ESA ESRIN'S VALUE FOR ITALY

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1 A historical overview of ESA ESRIN

1964
1974

1. The foundation of ESA ESRIN

More than 50 years ago, during the negotiations for the foundation of the European Space Research Organisation (ESRO), the Italian delegation asked to establish a laboratory in Italy. The ESRO Council accepted the request and the European Space Research Institute (ESRIN) came into being. Initially, ESRIN was designed as a centre dedicated to undertaking laboratory and theoretical research in basic physics and chemistry.

H.L. Jordan was appointed in 1964 as the first director of ESRIN and he placed the new research centre in Frascati because it would be close to a growing concentration of establishments with similar interests. Nine months later, a small team rapidly organised the first conference on plasma physics. It was held in May 1966 but due to several difficulties, the cornerstone for ESRIN's new building was not laid until September 1968.

More difficulties lay ahead. In 1971, although it was agreed that the work done by ESRIN was of high scientific calibre, the Council ruled that ESRIN's activities were not directly related to ESRO's operational programme. It therefore decided to terminate ESRIN's scientific activities and close the research centre by September 1973. ESRO's Italian delegation refused to accept the end of ESRIN. Quite apart from the technological and scientific reasons, Italy wanted an ESA establishment. At the end of the negotiation, ESRIN was repurposed. Research activities were stopped and the Space Documentation Service (SDS) was opened in late 1972 or early 1973.

1964

ESRIN founded as a research point for plasma and basic physics

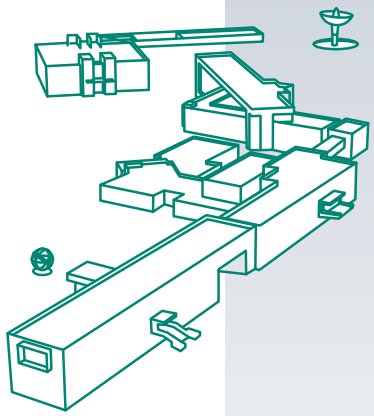
1975
1985

2. The first steps of ESA ESRIN within the European Space Agency

ESA was born in 1975 as a product of the merger between the European Launcher Development Organisation (ELDO) and ESRO. The SDS on-line database became one of the world's largest, with all data acquisition and data entry centralised at the Frascati establishment. In 1976, considerable progress was made on the Earthnet Programme, which provided European users with imagery generated by NASA's remote-sensing satellites, and promoted the use of such data for research and application purposes.

By 1981, ESRIN's activities had significantly expanded since the days of space documentation and information retrieval for external customers. The establishment now also encompassed a major service to internal clients. Therefore the possibility of treating ESRIN as a support establishment rather than a basic activity was considered. This change of perspective enabled the costs to be 'recharged' to internal users and projects. Hence, it provided ESRIN with a fixed minimum level of financing, independent of fluctuating programme requirements.

In 1982, the ESA Director General set up a review group to examine the possibilities of introducing further on-site activities at ESRIN. As a result, the Information Retrieval Service (IRS, which was formerly known as SDS) had its interfaces revised to cope with national public packet switching networks, now interconnected among them and with Euronet, the public telecommunication network devised by the EEC (European Economic Community). By 1986, it became clear that ESRIN's future would be to play an important role in payload data handling, using the expertise acquired in its many years of data processing activities.



1981

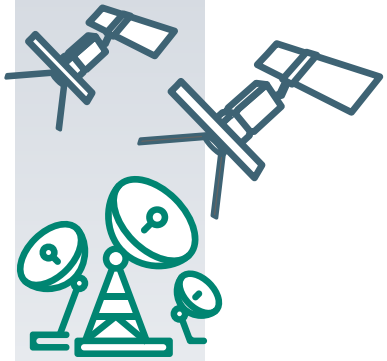
ESRIN's activities significantly expand

3. The development of ESA ESRIN and the consolidation of its role

1986
1995

At the beginning of the 90s, the IRS was involved in the implementation of an expansion plan. The Information Systems Division (ISD) completed the design phase for most of its projects during 1991, and in 1992 its implementation began. 1991 was an important year for telecommunications, with capacity having to be maintained on a 24-hour basis. An ESA Home Page was created for the worldwide web, carrying institutional details on the Agency and its establishments, and with pointers to topical information services on site. In December 1995, the ESA Director General announced his decision to transfer the management of all the Agency's information systems dealing with non-operational data to ESRIN. This resulted in the need for an internal reorganisation of the establishment.

Core innovations were experienced mostly in the field of Earth Observation. Indeed, at the beginning of the 90s ESRIN consolidated its position as "The gateway to Earth observation from space". With the launch of ERS-1 (the first ESA Earth Observation satellite) in 1991, for the first time ESRIN provided support to the ground facilities during operations. In 1992, two new departments were created in ESRIN, one covering Exploitation and one involved in Projects & Engineering. In 1993 came the operational success of the Processing and Archiving Facilities (PAF). In the same year, a number of new stations on all continents underwent station validation tests. With the successful launch of ERS-2 in April 1995, the continuation of the Agency's Earth Observation Programme and ESRIN's supporting activities were assured. During 1996, the use of ERS-based information in pre-operational applications increased sharply, therefore most of the facilities of the ERS Ground Segment were upgraded to manage the more consistent data and service requirements. Where applicable, they were also modified to handle data from the new sensors. Finally, commercial exploitation via the ERS industrial data consortium showed steady growth, and ESRIN became very active in raising existing and potential users' awareness of Earth observation.



