaturized using more up-to-date technology as compared to larger satellites. Tiny satellites such as nanosats and microsatellites may lack the power supply or mass for large conventional radio transponders, and various miniaturized or innovative communications systems have been proposed, such as laser receivers, antenna arrays and satellite-to-satellite communication networks. Few of these have been demonstrated in practice.

Electronics need to be rigorously tested and modified to be "space hardened" or resistant to the outer space environment (vacuum, microgravity, thermal extremes, and radiation exposure). Miniaturized satellites allow for the opportunity to test new hardware with reduced expense in testing. Furthermore, since the overall cost risk in the mission is much lower, more up-to-date but less space-proven technology can be incorporated into micro and nanosats than can be used in much larger, more expensive missions with less appetite for risk.

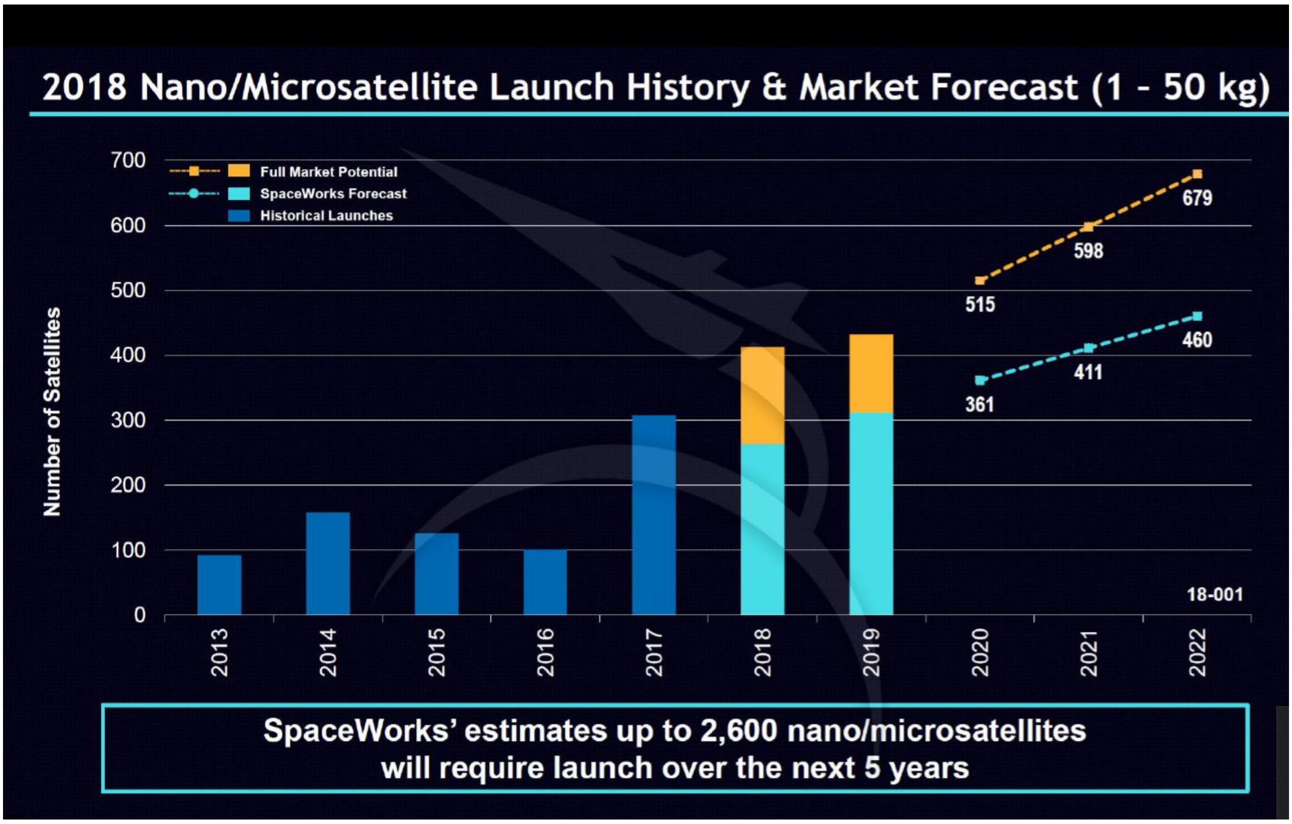

Figure 5: Numbers of microsatellites that will be launched in the next years.

3.1.9. CubeSats

A CubeSat is a type of very small satellite which is based on a standardized unit of mass and volume. The initial basic CubeSat unit measured 10x10x10 centimeter, conforming to specific interfaces for allowing a standardized containerized launch and had a maximum mass of 1 kilogram (the mass was later on increased to 1,33 kilogram). It was quickly realized that such basic CubeSat units could be combined to form slightly larger spacecraft while mostly adhering to the same requirements and constraints. Multiples of the basic CubeSat unit were combined together to establish larger CubeSats. For example, a 1-Unit CubeSat measures one single basic CubeSat unit as described above, while a 3-Unit CubeSat consists of 3 standard CubeSat units stacked together.

The CubeSat concept has become very popular, both in university groups, as well as for researchers, space agencies, governments, and companies. CubeSats offer a fast and affordable way for a wide array of stakeholders to be active in space and allow for a fast innovation cycle.

3.2. From the upstream to the downstream

The history of EO in the last 40 years was dominated by a strong separation between UpStream and DownStream activities. The UpStream was strongly dominated by technology push and in more successful cases by Defence Demand i.e., Image Intelligence. The Downstream started an integration process on cloud, oriented offer a common platform for BigData.
The Satellite Missions scenario, from Earth Observation to Science, to planetary rovers, is enormously changing both for the number of the deployed assets and for the acquisition capability of the embarked sensors. In fact, sensors evolve towards increasing acquisition capabilities, in terms of bands (hyperspectral in optical and full polarization in SAR), resolutions and duty cycles. The result is a considerably increased data volume to manage on-board and to download to ground stations.
Thus, we cannot continue to rely on the classical and sharp separation between **UpStream** and **DownStream** and we need to rethink the complete satellite value chain in terms of the new **SpaceStream** Paradigm, whose highest value is the capability to enforce an “application oriented” approach to space systems architectures, including uncertainty, flexibility and risk issues.

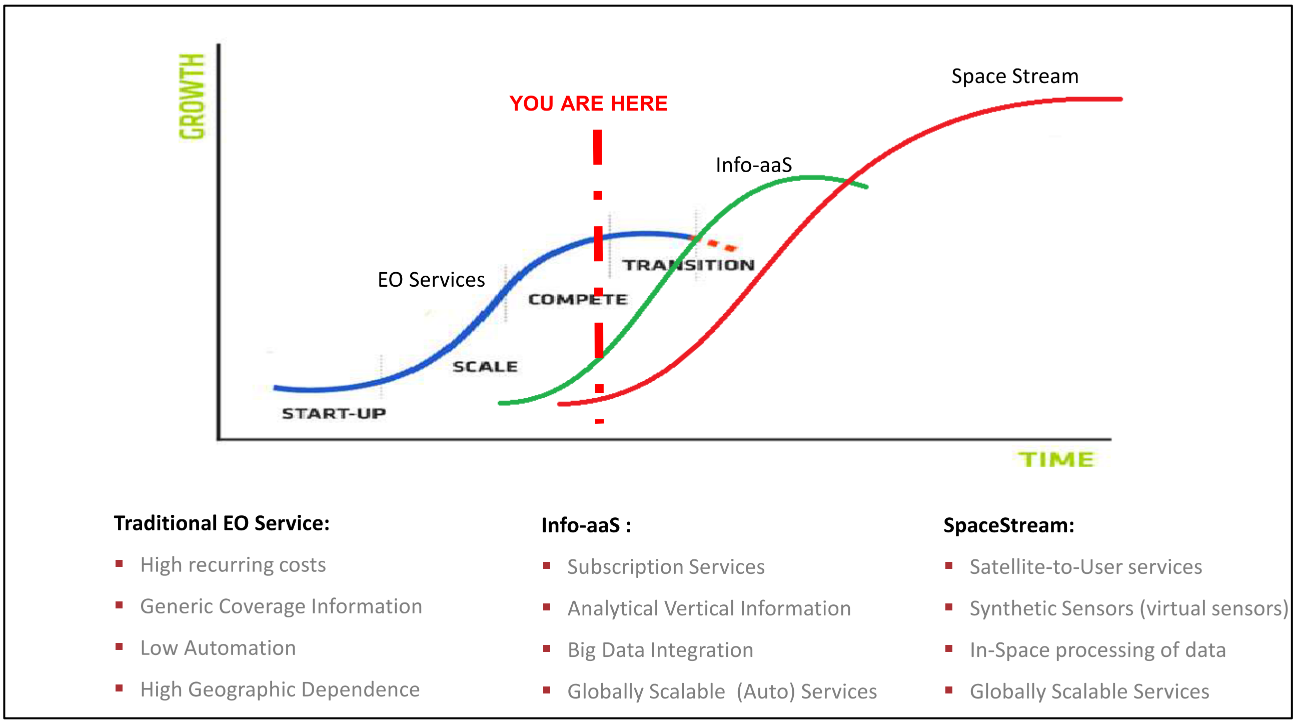

Figure 6: The evolution of EO services from traditional to Info-aaS and SpaceStream

The key technologies supporting the SpaceStream involve the full stack of the On-Board Payload Data Processing (OBPDP), going over the simple tasks of compression, binning, checking and reduction. In fact, new technologies like Artificial Intelligence, Blockchain, Low Power GPU, Compressive Sensing, and Computational Imaging may evoke a considerable boost towards this paradigm shift.