1991

first ESRIN participation in the operational phase of a satellite

4. ESA ESRIN impetus toward future Earth-observation missions and Vega small launches

1996
2005

During 1996, ESA's corporate website was extended and updated; and in 2000, it became the ESA Communication Portal. In 1997, the Informatics Department at ESRIN became part of the Agency's Directorate of Administration, and began to provide informatics support to all of the Agency's Establishments and Directorates.

As regards Earth Observation, in 1996 ESA set up a Data User Programme (DUP). This tackled all issues related to the extraction of information from remote-sensing data to meet user requirements. It also paved the way for future ESA Earth-observation missions, data exploitation, and commercialization. During the same year, the first release of the Multi-mission User Information Services (MUIS) infrastructure became operational. In 1997, the MUIS were fully embedded as a Multimission Remote Sensing Product Catalogue into the Earthnet On-line Internet user service.

During 1997, the Earth Observation Department at ESRIN became part of the Directorate of Applications. In 2000, the Mission Management Office for the Earth Observation Programmes was installed at ESRIN. During the same year,

2000

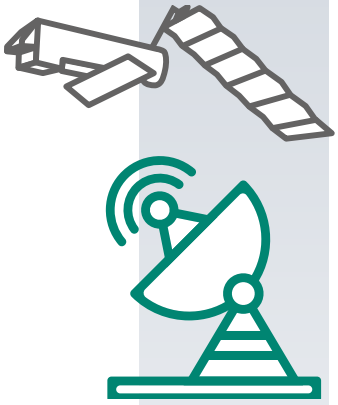
ESA Communication Portal is made operational

1996
2005

contributions to established international Earth observation activities were expanded. Important products were the European Digital Data Archive (EDDA), the Catalogue Interoperability Protocol (CIP) and the Committee on Earth Observation Satellites (CEOS) Dossier database on space-system capabilities and user requirements.

In 1998, considerable effort was devoted to the provision of educational activities through a cooperation with the European Association for the International Space Year (EURISY), with the European Project for the use of Space Technologies for Risk Management (EUROPA-STRIM Programme) and, at national level, with the Italian Space Agency (ASI) and the Italian Public Education Ministry now MUR Ministry of University and Research. During the same year, various international exhibitions and workshops related to Earth Observation applications were developed. The emphasis was on user services for remote sensing applications that had been generated by Small and Medium-Sized Enterprises (SMEs).

Following a re-organisation of the Directorate of Earth Observation Programmes, in 2001 two Earth Observation Departments were established at ESRIN: the Science and Applications Department and the Ground Segment Department. In addition to operation and exploitation of the ERS and third-party missions data, these departments were now also responsible for ENVISAT mission operations and services. The ESA ground segments were extended to include new missions such as CryoSat, Gravity field and steady-state Ocean Circulation Explorer (GOCE) and Japan's ALOS Earth Observation satellite.



2005

ESRIN becomes ESA's leading centre for Earth Observation

The International Charter Space and Major Disasters and the programme for Global Monitoring for Environment and Security (GMES) complemented the Earth Observation programmes. In 2004, a new Director of Earth Observation Programme and Head of ESRIN brought a new impetus to the establishment and, at the beginning of 2005, ESRIN became ESA's leading centre for Earth Observation.

Concerning other programmes, in 1999 ESRIN had acquired the Integrated Project Team (IPT) managing the Vega Small Launcher Development Programme. This aggregated staff from ESA, ASI and CNES and its presence introduced a completely new set of activities, including project reviews and regular progress meetings with European industry. In October 2004, the Vega IPT initiated the activities associated with the Vega ground segment in Kourou.

Finally, in 2004, the ESRIN Satellite Multimedia Infrastructure responded to a number of requests for support from external users, such as the French and Italian Civil Protection Authorities. A laboratory area was set up with appropriate uplink facilities to ensure good connections to the Internet and academic networks, to provide access to satellites and to serve as a showcase for ESA's telecommunications activities in the fields of telemedicine, tele-education, secure communications and other applications.

2006
2016

5. ESA ESRIN's launches, ICT and sustainability

In 2009, ESRIN's core role as payload operations centre for ESA's Earth Observation missions was consolidated by the start of the operational exploitation phases of the first three Earth Explorers (GOCE, SMOS and CryoSat-2). In the GMES Programme, work continued on preparing ground segment operations for several satellites in the upcoming Sentinel suite, and on further Earth Explorer missions (Swarm was planned for 2012 and ADM-Aeolus for 2014). Science and applications development

was pursued further on site, as was management of the International Charter Space and Major Disasters. Procurement activities for the Sentinel-1, -2 and -3 ground segment, processing and archiving facilities, and networks were completed in 2013.

In the launchers sector Vega's maiden flight successfully took place in February 2012, and soon the Vega Research and Technology Accompaniment Programme (VERTA) developed new launches. The first of the VERTA flexibility demonstration flights carried the ESA mission Proba-V. It successfully left Earth on 7 May 2013. This flight qualified a fundamental customer service improvement, namely the development of the multiple-payload launch capability for Vega named VESPA. At the end of the year, a contract was signed between Arianespace and ELV for the procurement of a batch of 10 launchers to be flown between 2015 and 2018. Following Vega success exploitation, in 2014 CM, the IPT activities were enlarged considering the Vega evolution activities with VEGA-C, and then VEGA-E programme. Additionally in 2016, also Space Rider programme, the first European re-entry vehicle, was set in ESRIN, within the IPT activities.

Furthermore, the ESA Space Situational Awareness Near Earth Object Coordination Centre (SSA-NEOCC) was opened on 22 May 2013 at ESRIN. This centre ensures European independence in NEO cataloging and impact monitoring. It also coordinates NEO follow-up observations worldwide and represents the central access point to a network.

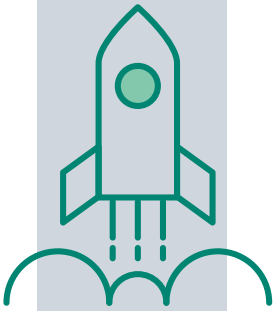
Turning to ESA corporate functions within the IT Department, Operational IT played a major role, providing valuable support to the Sentinel ground segment development. Operational IT was also instrumental in supporting many crucial events for ESA in 2014 and 2015 (the Rosetta landing, Sentinel-1A and Galileo launches, LISA Pathfinder, MSG-4, Sentinel-2A, the Intermediate eXperimental Vehicle (IXV) etc.).

The IT Department has also improved ESA's IT infrastructure. In 2013, a new private cloud computing infrastructure, called Esacloud, was introduced and in 2014 Esaconnect was made operational. In 2014, the IT Department worked to substantially update ESA-p, the corporate IT unified financial and procurement system. In 2015, the IT Department renegotiated its contracts with several suppliers for telecommunications, software and services, to provide better services for ESA under more efficient contracts, and the new communications service provider consortium became operational.

Finally, progress was achieved in the security assessment of ESA's programme-specific IT systems, in particular at ESRIN. The Security Office, established in 2007, prepared and approved the ESA COMSEC instructions for the security of electronic communications, and signed security arrangements with the European Defence Agency (EDA) and the European Global Navigation Satellite Systems Agency (GSA). In accordance with the new ESA security regulations on the evolution of security threats, the Security Office also carried out a revision of the ESA Security Directives.

Moving to facility management, 2010 saw the negotiation for the new ESRIN Host Agreement, and the approval process continued into 2011. Since the turn of the new millennium, the aim of making ESRIN more environmentally friendly becomes a major issue, as the principles of sustainable development have directly or indirectly inspired numerous scientific conferences, high-level scientific workshops, industrial meetings and reviews, as well as VIP visits and events for the general public.

2006
2016



2012

successful maiden flight of Vega

2013

ESA IT infrastructure consistently upgraded

2017
2021

6. ESA ESRIN's latest developments and the new programmes

The last five years have witnessed an unprecedented boost of the value of data in the world economy.

In this framework, ESRIN, as the ESA centre for Earth Observation, found itself at the centre of this digital revolution. In just few years ESRIN has extensively expanded its Earth Observation Envelope Programme (EOEP), the backbone for implementing the ESA Earth Observation Strategy 2040, whose prime objective is to foster the maximum benefit of Earth observation for science, society and economic growth in Europe. EOEP makes ESRIN a site of primacy in the management of space data: handling 16 satellite operations (plus 42 satellites in development), ESRIN is today the entity which manages the largest size of EO data in the world. EO for Society represents the main effort by ESA in fostering EO data exploitation to advance earth science, pioneer new applications, develop the downstream sector and collaborative platforms in the Space 4.0 era.

At the same time ESRIN has reinforced its prominence in the ESA's context through new programmes and activities. In this regard, these last years have witnessed the growth of the Vega programmes (in particular Vega, Vega C, Vega E & spin-off, SSMS + Venus), along with a constant increase of the Copernicus operations and new Earth Explorer missions such as Aeolus. Also in 2016, Space Rider programme, the first European re-entry vehicle, was set in ESRIN, within the IPT activities.

ESA and ESRIN have also created new activities in support of developing countries, in order to increase the adoption and practice of Earth Observation data, especially in sustainability issues. An example is the new programme, the Global Development Assistance (GDA) targeting Climate Resilience, Disaster Resilience, States subject to Fragility, Conflict & Violence, and Urban Sustainability.

Destination Earth is one of the most ambitious projects ever launched by the Agency. Commissioned by the European Commission in collaboration with the ECMWF and EUMETSAT, it aims at creating a detailed high-precision and constantly evolving model of the Earth which includes and predicts the impact of human activities. Destination Earth will also leverage Artificial Intelligence and new advanced weather prediction methodologies in order to estimate the impact of climate change on society and how human behaviours may affect this through early detection and interventions.