A growing interest exists in exploiting EO data as a source of ready available information about natural phenomena and anthropic attitude to shape our planet. The challenge is when we start talking about 'data fusion,' or the joining of many diverse data sources such as social media, satellite imaging, mobile phone telemetry, and weather sensors. We are tasked with finding the primary keys to join all of these data models together into a single, unified model that exposes the relationships between apparently unrelated data elements. The remaining challenge is transform these data in ready to use knowledge by user, but the growing of on board processing and the artificial intelligence may support this transformation and user-centric (i.e. on demand) information extraction.

Newly available satellite data reshape the design approach from geo-information to geo-analytics info@s scalable in space and time dimension .The advent of cloud computing, SaaS, the big data impose a deep reshape of EO services business model.

EO service market is rapidly moving from CAPEX, to OPEX[4] adopting Software as a Service model.

[4] Capital expenditures (CAPEX) and operating expenses (OPEX) represent two categories of business expenses. Capital expenditures are the amounts that companies use to purchase major physical goods or services that will be used for more than one year. Operating expenses are the costs for a company to run its business operations on a daily basis.

4. Economy

4.1. Circular economy

“We define **Circular Economy** (CE) as an economic system that replaces the ‘end-of-life’ concept with reducing, alternatively reusing, recycling and recovering materials in production/distribution and consumption processes. It operates at the micro level (products, companies, consumers), meso level (eco-industrial parks) and macro level (city, region, nation and beyond), with the aim to accomplish sustainable development, thus simultaneously creating environmental quality, economic prosperity and social equity, to the benefit of current and future generations.” [URL 18] CE is currently a popular concept promoted by the EU, by several national governments and by many businesses around the world.

The principles and challenges of circular economy may be illustrated by the waste management sector. While the production of waste has increased in the last decades, licenced landfills are still one of the main ways of treating waste materials throughout the world. Europe hosts more than 500,000 landfills (i.e. [RD 18], [RD 19]); 90% of these landfills are actually non-sanitary landfills, violating the EU Landfill Directive (1999). In most cases, non-sanitary landfills lack the required environmental protection technologies and will eventually require costly remediation. The Landfill Directive is therefore rather irrelevant for at least 450,000 landfills; around 80% of Europe’s landfills essentially contain Urban Solid Waste, while only 20% are landfills containing more specific industrial waste and residues. The most important difference between these types of landfills is that the former are typically publically owned, while the latter are privately owned (see Figure 1).

According the approach of Integrated Solid Waste Management (ISWM) strategy [RD 17], the term “waste” is becoming synonymous with “resource”, especially in promoting the 3Rs (Reduce, Reuse and Recycle) and on maximising recycling efficiency. In this sense, the 500.000 historic and still active landfills in EU, can be seen as a significant stream of secondary recovered materials (SRM) and energy.

As highlighted by UNEP [RD 20], the long-term vision for the waste sector is to establish a circular global economy in which the use of materials and generation of waste are minimised. Any unavoidable waste are recycled or remanufactured, and any remaining waste treated in a way that causes least damage to the environment and human health or even creating additional value by recovering energy from waste. The use of secondary raw materials and recycling was recommended by the European Commission as a strategy to improve resource efficiency and reduce and alleviate the supply risks facing critical raw materials (CRMs) (COM 2010a).

In line with these considerations, ***Earth Observation based services can support the trend of change, currently growing in the supply-chain management, especially in the product and industrial design part***. As an example of the most promising markets for the SRM, the construction and demolition waste (D&MW) is increasingly used in the construction and infrastructure industry to replace aggregates and sand, or biomass from different sources like forestry or agricultural residues are increasingly used as input to second generation bio-ethanol production. In this sense, a service providing a structured knowledge about the size and the type of waste accumulation into a standard inventory database at regional/national scale, could represent an important support to the recycling industry.

Raw materials are essential for the European economy, but their availability is increasingly under pressure. At the same time, several studies show that in many regions massive amounts of strategically important materials such as metals have been accumulated in landfills [RD 21], [RD 22]. The final aim of the EU legislation is to reduce the amount of wastes ending up on landfills, increasing the material that must be recycled. For example, the objective set by the EU legislation is to reduce landfilling to a maximum of 10% of municipal waste by 2030. The landfills are predicted to become the future mines for materials [RD 23]. To manage an old and currently active landfill as “raw material reserve”, versatile information on the content and characteristics of the specific landfill is required. This information has to be produced by similar methods or be at least comparable (even between the different type of landfills from different EU countries) to enable the reuse of SRM.

It is clear that the landfill mining is crucial for the recycling industry and represents part of what is called circular economy. This is one of the key challenges undertaken by the European Commission (e.g. Circular Economy Package, 2015), which proposes ambitious targets for recycling in the EU, up to 2030. In this sense, the EC initiative ‘Industry 2020 in the Circular Economy” will provide project funding of over € 650 million. The European Fund for Strategic Investment, EFSI will promote access to finance for companies applying innovative, circular economy with the overall target to mobilize investment of at least € 315 billion in Europe over three years [RD 25].

Within this framework it becomes important the engagement of experts able to cover different application fields ranging from waste management sector to earth observation technologies in order to respond with tailored EO based services to the rising market opportunities across Europe, derived from landfill mining.

4.2. Financial services

Financial services are the economic services provided by the finance industry, which encompasses a broad range of businesses that manage money, including credit-unions, banks, credit card companies, insurance companies, accountancy companies, consumer-finance companies, stock brokerages, investment funds, individual managers and some government-sponsored enterprises. Apart from specific applications, such as agricultural insurance based on indices derived from satellite information, the interest to combine geodata and financial services was only more recently explored. The publication “Geodata and ICT solutions for inclusive finance and food” [URL 24] and the organisation of the conference "Geodata for inclusive finance and food" [URL 25] (organised in Rotterdam in February 2017) were first steps to explore the potential of the combination of geodata and financial services for food producers.

The use of geodata (geospatial information) can benefit the delivery of financial services. Certain features of geospatial information, such as computerised maps (GIS: geographic information systems) and cadastral information, have been around for a long time. The use of satellite information, including EO data, for financial services is relatively new. The (full) potential for financial services still needs to be explored. The application of satellite data for geospatial information has the advantage to be a unique information source in areas whereas other sources of information are lacking.

To properly assess the potential benefit of geodata for financial service provision, it is important to indicate the priority areas for finance where the application of geodata can add value. These priority areas are:

- Improved risk management;
- Lower costs;
- Well-designed products;
- Increased outreach.

Geodata products and services are useful for financial service providers because:

- Risk management can be improved through geodata solutions on (natural) risk assessment and early warning and provision of more accurate information on the target group and by providing support to improve agricultural performance (which improves the capacity for loan repayment);
- Costs can be lowered for financial service providers by making use of location-based applications and databases, and by the analysis of historical records, reducing the need for field visits;
- Geodata solutions can be packaged with other products and services that make the offers of financial service providers more robust and attractive;
- The use of geodata platforms (in combination with mobile solutions) can improve the outreach of financial service providers by increasing the frequency of interactions and the number of people reached, and by gathering information to "know your customer" better (KYC).

As example of the positive effect of geospatial data and solution for the financial services is to gain information about the rate of fish growth that would support aquaculture farmers in sell at best price and avoid loss money in case of storm.

A main challenge is that the "geodata world" and "inclusive-finance world" need to find a common language. The geodata experts need to understand the priorities and requirements of the financial service providers and have to realise that financial service providers are real partners and have to be involved from the start. The inclusive-finance sector needs to know more about satellite information showing only relative differences in greenness of the Earth, the dependency of solutions for smallholder farmers and pastoralists on free data, and the need for local knowledge and in-situ data for calibration and validation. Professionals with both competences and skills are required.

4.3. Geospatial Business Intelligence (GeoBI)

Business intelligence (BI) comprises the strategies and technologies used by enterprises for the data analysis of business information. BI technologies provide historical, current and predictive views of business operations. Common functions of business intelligence technologies include reporting, online analytical processing, analytics, data mining, process mining, complex event processing, business performance management, benchmarking, text mining, predictive analytics and prescriptive analytics

Geographic location is usually a critical factor in business research and calculations about customers, suppliers, distributors, natural resources, transportation hubs, energy and many other things. Business intelligence platforms and applications need to help users find, use and communicate location information, so it follows that digital standards for system-to-system communication of geospatial information are a critical enabling factor for better business intelligence.

GeoBI is business intelligence that makes use of geospatial information. Business intelligence supports better business decision making leading to new revenue opportunities, improved cost calculation, and better risk management. Business intelligence (BI) refers to computer-based techniques used for identifying, extracting and analyzing business data, such as sales revenue by products and/or departments, or by associated costs and revenues. Common functions of business intelligence technologies are reporting, dashboards, scoreboards, online analytical processing (OLAP), data mining, process mining, business performance management analytics and predictive analytics.