2017

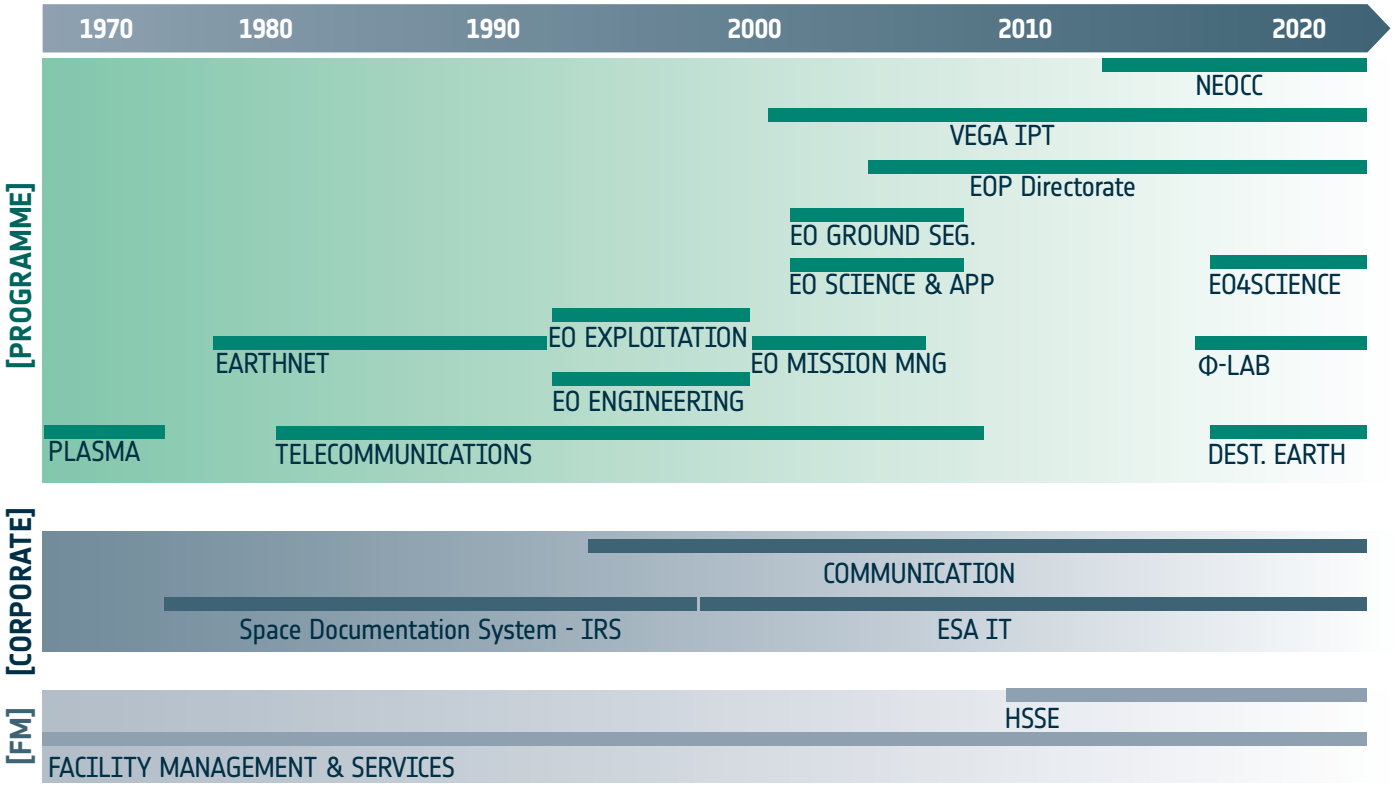
ESA Φ-Lab established

The expansion of traditional programmes and the creation of new ones have been followed by an increase of the physical infrastructure in ESRIN. In 2017, within the Division in the Future Systems Department of the EO Programmes, the ESA Φ-Lab was established. Considered the Agency's transformative innovation engine, whose mission is to accelerate the future of Earth Observation, the Φ-Lab is also the home of the ESA EO commercialization programme, which focuses on investing in industrial innovation (InCubed).

ESA is also at the forefront of tackling future but also current societal challenges. In this framework, in 2020 during the first stages of the outbreak of the Covid-19 pandemic, ESA launched from ESRIN the platform "Rapid Action Coronavirus Earth observation" or simply RACE, an effort to monitor current restrictive measures and to assess the future recovery.

Finally, the recent years have also highlighted a centralisation of several ESA corporate activities within ESRIN: IT and Cybersecurity, Communication and the Archives.

A snapshot of ESA ESRIN's evolution



Earth Observation Programme

1976 At ESRIN a computerised catalogue of available imagery is established within the existing Recon system connected to the SDS.

1977 Earthnet is incorporated as an optional programme by eight Member States (including Italy).

1985
- Council approves the Earthnet Medium-Term Plan 1985-1990, as well as the start of two elements: "the ERS-1 off-line Phase-BfI" and the "Access to Third-Party Missions".
- The Earth Observation Preparatory Programme (EOPP) is elaborated and proposed.

1991 With the launch of ERS-1, ESRIN has to support ground facilities during the operational phase of a satellite for the first time.

1992 Two new departments are created at ESRIN, one covering Exploitation, and the other involved in Projects & Engineering.

1993 The Processing and Archiving Facilities (PAF) proves an operational success and ESRIN consolidates its position as "The gateway to Earth observation from space".

1994
- Intense activity to educate users about ERS-1 data applications takes place in many parts of the world and in ESRIN itself.
- The ground segment and network facilities are technically upgraded to be ready for ERS-2, and the agreement with the ERS Consortium for worldwide data distribution is extended to ERS-2.

1995 ERS-2 is successfully launched in April and the Global Ozone Monitoring Experiment (GOME) opens a new field of research in atmospheric chemistry.

1996 ESA sets up a Data User Programme to tackle all issues related to the extraction of information from remote-sensing data.

1997
- The Earth Observation Department at ESRIN becomes part of the Directorate of Applications.
- ESRIN improves cooperation in educational activities (EURISY, EUROPA-STRIM, ASI and MIUR).

1998
- The first release of the Multi-mission User Information Services (MUIS) infrastructure becomes operational.
- ENVISAT site is ready for Payload Data System deployment.

2000 The Department's Mission Management Office for the Earth Observation Programmes is installed at ESRIN.

2001
- Two EO Departments are established at ESRIN: the Science and Applications Department and the Ground Segment Department.
- ESA ground segments are extended to include new missions such as ALOS, CryoSat, and GOCE.
- The International Charter Space and Major Disasters is included in the EOP.
- The programme for Global Monitoring for Environment and Security (GMES) is included in the EOP.