Traditional GIS and image processing software products provide powerful techniques for dealing with geospatial data in geospatial-centric applications, but geospatial data and processing are no longer confined to local desktop software. With the advent of the Web, and partly due to OGC standards, geospatial data have become an enabler for many mass-market applications, such as Web mapping and location based services (LBS). Much less expertise is now required to use geospatial information for business tasks

Below are some example value propositions showing the usage of geospatial information and business intelligence in decision making:

- **Agriculture**: GeoBI enables dashboards where various parameters like crop yield, fertilizer consumption, agriculture-water intensity, average rainfall, crop-production, etc. can be shown for each agricultural field or over an administrative or catchment area.
- **Public Safety**: For many years, law enforcement organizations have been mapping the occurrence of crime in metropolitan areas. GeoBI enables various stakeholders including law makers, law enforcement agencies, police and citizens to see trends and patterns of crime over an administrative, municipal, state or country level.
- **Healthcare**: The diffusion of an illness can be tracked much more effectively when geospatial data are displayed on a screen and the number of cases can be color coded to indicate both intensity as well as timing. GeoBI adds the power of spatial analytics to healthcare related information. Parameters like disease incidents, reported cases, available doctors, hospitals, beds, medicine consumption, etc. can be analyzed geographically.
- **Insurance:** Through the use of GeoBI, insurers can better understand the location and temporal distribution of policyholders and their assets and can improve their estimation of policy risk in hazard-prone areas.
- **Real Estate:** Retail site location, mortgage review and monitoring, leasing patterns, and real estate investment portfolio review and risk analysis are all strong drivers for increasing the use of spatial analysis.
- **Customer Relationship Management (CRM):** The use of spatial analysis for demographic segmentation and market analysis first brought GIS to the general business community. The next generation of GeoBI expands this use into a more flexible services-based architecture and exposes data and analyses, and control, to a larger organizational audience.
- **Weather**: Weather is critical for agriculture, transportation, law enforcement, military and many other aspects of our economy, and meteorology is anchored in geography. Weather information helps us predict weather's impact on air travel, crop yields and energy costs.
- **Utilities**: Spatial parameters have significance in every scenario affecting utility grids. Spatial parameters include, for example: presence/absence, street address and property description, location within a building, route, proximity to hazard, and temperature readings.

5. Citizen role

5.1. The role of the Citizen Science

With the increasing importance and amount of EO data availability, it is critical to understand how the value of such data can be integrated and completed with other sources of data in order to derive advanced EO based services able to support complex decision making processes [RD 37]. The wide adoption and availability of smartphones, Internet devices and increased accessibility to information has fostered the participation of large numbers of citizens and communities to scientific, technological, societal and decision-making activities (e.g. [RD 26]). Large numbers of volunteers can be recruited over wide geographical areas to collect, submit and interpret data at low cost [RD 27]. Such widespread data collection (potentially over extended temporal periods) would be simply infeasible without citizen volunteered information. Indeed, such geographical spread can play a crucial role in understanding some of the processes behind the most important global current challenges: vegetation loss, climate change, natural resource management, migration patterns, etc. In addition to geographical coverage, the volume of observation data (satellite-, airborne- and land-based)—some of which can only be interpreted by humans—is constantly growing. The ability to crowdsource detailed, high-resolution annotations of such data facilitates timely scientific analysis and decision-making. Citizen science has evolved from a hobby through to serious science and is rapidly becoming a preferred approach to conducting large-scale research [RD 28]. Each type of citizen science and crowdsourcing initiative relies on a different degree of engagement from the citizen (and hence, a different degree of engagement on behalf of the organiser - usually an NGO or research organisation). Similarly, the geographic extent of the initiative has strong implications for the suitability of particular forms of citizen science that can be employed - none is excluded at any one particular scale but organisational and governance overheads can become problematic. Citizen science and the wider active participation of citizens in science and governance will continue to grow. The benefits are mutual: citizens can enjoy making a positive impact at local, national or international levels in a variety of domains (e.g. environment, ecology, medical research). On the other hand, professional researchers and decision-makers can benefit of an unprecedented wealth of knowledge and expertise collecting large amounts of data across a large geographical area. Data collection can be much more quickly and at must lower costs compared to traditional research approaches.

The role of **citizen science** (CS) and **crowdsourcing** is becoming vital to a wide range of applications, related to a large number of fields such as science, governance, public policy, environmental studies and decision-making. Citizens have been employed in scientific studies and decision-making processes over the years and several excellent examples have showcased how citizen-generated data can provide high-quality data. Although concerns exist regarding the assessment of quality and reliability of Citizen Science data ([RD 29], [RD 30]), several domains such as knowledge bases, mapping, classification have demonstrated high quality achieved through the rigour of CS combined with multiple independent reviews to check reliability. It has also been reported that such data can be more detailed and with higher quality than those ones provided by official institutions [[RD 31] - [RD 34]]. Several large organisations such as Amazon, Trip Advisor, Twitter and Facebook also rely on crowdsourcing as primary sources of information, comprising a critical aspect of their entire business model. Wikipedia and OpenStreetMap, on the other hand serve as long-standing testament to the provision of open data which is created, maintained and enriched by the public.

The EO domain is increasingly employing CS and crowdsourcing for tasks such as calibration and validation of data as demonstrated by the growing number of publications in the field [RD 35]. This can be achieved using a number of different levels of citizen science project ranging from volunteer computing through to participatory sensing. The identification of new applications or disruptive products could be achieved through hackathons and crowdsourced solution contests. However, the use of crowdsourcing and citizen science is not without risk. The two main areas which must be considered with care are engagement and data quality.

These two aspects are critical to the sustained success of an initiative both in terms of maintaining the amount of data collected or processed over time as well as the value of the final crowdsourced information. Crowdsourced data collected from social media can be a significant source of information, but dealing with such data requires a great deal of consideration. Social media data are usually high in volume and constantly increasing, often duplicated, incomplete, imprecise and potentially incorrect; informal (short, unedited and conversational) and less grammatically bounded text. These characteristics make the automation of intelligence gathering difficult. The applicability of the data varies widely on each use case, and as a result, different sources provide more contextually relevant information than others do. As an example of the potential of CS applied to EO, the ESA funded Crowd4Sat project led by the University of Sheffield has investigated different aspects of how crowdsourcing and citizen science influences the validation, use and enhancement of Observations from Satellites products and services. For example, in flood emergency scenarios, Twitter resulted as the most relevant channel to achieve information not only as primary source provided by the users, but also as an indirect way to access other social data content through sharing of a variety of information channels (e.g. news, institutions and public bodies providing usually more relevant information as compared to citizens sharing information). Especially, videos and images shared on YouTube and Twitter provide immense help in understanding scenarios on the ground. Anyway, in order to exploit such data sets, there needs to be strategies in place to deal with missing information, such as the lack of geotagging. For instance, in the use case analysed in [RD 36], only a very small fraction of Twitter data (<1% of analysed Tweets) actually contained geolocation information, and in most cases, the Tweets were positioned outside the area of interest. Also, social media platforms such as Twitter are not available or accepted everywhere and depend on cultural context and technical prevalence. Moreover, mechanisms would need to be installed to manage the redundancy of the information and to limit the effort due to the analysis of social data. On the other hand, understanding the extent of how much a piece of information has been shared can be helpful in understanding how important or critical it is (see Crowd4Sat, Demonstration Project 3, [RD 36]).

Exploitation of citizen science and crowdsourcing should be a priority in future EO based initiatives and particular attention should be paid to aspects like schemes of engagement, security and privacy. Furthermore, understanding how different forms of crowdsourcing can be used in different scenarios and settings is highly recommended. The definition of new strategies to collect, analyse and reuse citizen science data could play important role in the configuration of proper guidelines and standards for the generation and visualization of data generated by contributors.

5.2. Citizen Observatories

"**Citizen Observatories**" have been created with the help of new technology to allow the public to collaborate with authorities and organisations in day to day and emergency management issues.

"Citizen science" is defined as "scientific work undertaken by members of the general public, often in collaboration with or under the direction of professional scientists and scientific institutions".[RD 43].

A collaborative approach has been taken to develop solutions that involve an exchange of information and expertise from all participants and where the focus is on arriving at practical solutions with a clear vision and direction. Implementation has been through a combination of **crowdsourcing**, custom applications and dedicated web portals designed to foster collaboration, and which has created a shared knowledge base that facilitates decision making processes and engages with communities. Data is captured via innovative sensors that are used directly by citizens and crowdsourcing from social networks (or by collective intelligence).

Real-time high quality sensors provide "live" ground information on the current environmental conditions of a locality, and hence are critical to the understanding of areas of interest. Data from sensors are processed in a variety of ways and made available to decision makers as visualisations, predictive analyses or real-time alerts and triggers. All of these approaches together help inform decision makers of the existing and predicted conditions at specific locations. High precision sensors are highly expensive, need constant maintenance and are static, but can provide high volumes of data regarding areas that have been previously determined to be of interest.

However, with the rapidly evolving environmental conditions and landscapes, critical areas of interest can be dynamic and different areas in cities can be of interest at different times. This challenge has been addressed by the development and deployment of low-cost sensor technology, as well as maintaining communication between citizens and the authorities. A variety of information can be provided by citizens and key to their participatory role is the large scale installation of low cost analogue devices across wide geographical areas.

Citizens and communities participate in two ways; explicitly by providing information via mobile and online portals that were developed in the project, and implicitly by using social media platforms, opportunistically sourced to provide an assessment of evolving situations. Explicit data collection is undertaken by participatory sensing, where citizens are encouraged to report if they observe anything of relevance.

6. The Agenda 2030 Sustainable Development

6.1. Background

In 2000, 189 countries of the world came together and created a plan, called the Millennium Development Goals trying to achieve a better world by 2015. In 2015, countries reconvened to set new Sustainable Development Goals (SDGs). With the SDGs, the connection between global well-being and planet's natural systems has been recognised. The 2030 Agenda marks a milestone in the evolution of global community efforts to steward the progress towards economic, environmental and social dimensions of sustainability.

Figure 7: The 2030 Agenda implementation aims to achieve specific 17 goals (UN, 2015).

Table 1: The Agenda 2030 Sustainable Development Goals

Goal 1	End poverty in all its forms everywhere
Goal 2	End hunger, achieve food security and improved nutrition and promote sustainable agriculture
Goal 3	Ensure healthy lives and promote well-being for all at all ages
Goal 4	Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all
Goal 5	Achieve gender equality and empower all women and girls
Goal 6	Ensure availability and sustainable management of water and sanitation for all
Goal 7	Ensure access to affordable, reliable, sustainable and modern energy for all

Goal 8	Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all
Goal 9	Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation
Goal 10	Reduce inequality within and among countries
Goal 11	Make cities and human settlements inclusive, safe, resilient and sustainable
Goal 12	Ensure sustainable consumption and production patterns
Goal 13	Take urgent action to combat climate change and its impacts
Goal 14	Conserve and sustainably use the oceans, seas and marine resources for sustainable development
Goal 15	Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss
Goal 16	Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels
Goal 17	Strengthen the means of implementation and revitalize the global partnership for sustainable development

The new set of SDGs and the associated Global Indicator Framework of more than 200 indicators represent a data-driven global development framework. Countries can introduce evidence-based decision making for their development policies.

6.2. Earth Observation and the Agenda 2030

Earth Observation (EO) data and Geographic Information (GI), combined with a large amount of socio-economic and other statistical data and different output models provide a unique input to governments in their policy preparation, monitoring and evaluation. To achieve SDGs, GI and EO play critical roles in monitoring the targets. Technology can help provide insight, track progress and help nations make mid-course adjustments.

SDGs require new, evidence-based science to give insights in the interdependence of the natural, socio-economic and other subsystems. EO can track many global, regional and local changes in high resolution and in real time. EO is rapidly expanding its monitoring capabilities across different natural, manufactured systems and sectors providing almost real-time data. Governments, authorities, businesses and the public at large have increasing access to rapidly growing dynamic data. The creation of knowledge building platforms should help nations, businesses and other stakeholders make better informed and timely development and investment decisions toward achieving the SDGs.

To advance on SDG related complexity and interconnectivity, we need to recognise the necessity for new knowledge development and sharing types. Connecting EO knowledge and innovations with authorities, businesses and other stakeholders require unprecedented strategies. Co-creating knowledge platforms linked to different knowledge providers and users could increase the uptake of innovations for achieving the political, economic and social change for meeting SDGs. Sharing EO related scientific knowledge, technologies and experiences can significantly reduce the costs of monitoring the progress towards SDGs.

This requires wide collaboration among different actors and integration of different knowledge systems. Co-creation contributes to new knowledge through the integration of scientific knowledge and participation from policy, business and other partners.

The publication entitled **"Earth Observations in support of the 2030 Agenda for Sustainable Development"** prepared by the Group on Earth Observation (GEO, 2017) highlights the potential role for EO in supporting the global Indicator framework for the SDGs. A number of case studies demonstrate the opportunities for EO data integration into the reporting systems. Case studies cover wide range of sectors: agricultural monitoring, algal bloom, flood prediction, mangrove watch, water-related ecosystem monitoring, urban growth, air pollution monitoring, water quality monitoring, forest cover change, land degradation, etc. The publication [URL 19] also provides the insight of connection between different SDGs.

The European Space Agency has prepared a handbook "**Satellite Earth Observation in Support of the Sustainable Development Goals", Special 2018 Edition** [URL 20]. Part I of the documents explains the role of EO in supporting the SDG, Targets and Indicators, as well as accessing EO data. Part II consists of several contributed articles about practical examples of EO data usage. Part III focuses on five specific SDGs highlighting the potential nature of the contribution from EO satellite data. Several best practice examples are given for Goal 2 - Zero hunger, Goal 6 - Clean water and sanitation, Goal 11 - Sustainable cities and communities, Goal 14 - Life below water and Goal 15 - Life on land [URL 20].

The table below represents some of ESA's programmes specifically related to the SDGs (ESA, 2017)

Table 2: ESA's programmes for SDG (ESA 2017)

SDG topic	Keywords	ESA programme
SDG 1: No Poverty	Supporting banking systems International development Sustainable production of food Supporting development banks	Support to development banks Earth observation for international development Herding from space

Co-funded by the Erasmus+ Programme of the European Union

		Satellites for remote banking
SDG 2: Zero Hunger	Sustainable agriculture Monitoring food production and security	Agriculture and food security Global monitoring for food security Health of livestock
SDG 3: Good Health and Well-Being	Telemedicine Space for Health ISS research	Telemedicine using Satcoms Space aids Ebola patients Mapping deadly mosquitos Satellites helping to assess the risk of epidemics Space for Health
SDG 4: Quality Education	Tele-learning Tools for educators	Satcoms linking rural schools in South-Africa and Italy ESA kids e-Learning in rural areas ESA educational projects
SDG 5: Gender Equality	Attracting more women to science and technology careers	Space Girls-Space Women Women choosing STEM careers (video)
SDG 6: Clean Water and Sanitation	Recycling water Closed-loop systems Monitoring water quality	TIGER project GEO-Aquifer project (PDF) Worldwide water quality app MELiSSA
SDG 7: Affordable & Clean Energy	Solar energy Energy research	Energy research at ESA Electric propulsion innovation and competitiveness
SDG 8: Decent Work and Economic	Regional development	Copernicus opportunities for economic

Growth	Job creation	growth and regional development First ESA facility in UK, catalyst for growth Job creation and growth with space Copernicus benefiting society and the environment
SDG 9: Industry, Innovation & Infrastructure	GPS Telecom satellites	Broadband for all Technology transfer and business incubation Protecting our infrastructure from space weather Tracking trains Satellites for remote banking Galileo-based solutions for transport and infrastructure
SDG 10: Reduced Inequalities	Supporting developing countries Providing applications and services	Providing energy, clean water, food, education, ... (see other SDGs)
SDG 11: Sustainable Cities and Communities	Living on the ISS/Concordia Urban areas Air quality Transport systems Cultural heritage	The international space station (ISS) Concordia, Antarctic research station Mapping urban areas Monitoring air quality Mapping of global air pollution Integrated applications projects - Transport Satellites in support of world heritage
SDG 12: Responsible consumption and	Recycling	The ISS as closed-loop system

production	Closed-loop systems	Concordia, Antarctic research station MELiSSA, closed-loop ecological system
SDG 13: Climate Action	Research in arctic/antarctic Monitoring ice sheets Climate change initiative Desertification	Looking out for landslides Supporting the healthcare in emergency areas Desert watch SMOS: Monitoring the oceans and surface moisture ESA's climate change initiative Monitoring the atmospheric composition and climate Cryosat: monitoring the arctic/Antarctic Sentinel 1A-radar monitoring of oceans and ice ESA and the arctic ESA and the Antarctic
SDG 14: Life below Water	SAT-AIS Sustainable fishing Soil moisture and ocean salinity (SMOS) satellite	Tracking marine animals with satellites Vessel tracking from space SMOS Maritime security (video) ESA and oceans Copernicus - Marine projects
SDG 15: Life on Land	Forestry/deforestation Biodiversity Land use detection	Trees tell their own story Smart logging Tracking biodiversity

		Burned area land use change detection Monitoring forest degradation and deforestation Forest fires Land cover maps
SDG 16: Peace and Justice - Strong Institutions	Support to identify illegal actions Support of election processes	Detection of ship movements Maritime surveillance e-Training via satellite in support of African electoral cycles
SDG 17: Partnerships	Partnering with other space agencies Partnering with other companies Partnering with institutions	ESA partners

EO opportunities for the implementation of SDG is being analysed not only at global scale, but also at national levels. For example, the Netherlands Space Office has prepared a publication entitled "**Earth Observation and Sustainable Development Goals in the Netherlands**" (NSO, 2017) which is based on literature studies and interviews, discusses how satellite data can contribute to achieving the SDG, both domestically and internationally. The Netherlands aims becoming a circular economy by 2050. Inclusive green growth, sustainable development and sustainable landscapes are key elements for achieving the circular economy. The report provides an overview of SDGs and the possible contribution of EO meeting targets and indicators. This is done for the following categories: general, agriculture, water, sustainable landscape management and climate [URL 21].

6.3. Trends, challenges and opportunities of EO in the context of SDGs

Geospatial data provided by EO represents an opportunity to provide information directly linked to SDGs. The main advantages are:

Research and data related: Free, open and easily accessible datasets, data disaggregation, integration of different data sources, complementing statistical methods with other methods of data acquisition, new data acquisition and integration approaches, accounting for the effect of scale, standardisation, interoperability, harmonisation, multiple use of data, operating massive volumes of complex data, etc.

Synergies and development related: cooperation across disciplines, complexity-of-use for non-experts, getting from isolated initiatives to integrated efforts, implementation of data applications and solutions for policy use, creation of in-situ networks and citizens' observatories, public-private partnerships, cooperation between government, academia and business, uptake of EO knowledge in business development and policy making, etc.

The challenge of capacity building and role of knowledge platforms

Many countries have their interpreted national SDGs, however, Agenda 2030 is global. Capacity building and research are important at the national levels, but even more so at the international level. A significant contribution of EO to the SDGs on both at national and global levels, may be achieved through the use of distributed knowledge platforms.

Interaction between Earth's natural systems and socio-economic performance is very complex. The nexus between different SDGs adds to this complexity. Provision of EO information services to policy makers, businesses, academia and public requires unprecedented user-friendly knowledge building and distributing platforms.

6.4. Review of EO contribution to the SDG Targets and Indicators

The importance of Geospatial Information and Earth Observations (including satellite observations) for the SDG Targets and Indicators has been clearly highlighted within the 2030 Agenda for Sustainable Development [RD 01]: "... We will promote transparent and accountable scaling-up of appropriate public-private cooperation to exploit the contribution to be made by a wide range of data, including earth observation and geo-spatial information, while ensuring national ownership in supporting and tracking progress." (UNGA resolution A/RES/70/1. Paragraph 76) [

Socio-economic data traditionally exploited by countries to assess their development policies, such as household surveys, population census and other types of administrative data collections need to be integrated for an effective monitoring of the SDG Indicators and reporting of the progress towards the SDG Targets.