2002 ENVISAT is successfully launched.

2004 Arrival of the new Director of Earth Observation Programme and Head of ESRIN.

2005 ESRIN becomes ESA's leading centre for Earth Observation.

2009 Operational exploitation phases of the first three Earth Explorers (GOCE, SMOS and CryoSat-2) begins.

2013 Sentinel-1, -2 and -3 procurement activities in the area of Ground Segment, Processing and Archiving Facilities, and Network are completed.

2014 Copernicus Sentinels 1A and 2A are launched.

2016 Copernicus Sentinels 3A and 1B are successfully launched.

2017
- Copernicus Sentinel 2B is successfully launched.
- Copernicus Sentinel 5P is successfully launched.
- The Φ-Lab is established in ESRIN.

2018 Sentinel-3B is successfully launched.

2020
- Sentinel-6: the first satellite is launched into orbit on 21 November 2020.
- Launch of the "Rapid Action Coronovirus Earth observation" platform (RACE) against Covid-19.

2021 Launch of Destination Earth programme.

Vega IPT

1999 The integrated Project Team managing the Vega Small Launcher Development Programme is located at ESRIN.

2001 Vega IPT consolidates with the recruitment of ESA (internal and external), ASI and CNES staff. This leads to a team of 12 at ESRIN by year's end.

2004 The Vega IPT begins activities associated with the Vega ground segment in Kourou.

2012 Vega's maiden flight successfully takes place, and the VERTA programme develops new launches.

2013 VV02 is successfully launched.

2014
- VV03 is successfully launched.
- Member States, during the ESA Ministerial meeting in 2014, agreed to develop the more powerful VEGA-C.

2015
- VV04 (IXV), VV05 (Sentinel 1A) and VV06 (LISA Pathfinder) are successfully launched.
- VERTA ends in December and Vega commercial exploitation begins.

2016
- VV07 and VV08 are successfully accomplished (both SSO).
- Space Rider programme, the first European re-entry vehicle, was set in ESRIN.

2017 Three new launches are successfully accomplished: VV09 (Sentinel-2B), VV10 and VV11 (all SSO).

2018 The new Vega Flights VV12 and VV13 are successfully launched in the Sun-Synchronous orbit (SSO).

2019 Another Vega Flight (VV14) commissioned by the Italian Space Agency is successfully completed (SSO). The launch of the VV15 failed.

2020
- Vega Flight VV16 is successfully launched in September (SSO). In November the VEGA flight VV17 failed.
- All the new solid motors for Vega-C have completed qualification testing.

2021
- VEGA Flights VV18 (April -SSO) and VV19 (August-SSO) are successfully launched.
- In November another VEGA flight VV20 was successfully launched.
- Preparatory activities are under way for VEGA's evolution into a family of configurations (VEGA-E) beyond 2025.

Information Technology Department

1973 SDS moves to ESRIN and a new IBM 360/50 is installed.

1974 The SDS online database becomes one of the world's largest. All data acquisition and entry is centralized in ESRIN.

1979 IRS interfaces are revised to cope with Euronet and with increasing Earthnet data storage.

1982 IRS interfaces are revised to cope with newly established national public packet switching networks.

1990 ESA-IRS begins the implementation of an expansion plan.

1995 ESA's Director General announces his decision to transfer the management of all the Agency's information systems dealing with non-operational data to ESRIN.

1997 The Informatics Department at ESRIN becomes part of the Agency's Directorate of Administration, and begins to provide informatics support to all of the Agency's Establishments and Directorates.

2001
- A Computer Emergency Reaction Team (CERT) is created to defend any ESA systems that come under cyberattack.
- An important success is achieved with the establishment of the ESA Intranet.

2002 The Information Systems Department achieves successful ISO 9001:2000 certification of its Quality Management System (QMS).

2011
- ESRIN IT provides support to the Sentinel ground segment development.
- IT infrastructure is prepared for Security Office accreditation (SDIP phase 2).

2013
- The IT Department brings Esacloud into operation.
- The IT Department provides the design and implementation for the new NEO data centre as well as the IT infrastructure for the SSA programme.

2014
- Virtualisation technology allows consolidation and rationalisation of computing needs.
- Esaconnect is introduced.

2015 Security information and event management (SIEM) technology put in full operations to support threat detection, compliance and security incident management. New corporate solution deployed to manage Industrial Policy member States contributions.

Information Technology Department

2016
- Deployment of the ESA automation and cloud resources platform (go.esa.int).
- Deployment of the ESA software development environment (Github).

2017 New HR suite of applications deployed to support personnel administration.

2018 New corporate solution deployed for end to end digital procurement.

2019
- ISO 27001 Certification for corporate IT services achieved.
- New Classified Information Exchange solution deployed in all ESA.

2020 Full teleworking mode for all staff and services established across ESA.

2021 First deployment of office365 suite, including new collaboration tools (Teams) and security accreditation.

Communication Department

1993 ESRIN establishes a number of services reachable from the worldwide web. An ESA Home Page is created, carrying institutional details on the Agency and its Establishments, with pointers to topical information services on site.

1995 ESRIN provides substantial support in the form of visual exhibits to a number of thematic Earth Observation conferences and workshops, to in-house events at ESA ESRIN, and for the ESA Pavilion at the Le Bourget Air Show.

1998 Various international exhibitions and workshops related to Earth Observation applications are prepared at ESRIN. The emphasis is on user services for remote sensing applications being developed by Small and Medium-Sized Enterprises (SMEs).

1999 Contacts with Italian institutions (Italian Civil Protection Agency, Environment Ministry and Defense Ministry) and ASI are maintained throughout the year. Meetings are also arranged with the Italian Parliamentary Committee on Space, the European Commission, and the European Union.