The **Independent Expert Advisory Group** (**IEAG**) on the "Data Revolution for Sustainable Development" stressed the importance for countries, to use multiple data coming from new technologies and traditional statistical data, in order to produce high-quality and timely information, with more detail, with higher frequencies and with the ability to successfully extract development indicators.

Geospatial Information and Earth Observations, together with modern data processing and Big Data analytics, offer unprecedented opportunities to modernise the national statistical

systems and consequently to make a huge advance in the capacities of countries to efficiently track all facets of sustainable development. Satellite Earth Observations, with their global spatial coverage and high frequency of observations, can reveal to be essential in capturing important aspects of sustainable development and in particular the environmental dimension of the SDGs. An effective integration within national statistical systems can also significantly reduce the monitoring costs and consequently enable countries to monitor and report progress on the Goals and the Targets.

Satellite Earth Observations offer another important advantage related to the spatial coverage of measurements, which allows disaggregating spatially the derived indicators according to environmental and also socio-economic data. The open and free data policies of government funded satellite data, along with assurance of long-term continuity of observations, are important incentives for countries, and for their National Statistical Offices, to integrate EO data in their work during definition, planning, implementation, monitoring and assessment of development projects.

The 2030 Sustainable Development Agenda involves a large and heterogeneous group of stakeholders that all have different degrees of awareness and knowledge the value of Geospatial Information and in particular satellite Earth Observation data can offer to the SDGs. At its 3rd meeting in March 2016, the **IAEG-SDGs** created the following three working groups to address transversal topics that are critical for the SDGs implementation:

1. Working group on Statistical Data and Metadata eXchange (SDMX),
2. Working group on indicator inter-linkages,
3. Working Group on Geospatial Information (WGGI).

   The work of the **WGGI** is of the highest relevance for the promotion of Geospatial Information and Earth Observations in the SDG monitoring. Its mandate is to review the Global Indicator Framework from a “geographic location” perspective, in order to:

   a. identify existing geospatial data gaps and methodological issues, and
   b. consider how Geospatial Information and Earth Observation can contribute to the Global Indicator Framework.

   The establishment of the **IAEG-SDGs WGGI** acknowledges the demand from the 2030 Agenda on Sustainable Development for new data acquisition and integrated approaches that can improve the availability, quality, timeliness and extraction of data, and consequently support the implementation of the SDGs at all levels.

The **UN Committee of Experts on Global Geospatial Information Management (UN-GGIM)** [URL 01] is another key player in the combined management of Geospatial Information and Earth Observation data within National Statistical Systems (NSSs). UN-GGIM, created in July 2011 under the auspices of the UN Economic and Social Council (ECOSOC), aims at playing a leading role in setting the agenda for the development of global geospatial information and in promoting its use within and across countries. UN-GGIM established a forum to liaise and coordinate amongst Member States, and between Member States and international organizations, for the development of effective strategies on how to build and strengthen national capacity on geospatial information. The UN-GGIM vision is to make accurate, authoritative and reliable Geospatial Information (including satellite Earth Observations) readily available to support national, regional and global development. UN-GGIM is engaged in the SDG process primarily through their active participation in the WGGI to which they provide the secretariat. UN-GGIM has also a European branch which focusses on how to implement an efficient strategy in Europe.

The WGGI group has identified 15 indicators (including 8 Tier III Indicators) where geospatial information together with statistical data can contribute directly to the production of the identified indicators, and an additional list of 9 indicators (including 4 Tier III Indicators) where geospatial information can significantly support the production of the indicators.

Table 3: Short-list of 15 indicators (4 Tier I; 3 Tier II; and 8 Tier III) where geospatial information together with statistical data can contribute directly to the production of the identified indicators (IAEG-SDGs WGGI, Working Group on Geospatial Information, Europe – ESS meeting on the integration of statistical and geospatial information Luxembourg, 31 March 2017)

	Indicators							
Tier I	9.c.1	14.5.1	15.1.1	15.1.2				
Tier II	11.2.1	11.3.1	15.4.1					
Tier III	2.4.1	6.3.2	6.5.2	**6.6.1**	**9.1.1**	11.7.1	14.2.1	**15.3.1**

Table 4: Additional short-list of 9 indicators (1 Tier 1; 3 Tier II; 4 Tier III and with multiple classifications) where geospatial information can significantly support the production of these indicators (IAEG-SDGs WGGI, Working Group on Geospatial Information, Europe – ESS meeting on the integration of statistical and geospatial information Luxembourg, 31 March 2017)

	Additional indicators				
Tier I	1.1.1	(4.5.1)			
Tier II	5.2.2	5.4.1	15.4.2	(4.5.1)	
Tier III	1.4.2	5.a.1	5.a.2	11.7.2	(4.5.1)

The WGGI group is currently made of three Task Teams working on the following Tier III Indicators:

1. SDG Indicator 6.6.1 on extent of water related ecosystems;
2. SDG Indicator 9.1.1 on the proportion of the rural population who live within 2 km of an all-season road; and
3. SDG Indicator 15.3.1 on the proportion of land that is degraded in support to Land Degradation Neutrality)

Furthermore, other three Task Teams are working on the following transversal issues:

- Data disaggregation by geographic location;
- Alternative data sources;
- International global geospatial datasets.

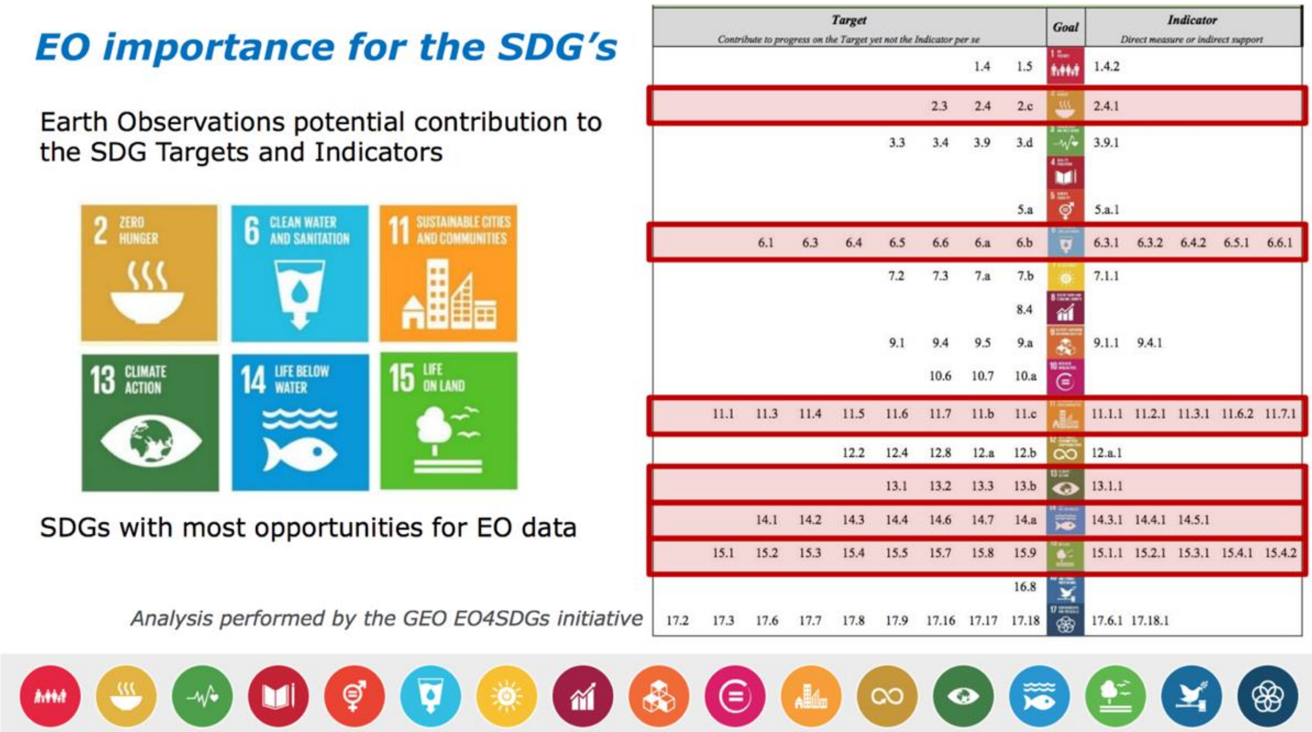

Figure 8: The Contribution of EO to the realization of the SDGs. Part of the presentation of Marc Paganini (ESA) to the 4th Plenary UN GGIM Europe, 7-8 June 2017, Brussels, Belgium. [URL 02]

As a result of a study of the EO supporting SDGs, 34 indicators were selected (expanding the initial work done by WGGI group within the EO4SGDs initiative) that are highly related with EO (at least at a preliminary basis) and are currently classified as Tier II or III [RD 46].

Table 5: Preliminary analysis of SDG Target and Indicators that are classified as Tier II or III and EO has a major impact in achieving and informing them correspondingly

Target	Indicator	Possible Custodian Agency(ies)	Partner Agency(ies)	Updated Tier Classification (by IAEG-SDG Members)
1.4	1.4.1	UN-Habitat	UNEP, ITU, UPU	**Tier III**
	1.4.2	World Bank, UN-Habitat	FAO, UNSD, UN Women, UNEP, IFAD	**Tier III**
1.5	1.5.1	UNISDR	UN-Habitat, UNEP, DESA Population Division	**Tier II**
	1.5.2	UNISDR	UNEP, FAO	**Tier II**
	1.5.3	UNISDR	UNEP	**Tier II**
	1.5.4	UNISDR		**Tier III**
2.3	2.3.1	FAO		**Tier III**

	2.3.2	FAO	World Bank	**Tier III**
2.4	2.4.1	FAO	UNEP	**Tier III**
2.5	2.5.1	FAO	UNEP	**Tier II**
	2.5.2	FAO	UNEP	**Tier II**
3.9	3.9.2	WHO	UNEP	**Tier II**
	3.9.3	WHO	UNEP	**Tier II**
4.5	4.5.1	UNESCO-UIS	OECD	**Tier I/II/III depending on indice**
6.3	6.3.1	WHO, UN-Habitat, UNSD	UNEP, OECD, Eurostat	**Tier II**
	6.3.2	UNEP	UN-Water	**Tier III**
6.4	6.4.1	FAO	UNEP, IUCN, UNSD, OECD, Eurostat	**Tier III**
	6.4.2	FAO	UNEP, IUCN, UNSD, OECD, Eurostat	**Tier II**
6.5	6.5.1	UNEP	UN-Water, IUCN, Ramsar	**Tier II**
	6.5.2	UNESCO-UIS, UNECE	UNECE, IUCN	**Tier II**
6.6	6.6.1	UNEP	UN-Water, IUCN, Ramsar	**Tier III**
9.1	9.1.1	World Bank	UNEP, UNECE	**Tier III**
11.3	11.3.1	UN-Habitat	UNEP	**Tier II**
	11.3.2	UN-Habitat		**Tier III**
11.4	11.4.1	UNESCO-UIS	IUCN	**Tier III**
11.a	11.a.1	UN-Habitat	UNFPA	**Tier III**
14.1	14.1.1	UNEP	IOC-UNESCO, IMO, FAO	**Tier III**
14.2	14.2.1	UNEP	IOC-UNESCO, FAO	**Tier III**
14.3	14.3.1	IOC-UNESCO	UNEP	**Tier III**
15.2	15.2.1	FAO	UNEP, UNFCCC	**Tier II**
15.3	15.3.1	UNCCD	FAO, UNEP	**Tier III**
15.4	15.4.1	UNEP-WCMC, UNEP		**Tier II**
	15.4.2	FAO	UNEP	**Tier II**
15.5	15.5.1	IUCN	UNEP, CITES	**Tier II**

Two of the targets of “SDG1 - No poverty”, 1.4 and 1.5, seem to have the potential to be EO relevant, since they involve climatic and geophysical information or man-made structures. The remaining targets involve statistical data. None of the six indicators of targets 1.4 and 1.5 fall under the two WGGI short-lists mentioned in Table 1 and Table 2 [URL 03]. Both targets, as well as one of the indicators (1.4.2), are amongst those identified by the GEO as being relevant to be supported by Earth observations, as shown in Figure 2 [RD 03].

GEO GROUP ON EARTH OBSERVATIONS

Sustainable Development Goals

Earth Observations in Service of the *Agenda 2030*

Target Contribute to progress on the Target yet not the indicator per se									*Goal*	*Indicator* Direct measure or indirect support				
							1.4	1.5	1	1.4.2				
						2.3	2.4	2.c	2	2.4.1				
					3.3	3.4	3.9	3.d	3	3.9.1				
									4					
								5.a	5	5.a.1				
		6.1	6.3	6.4	6.5	6.6	6.a	6.b	6	6.3.1	6.3.2	6.4.2	6.5.1	6.6.1
					7.2	7.3	7.a	7.b	7	7.1.1				
								8.4	8					
					9.1	9.4	9.5	9.a	9	9.1.1	9.4.1			
						10.6	10.7	10.a	10					
	11.1	11.3	11.4	11.5	11.6	11.7	11.b	11.c	11	11.1.1	11.2.1	11.3.1	11.6.2	11.7.1
				12.2	12.4	12.8	12.a	12.b	12	12.a.1				
					13.1	13.2	13.3	13.b	13	13.1.1				
		14.1	14.2	14.3	14.4	14.6	14.7	14.a	14	14.3.1	14.4.1	14.5.1		
	15.1	15.2	15.3	15.4	15.5	15.7	15.8	15.9	15	15.1.1	15.2.1	15.3.1	15.4.1	15.4.2
								16.8	16					
17.2	17.3	17.6	17.7	17.8	17.9	17.16	17.17	17.18	17	17.6.1	17.18.1			

Figure 9: SDG Targets and Indicators that can be supported by Earth observations. (Source: EO4SDGs / CEOS, Earth Observations in support of the 2030 Agenda for Sustainable Development)

A preliminary estimate is that all six indicators (all Tier II or III) are EO relevant, because of their compound nature, involving one or more of the major categories of EO contributions to Indicators identified by EO4SDG [RD 04]. I.e.:

- Direct/indirect monitoring (Forest, agricultural land, air pollution, water stress, water bodies with good ambient water, extent of water related ecosystems, build-up areas of cities, land degradation, etc.)

- Population estimation (Proportion of populations with access to electricity, transport, basic services, within 2km of all-season roads*, with secure tenure rights to land, etc.)
- Other statistics (Level of Integrated Water Resource Management, disaster economic loss, number of countries with DRR strategies, coverage of protected areas, etc.)

6.5. EO products supporting SDG Indicators

A concept on "How Earth Observation products can support the achievement of the SDGs Targets and the calculation of the SDGs Indicators" is shown below:

Table 6: Earth Observation supports SDG Targets & Indicators

Sustainable Goal	Target	EO Contribution help achieving the target	Indicator	EO Contribution help informing the indicator
1 NO POVERTY	1.4	mapping of land use and developments, base mapping for land administration, assessment of compliance with land use regulations and property rights, infrastructure mapping (for market access and access to basic services)	1.4.2	mapping for verification of land tenure rights
	1.5	risk assessment and simulation models / forecasting and early warning		
2 ZERO HUNGER	2.3	agricultural knowledge and information systems, crop health and yield monitoring, market access, agricultural land rights, agricultural market information, site evaluation, tackling pest and diseases, fertilizer advice, crop calendars	2.3.1	parcel identification and crop monitoring
	2.4	see 2.3 + drought early warning, agricultural insurance, market access and infrastructure analysis, climate adaptation scenarios	2.4.1	land use / land cover mapping and monitoring
3 GOOD HEALTH AND WELL-BEING	3.3	early warning systems for vector-borne diseases	3.3.3	Number of people requiring interventions against neglected tropical diseases
	3.6	base mapping for the identification of roads and assessment of road conditions (paved, unpaved)		
	3.8	infrastructure and population density mapping to assess access to basic services (health facilities) disaggregated by population group; base map for planning of creation of health facilities		
	3.9	air quality and water quality monitoring systems; mapping of potentially dangerous infrastructure (waste management facilities, industry, mining, nuclear facilities, etc.)	3.9.1	air quality monitoring and early warning systems
			3.9.2	surface water quality monitoring
4 QUALITY EDUCATION	4.2 + 4.3	infrastructure and population density mapping to assess access to educational services (schools) disaggregated by population group; base map for planning of creation of schools		

5 GENDER EQUALITY	5.4 + 5.6 + 5.a	assessment of access to health facilities, arable land, infrastructure, schools, etc. in terms of travel time (throughout the year)		
6 CLEAN WATER AND SANITATION	6.1	assessment and monitoring of available water resources for drinking water		
	6.2	assessment of proximity to and availability of drinking water, sewerage and drainage systems and wastewater treatment plants		
	6.3	water quality monitoring	6.3.2	(surface) water resources monitoring and water quality monitoring
	6.4		6.4.1	water resources assessment and monitoring; input for water accounting and water productivity assessments
	6.4		6.4.2	water resources assessment and monitoring; input for water accounting and water productivity assessments
	6.5		6.5.1	water resources assessment and monitoring; input for water accounting and water productivity assessments
	6.6		6.6.1	land use / land cover mapping and monitoring
7 AFFORDABLE AND CLEAN ENERGY	7.1	solar, wind, hydropower and biofuel potential assessment and monitoring of performance	7.1.1 + 7.1.2	
	7.2	solar, wind, hydropower and biofuel potential assessment and monitoring of performance	7.2.1	
	7.b	mapping of energy utilities and access to electricity		
8 DECENT WORK AND ECONOMIC GROWTH	8.4	mapping and monitoring environmental degradation and environmental impact of extractive industries	8.4.1	data input for footprint calculations (same as 12.2.1)
9 INDUSTRY, INNOVATION AND INFRASTRUCTURE	9.1		9.1.1	mapping, monitoring and analysis of rural settlements and roads
	9.4	mapping and monitoring of infrastructure (projects) and vulnerability assessment of infrastructure	9.4.1	measuring CO2 in atmosphere and climate modelling
10 REDUCED INEQUALITIES	10.1	combination of actions for SDG-1 – 9 with emphasis on vulnerability		
	10.7	mapping and monitoring migration patterns (refugee camps, settlements)		
11 SUSTAINABLE CITIES AND COMMUNITIES	11.1		11.1.1	mapping and monitoring of slum extent and housing quality
	11.2 + 11.3	assessment of sustainable urban planning through a combination of actions for 1.4, 1.5, 3.6, 3.8, 3.9, 4.2, 4.3, 5.4, 5.6, 7.b and 9.1	11.3.1	mapping and monitoring of urban sprawl and impervious surfaces; land use / land cover mapping and monitoring
	11.4	mapping and monitoring of cultural and natural heritage sites and identification of threats		