2000 The new ESA Web Portal is launched on the web and a staff dedicated to its management is formed. For the first time, ESA's web site gains a multilingual dimension.

2002
- A number of new features are added to the ESA Web Portal, including the Multi-media Gallery, Focus On, and Space Live.
- ESRIN hosts the CEOS (Committee on Earth Observation Satellites) 16th Plenary Meeting in November, and the CEOS high-level open session on Earth Observation related follow-up actions from the World Summit on Sustainable Development.
- EDUSPACE is an immediate success, with more than 200 schools registered.

2004
- The ESA Web Portal experiences a considerable increase in visitor numbers and implements new measures targeting improved security and wide broadband access.
- The 100th meeting of the ESA Earth Observation Programme Board is held at ESRIN on 27 May.

2005 A new ESRIN web site is launched in 2005, including a virtual tour of the site and facilities.

2007 The ESA Corporate Design Service was established at ESA ESRIN, responsible for the use of the ESA corporate identity on all channels.

2009
- The Vice-President of the European Commission and European Commissioner for Industry and Entrepreneurship, Antonio Tajani, visits ESRIN.
- ESA ESRIN hosts delegation visits and bilateral meetings with partner agencies, such as NASA and the Canadian Space Agency.

2011
- Vega launch communication campaign at the Auditorium Parco della Musica in Rome.
- A permanent installation of a mock-up Galileo satellite atomic clock is installed.

2014 Annual visits to ESRIN reach 45,000, making ESRIN the most visited ESA establishment after ESTEC.

2015 Visits in ESRIN reach more than 59,000 including the business partners category.

2017 The communication activities of the entire Agency are centralized in ESRIN. In particular, the Frascati's facilities host one of the 2 Divisions of the ESA Communication Department: the Production and Management Support Division, which oversees the development and management of all ESA communication channels. Moreover, it is responsible for the coordination of outreach communication activities through the Agency.

2018
- 10.300 Meetings and 150 Conferences held in ESRIN.
- The 50th anniversary of ESRIN was celebrated with an event with Italian and European institutions, and with a photographic exhibition.

ESRIN Estates and Facilities Management Service

1968 ESRIN's cornerstone is placed.

1979
- The sale to the CNR of some ESRIN buildings and technical installations dismissed during the downsizing of 1973 allows the building of new facilities for ESRIN that ensure the smooth running of the IRS.
- Computer and related facilities dismissed during the downsizing of 1973 are re-housed in custom facilities, and the ESRIN Conference facilities are reinstated.

1986 A new building is inaugurated, increasing office and other space by some 2000 m^2.

1988 A new extension is built to provide even more offices, a fully equipped training/seminar room, and some archiving space.

1993 A prefabricated two-storey building and a new computer area dedicated to Earth Observation Data Network services are founded.

1994 ESRIN is granted an additional 4-5 hectares of land by the Italian authorities, which allows the construction of a new office building.

1996
- A new office building dedicated to Edoardo Amaldi is officially inaugurated.
- The construction of a new building to house the ENVISAT ground segment activities begins.
- The installation of the Envisat Ku-band antenna begins.

1998 The logistics for Vega IPT are prepared.

2002 The new European Centre for Space Records (ECSR) becomes operational in October.

2004
- A Virtual Reality Theatre is installed.
- A new social centre with childcare facilities is inaugurated.

2009
- ESRIN employs its own Health, Safety and Security officer responsible for procedure maintenance and site security.
- ESRIN's workplace canteen is the first in Italy with a Zero Impact certification, which equates to a net zero carbon footprint.

2010 ESRIN receives full certification from the British Standards Institute for Occupational Health and Safety Management, and Environmental Management.

2012
- ESRIN is recertified for the ISO 14001 environmental management system and OHSAS 18001 health and safety management system by the British Standards Institution.
- Frascati experiences a light earthquake and it emerges that some (older) buildings need reinforcement.
- Work begins on ESRIN's new canteen seating area, refurbished kitchen and self-service sector.

2013
- ESRIN's Energy Management System is compliant with the ISO 50001:2011 standard.
- Construction works for a new bridge start as part of the new ESRIN Host agreement.
- The canteen refurbishment work is completed and the new lunch room is opened.

2014
- ESRIN's Energy Management System is certified according to ISO 50001:2011.
- ESRIN reduces its overall energy use by 7% from the baseline year of 2007, and by 25% from 2010.
- ESRIN CO^2 emissions are reduced by 28% from the baseline year.

2015 The anti-seismic consolidation project is completed for buildings 3, 6, 7 and 10.

2016
- Renewal of the ESRIN EOP Data-Centre with availability of 80 racks and a full redundant infrastructure in place.
- The electrical energy supply from the main grid is 100% green certified (guarantee of origin).
- Facility Management recertified for the ISO 9001 Quality Management by the British Standards Institute.

2017
- ESRIN is certified for the ISO 22301 Business Continuity Management System by the British Standards Institute.
- New building (Φ-Lab) constructed in line with a new concept of modern working environments.

ESRIN Estates and Facilities Management Service

2018
- An innovative area, named Φ-Experience and focused on space data visualization, is built and delivered.
- The site seismic consolidation project reaches 68% of the site buildings completed.
- An agreement for the extension of the ESRIN site is undersigned and 24.000 m^2 of new land is added to the establishment's footprint.
- ESRIN is certified for the ISO 45001 Occupational Health and Safety by the British Standards Institute.

2019
- A new IT Network Security Centre is designed and built.
- The ESRIN EOP data-centres obtain the TIER3 level certification from Bureau Veritas.
- ESRIN energy management receives an award from the FIRE (Federazione Italiana per l'uso Razionale dell'Energia).