	11.5	risk assessment and simulation models; forecasting and early warning; monitoring of disasters and damage assessment		
	11.6	mapping of waste sites and assessment of impact of urban expansion on the environment	11.6.2	urban monitoring and change detection, including green and public spaces
	11.a	mapping and monitoring of land use, land cover and urban processes		
	11.c	mapping and monitoring of urban housing		
12 RESPONSIBLE CONSUMPTION AND PRODUCTION	12.2 + 12.4 +12.5	mapping and monitoring of use of natural resources (agriculture, water, forests, fishing, mining, energy, air, environment, etc.)	12.2.1	data input for footprint calculations
	12.8	overarching purpose of EO in combination with mobile and web applications		
13 ACCIÓN POR EL CLIMA	13.1	support to modelling for prevention, early warning and monitoring of disasters (storms, floods, earthquakes, volcanic eruptions, landslides, industrial disasters); mapping and monitoring of actions for rehabilitation and strengthening of resilience	13.1.1	Mapping of the disaster impact
14 LIFE BELOW WATER	14.1		14.1.1	(surface) water quality monitoring
	14.2		14.2.1	ecosystem mapping and monitoring; coastal land use / land cover mapping and monitoring
	14.3	monitoring of ocean acidity		
	14.4	identification, monitoring and analysis of potential fishing zones & detection of harmful algal blooms	14.4.1	
	14.5	assessment of impact of economic activities on protected coastal and marine areas	14.5.1	mapping and monitoring of marine protected areas extent
	14.6	detection and tracking of fishing vessels	14.6.1	
	14.7	Mapping and monitoring of tourism infrastructure, environmental impact, and access to markets for fisheries and aquaculture; identification, monitoring and analysis of potential fishing zones & detection of harmful algal blooms		
15 LIFE ON LAND	15.1	mapping and monitoring of ecosystems, including forests, wetlands and drylands and mapping and monitoring of phenomena that may affect these ecosystems (land degradation, urbanization, economic activity, disasters, etc.)	15.1.1	forest cover mapping and monitoring
			15.1.2	ecosystem and natural habitat mapping and monitoring
	15.2		15.2.1	mapping and monitoring of forests, including forest degradation, rehabilitation and recovery
	15.3		15.3.1	Land degradation monitoring; land use / land cover mapping and monitoring
	15.4		15.4.1	ecosystem mapping and monitoring
			15.4.2	ecosystem mapping and monitoring
	15.5		15.5.1	natural habitat and biodiversity mapping and monitoring

	15.9		15.9.1	ecosystem, natural habitat and biodiversity mapping and monitoring
16 PEACE, JUSTICE AND STRONG INSTITUTIONS	16.1	monitoring of conflicts (bombing, military presence) and humanitarian efforts (refugee camps) from space		
	16.2	mapping and monitoring of properties and illegal constructions and activities (deforestation, mining, disturbance protected areas)		
	16.6	mapping and monitoring of spatial dimension of public spending, such as infrastructure		
	16.7	overarching purpose of EO: increasing visibility of environmental and societal processes and monitoring of changes over time		
17 PARTNERSHIPS FOR THE GOALS	17.1 – 17.5	mapping and monitoring of properties and illegal constructions and activities (deforestation, mining, disturbance protected areas) and spatial dimension of public spending, such as infrastructure		
	17.6 – 17.8 & 17.9	mapping and monitoring of effects of technology transfer, such as improved air quality, reduction environmental pollution, sustainable cities, environmental management, etc.		
	17.10 – 17.12	mapping and monitoring of agricultural production, industrial activity and transport characteristics		
	17.16 + 17.17	mapping and monitoring of transboundary issues and public-private issues (sustainable use of natural resources, environmental pollution, extractive industries, fisheries)		
	17.18		17.18.1	portfolio of EO applications that support natural wealth accounting (environmental accounting, ecosystem accounting and footprint calculations)
	17.19	mapping and monitoring of infrastructure and economic, environmental and societal processes		

7. Techno logy Watch

7.1. Introduction

The technology and non-technology watch will provide input for the strategy in terms of the expected/future skills needs and also to feed the description of the space/geospatial sector in the proposed Body of Knowledge for GI and EO. The value of technology monitoring and forecasting lies more in its potential to minimize surprises. It does this by various means:

- Defining and looking for key enablers and inhibitors of new disruptive technologies,
- Assessing the impact of potential disruption,
- Postulating potential alternative futures, and
- Supporting decision making by increasing the lead time for awareness.

This section describes the Technology Watch (TW) as a system implemented in order to monitor technological trends and support the decision making in the education and academic sector, for example for curriculum development research initiatives, new collaborative patterns.

A complete and precise list of requirements is needed in order to proceed with the conceptual design as well as with the implementation of the TW. The conception and implementation of the TW might be quite challenging and in order to fulfil its goals in the context of this project certain characteristics must be met.

In order to build an efficient TW some steps have to be followed such as:

- Defining the goals of the mission by understanding key stakeholders' objectives.
- Determining the scope of the mission by ascertaining which people and resources are required.
- Selecting appropriate methodologies to meet the mission objectives given the requirements.
- Gathering information from key experts and information source the availability of data and resources.
- Optimizing the tools used to process, monitor.

7.2. Attributes of an effective system

It is important to have a forecasting system that monitors, tracks, and reformulates predictions based on new inputs and collected data in a persistent manner. An open approach allows the use of crowd resources to identify potentially disruptive technologies and to help understand their possible impact. The system should publish and adhere to policies on how it uses, stores, and tracks information in order to achieve transparency. Another characteristic should be its structural flexibility in order to enable an efficient response to complexity, uncertainty, and changes in technology and methodology. The system should be easy to use and broadly available to all users, while encouraging the participation of individuals from a wide variety of cultural, geographic, and linguistic backgrounds to ensure a balance of viewpoints in order to avoid mitigating bias. Last but not least, the reliability of the data and their maintainability are of the utmost importance as well as the way that those are visualized by the users.

7.3. Description of Technology Watch concept

The need for monitoring technological changes is imperative since small changes in one sector may trigger significant disruptions in other sectors. The decision makers in government, corporations, and institutions are faced with shrinking time frames in which to plan and react to disruptions. Establishing a systematic information alert system, the so-called Technology Watch (TW) is paramount to anticipate threats and opportunities, and to adapt to a changing environment as well. These systems allow us, among other aspects:

- to detect signals of change
- to alert of possible threats / opportunities
- to look for solutions to technological problems
- to avoid the waste of resources
- to reduce risks, to identify substitute products
- to detect technological advances
- to be aware of the evolution of emerging technologies
- to identify who generates technology, etc.,

It is also important to understand that the time frame for a forecast will depend on the type of technology as well as on the planning horizon of the decision maker. The geospatial sector is heavily influenced by technologies that perform within a short time frame. The objective is to understand the state of the global marketplace and the nature of disruption itself and find an optimized way to save time and resources when it comes to being alert of what is happening around us. Traditionally Technology Watches have been used in a competitive context in order to help companies and institutions to take **the right decisions at the right moment with the right timing on particular aspects** (e.g. decide to develop and/or implement a standard, to apply a technology, to develop an R&D project …). When it comes to decisions, not just technological advancements are important, but also economic or legal regulations could have their impact in any sector. Following Michael Porter [RD 45], there are five forces which shape strategy.

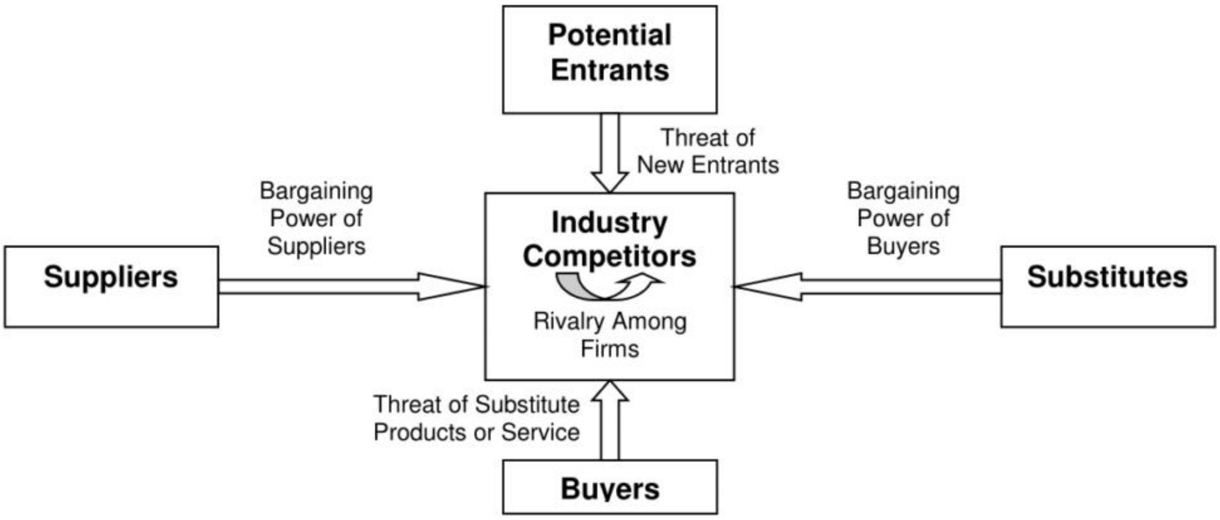

Figure 10: Porter forces which shape strategy

According to Kotler [RD 44], the macro environment consists of main forces such as demographic forces, economic forces, natural forces, technological forces, political forces and cultural forces. These forces shape the development of a sector while the forces mentioned by Porter are more related to the individual company. Kotler macro environment can be a way to structure the TW considering also the non-technological factors.

As stated before, technologies used for monitoring a sector are company-oriented. That means that in EO4GEO, as a project, the orientation we intend to give to our Technology Watch system will not always meet the same requirements as a TW system will entail. In TW monitoring System there are some steps to be followed:

1. (Re)Defining Information needs (KITs +- Key Intelligence Needs) & looking for the appropriate information sources

2. Information gathering and storing
3. Information treatment, validation & analysis
4. Dissemination
5. and back to 1 in a continuous process

7.4. *The OGC Technology Watch*

Change in the technology industry is constant and rapid. The OGC Technology Trends process takes into consideration a large variety of sources for trends information. Such sources include industry reports, international research on the matter as well as OGC members, alliance partners and staff. OGC adopts the Technology Watch as a methodology to monitor the technological trends mature for standardization.

OGC standards are technical documents that detail interfaces or encodings, amongst others. Software developers use these documents to build open interfaces and encodings into their products and services. These standards are the main "products" of the Open Geospatial Consortium and have been developed by the membership to address specific interoperability challenges.

The Tech Trends process is overseen by the OGC's Architecture Board (OAB). These individuals are selected by the OGC membership for their international technical expertise and knowledge. They meet regularly to review new trend information and advance in technology in order to map its relevance and impact on the geospatial industry. The result is the OGC Trends Mind Map that is displayed below.

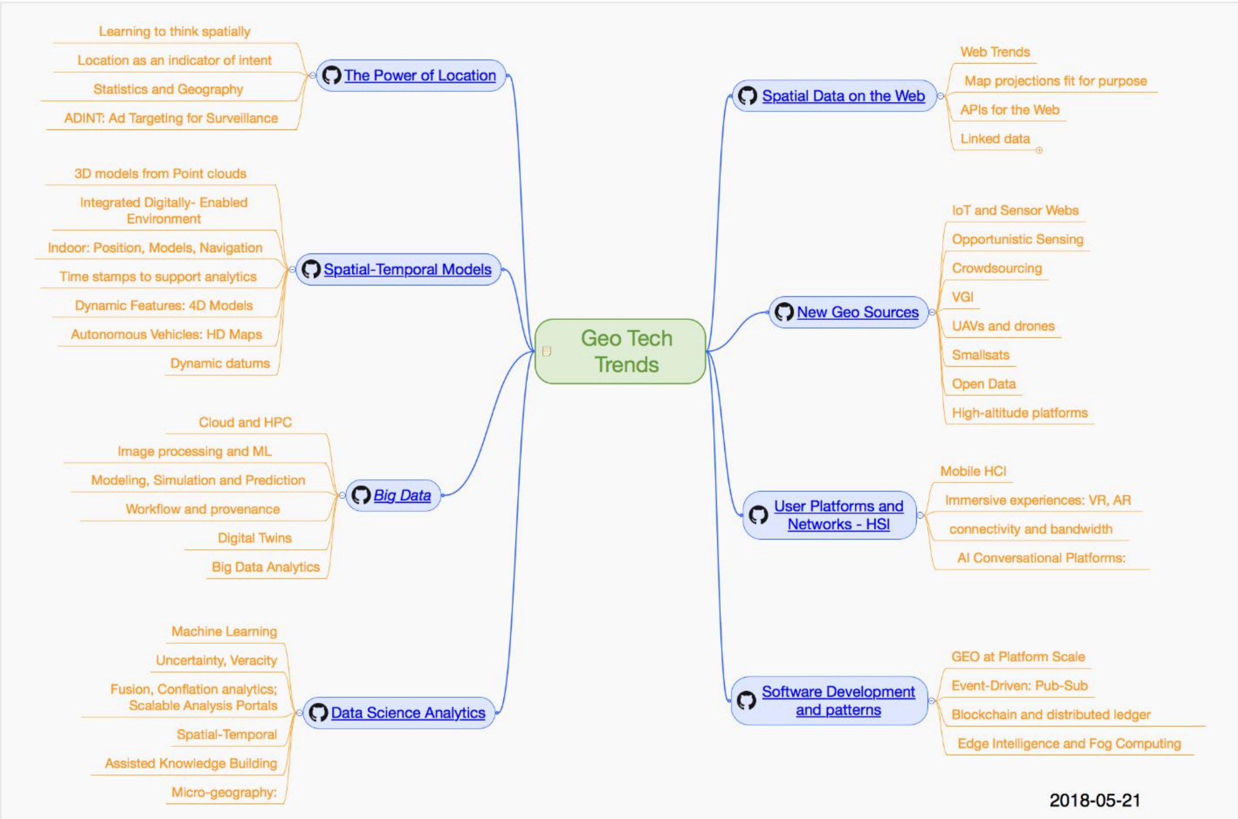

Figure 11: Geospatial technology trends as tracked by the Open Geospatial Consortium (OGC) and the OGC Architecture Board (OAB).

Trends grouped in topic areas:

- The Power of Location
- Spatial and Temporal Models
- Big Data
- Data Science Analytics
- Spatial Data on the Web
- New Geo Sources
- User Platforms and Networks – HCI
- Software Development and Patterns

Once assessed by the OAB the trends information is the used to develop the OGC roadmaps. These are practically used to show the direction in which the world of open geospatial standards would potentially progress in response to the technology trends that are identified. The aforementioned Roadmap is used to define actions and it strongly affects the innovation program planning. This may be either a new pilot or prototype in the Innovation Program or a new specification work or discussion in Future Direction in the Standards Program. It might as well be an extension to the Compliance tests or increased education and outreach for the wider community.

The Roadmap and Actions are shared regularly with OGC members throughout the broad range of activities within the consortium.

All OGC trends are relevant for the EO4GEO analysis. The analysis of level 2 trends, opportunely updated in the time can support the identification of gaps in current educational programmes and profiles.

7.5. EO4GEO Technology Watch

Education is an aspect of the groundwork for disruptive technology to be considered. How will the priorities of academic education affect the future workforce? How would a workforce educated in science and engineering exert disruptive effects in the years to come?

When assessing the disruptive influence of a new technology, one may ask whether the technology does any of the following:

- Delivers a capability at a previously unavailable level, which may create disruptive forces;
- Combines with other technologies to create synergies, which may also be disruptive;
- Evolves from seemingly unrelated technologies;
- Disrupts a workforce, society, or the economy when combined with multiple existing technologies;
- Generates products with new performance attributes that may not previously have been valued by existing end users;
- Requires users to significantly change their behaviour to take advantage of it;
- Changes the usual product and technology paradigms to offer a competitive edge;
- Exponentially improves the value received by the user;

- Creates industry growth through penetration or creates entirely new industries through the introduction of goods and services; or
- Becomes mainstream to a region, a country, or a community.

In practical terms, the EO4GEO technology trends watch will be set-up in close collaboration with OGC efforts. The trends watch will be used to identify topics that should be integrated in the Body of Knowledge in order to define the concept(s) behind, the relationship with other topics/concepts, the possible learning outcomes and existing reference materials. Based on the BoK entries those trends can be incorporated in the curricula design where appropriate and additional training materials can be developed.

8. Conclusions

Anticipating and building skills for the future is essential in rapidly changing labour markets. Skill anticipation relies on various methods that collate and summarize labour market information (the demand) to analyse skill shortages and labour market imbalances (the request). The Task 1.1 and 1.2 of the EO4GEO well addressed this point. The aim of task 1.3 is to explore the panorama of the geospatial world defining the actors and the main challenges that they will face in the next years and the major technological and societal trends that are transforming or at least have an influence on the geospatial sector.

The use of the geospatial information enables wholesome understanding and establishes the ground for analysis-based actions for necessary decision making by bringing together the bio-physical world and social elements. The geospatial information and EO data are part of the economic and social life, adding value at many aspects. The increase of geospatial demand requires and adequate geospatial offer. The incoming geospatial technicians shall be trained to offer solutions to new problems out of the more traditional fields of the earth mapping.

This document considered the cross-sectoral trends impacting on the transformation of the educational world. Big Data, IoT and cloud are the technologies that are profoundly changing not only the way to work but the way to live. Other relevant technology to take into account are and artificial intelligence. Also the panorama of remotely data devices is changing with the relatedly new drones and SmallSats and future CubeSats. Also the way to provide the information is rapidly changing. Less and less (produced) maps and (downloaded) images and more and more analytics. Also less traditional markets of EO services, such as the economy, nowadays makes large use of geospatial data. The communication mass tools enter in the processing chain value of the geospatial services with the citizen science.

A separate chapter was dedicated to the Agenda 2030 and SDG since they define the objectives that the Countries will reach and that will address the funding. Based on this, numerous research activities and applications for end users will be required taking the advantage of the geospatial data and this will increase the number and the skills of geospatial professionals. The diffusion of geospatial data at citizen level not only increases the providers of data in terms of workers but also the improvement of the geospatial skills of the utilizers.

As suggestion for the other project activities, this document identifies some challenges. The most relevant refers the lack of infrastructure for processing, storage and transfer, data access and the need to build competencies for operational service provision.

Not only trends and challenges, but also the following opportunities are evidenced in this analysis.

Awareness-raising campaigns will be organised at regional level, including the set-up of support networks such as the Copernicus Relays and the Copernicus Academy network.

The geospatial value chain has the advantage to be constructed in a way that each single step of the space services value chain could be integrated in different market sectors.

The assessment of quality and reliability of Citizen Science data use multiple data coming from new technologies and traditional statistical data, in order to produce high-quality and timely information, with more detail, with higher frequencies and with the ability to successfully extract development indicatorsrequires news models and validation methodologies.

Geospatial Information and Earth Observations, together with modern data processing and Big Data analytics, offer unprecedented opportunities to modernise the national statistical systems and consequently to make a huge advance in the capacities of countries to efficiently track all facets of sustainable development.

Giving a look to the future, the themes addresses in this report are in the programme of the next Geospatial World Forum in 2019. Five are the topic of the technology session track: AI, Blockchain, IoT, Big Data and Cloud. Of course the technology evolution run fast and surely in the next months new topics will increase this list.

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