2020
- The entire ESRIN site obtains the fire prevention certification (CPI), issued by the Fire Brigade.
- ESRIN complies with the EU 20-20-20 climate and energy package target, exceeding expectations by reaching 55-37-20.

2021
- The ESRIN photovoltaic power plant is more than doubled, passing from 185kWp to 405kWp.
- ESA's Centre for monitoring the Near-Earth Object population (NEOCC) (small solar system bodies at risk of collision with our planet) is designed and built in a dedicated area within ESRIN.
- A new infrastructure (data network and building management system) for the digitalisation of ESRIN Facilities is delivered.
- The site seismic consolidation project reaches 79% of the site buildings completed.
- A new building (B14), to be inaugurated at the end of the year, is under construction and will provide 1399.86 sqm of modern working environment for approximately 80 people.

Italian Agreements

1964 H.L. Jordan is appointed first Director of ESRIN.

1966 First Conference, on plasma physics, takes place.

1970 A Host Agreement is signed with the Italian Government.

1973 Scientific activities are terminated and ESRIN is downsized.

1981 ESRIN evolves from a basic activity to a support establishment.

1986 ESRIN is included on the map of "important international establishments" in Italy.

1993 The Italian Government and ESA sign a new Host Agreement.

2001 In January, the ASI Science Data Centre is inaugurated at ESRIN.

2002 The Host agreement for the Space guard Foundation is signed.

2003 A bilateral agreement with the University of Rome Tor Vergata is signed.

2004 An agreement with the CNR is signed in June to cover cooperation in the field of broadband connectivity.

2005
- ESA BIC Lazio agreement becomes operational and five incubators for SMEs are hosted at ESRIN.
- ESRIN signs an agreement with the European Commission Joint Research Centre (JRC) concerning the development of space-based information services and the access to and provision of Earth Observation data.
- ESRIN - Lazio Region agreement for MEGALAB is signed.

2008 ESA signed with Italian Government a MoU for the reinforcement of the role of ESRIN.

2012
- The new Host Agreement for ESRIN is signed.
- ESA and Tor Vergata University renew a 5-year agreement that allows for closer cooperation and increased collaboration in the field of space related research, education and innovation.

2016
- The Joint Consultative Committee (JCC) is appointed.
- The ESA BIC Lazio agreement is renewed, extending the activity until the end of 2019.

Italian Agreements

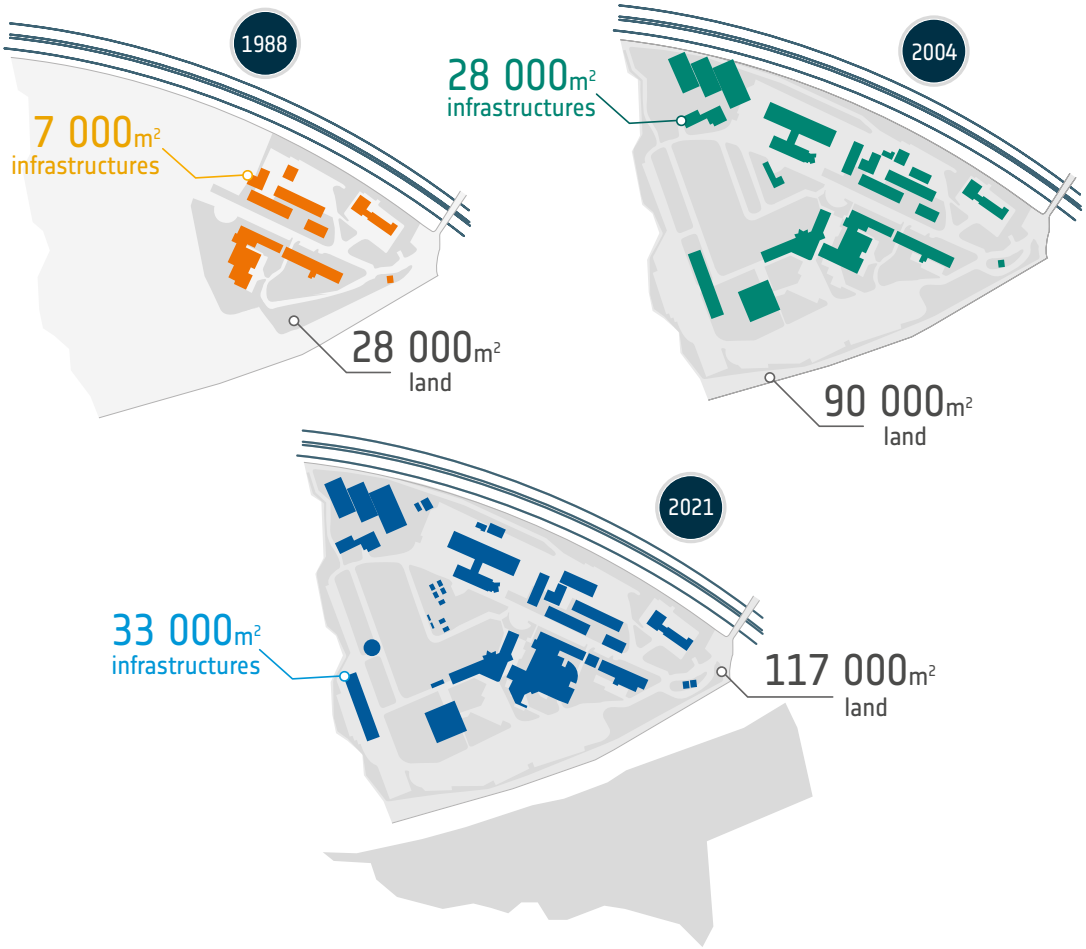
2019
- District Roma is signed to develop a network able to support the research and the local development, and to foster innovation for the community.
- ASI-ESA Statement of Intent to establish a "joint research fellowship scheme" is signed.

2021
A Memorandum of Collaboration (MoC), between ESA and the University of Rome Tor Vergata is signed, with the purpose of jointly supporting the creation of the ESA_Lab@UNITOV.

7. ESA ESRIN's role within ESA's ecosystem

Since its creation, ESRIN has constantly expanded its range of activities driven by its core function of ESA main centre for Earth Observation. Nonetheless, in the latest years, ESRIN's role within ESA's ecosystem has increased through the centralisations of critical corporate functions: Cybersecurity and several IT activities, Communication, as well as the establishment of the European Centre for Space Records first, and lately of the ESA Archives.

Programmes and activities have been implemented along with a physical expansion of the Frascati's site, summarized in the figure below. The recent acquisition of adjacent land by ESRIN represents an important opportunity for the possible development of structures aimed at adequately accommodating the growing number of visitors and events hosted in Frascati. An important initiative in this sense is represented by the 3D-Visit Centre (see Box 1).

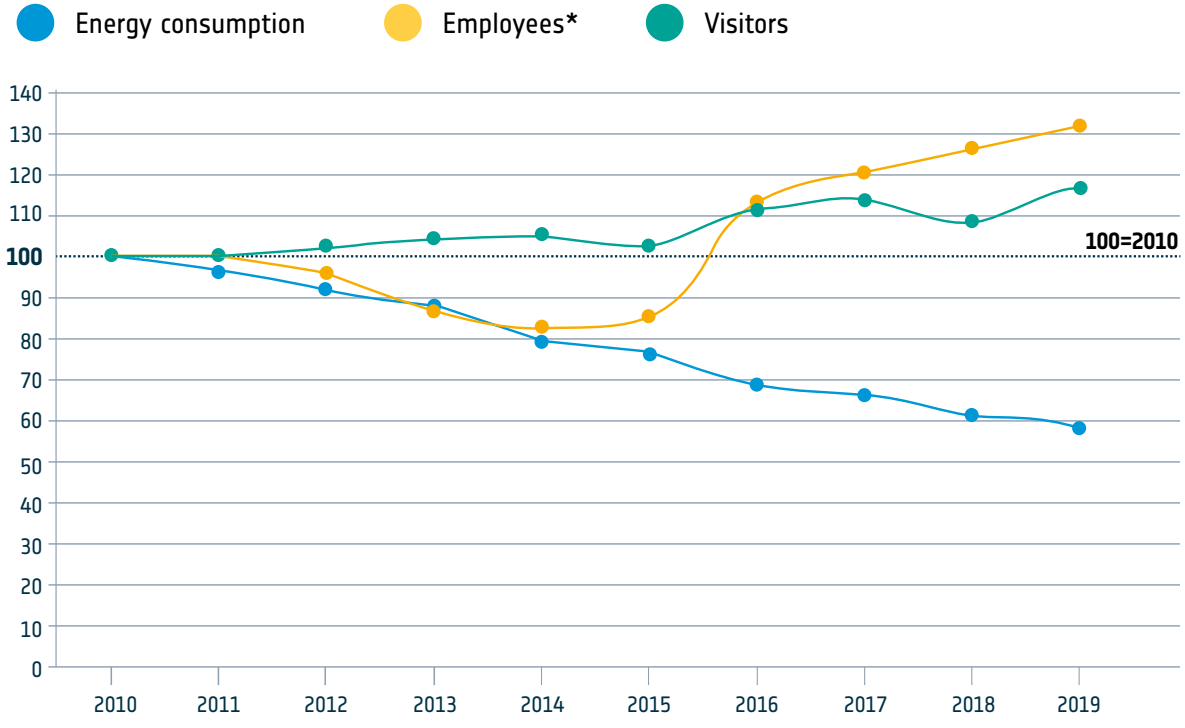


8. ESA ESRIN: a model for sustainability

In the heart of Frascati, the ESRIN site represents a reference point for sustainable development practices, placing itself at the forefront in demonstrating the importance of integrating sustainability at a structural and operational level. The valuable results reached in the last 10 years have laid the foundations for ESRIN to become an example not only in the ESA ecosystem, but also internationally.

The sustainable activities implemented in ESRIN naturally concern the mission of creating a competitive site from an energy efficiency standpoint. The outcomes are synthesized in the graph below, which shows the effectiveness of the sustainable practices established in ESRIN since 2010. Even if the main sources that impact on energy consumption rose - the number of site employees and of visitors increased in 2019 respectively by 30% compared to 2015 and to almost 50,000 visitors - energy consumption still recorded a virtuous decrease, with a significant reduction of 40% compared to 2010. These outcomes are even more notable considering the hosting by ESRIN of several data centres, which are traditionally less energy efficient.

Graph 1. Energetic consumption in relation to ESRIN site occupancy (2010-2019, 100=2010)



**Employee data based on activity badges*

Source: HIF-EP data (2020)

Box 1. The Φ-Experience: 3D-Visit Centre

The Φ-Experience in ESRIN is a 220 m^2 exhibition room aimed at promoting the awareness and visibility of ESA's Earth Observation programmes and applications in an innovative and interactive way. The focus of the exhibit is mainly on activities done in Earth observation in ESRIN, with a special focus on the environmental and socio-economic benefits.

The facility employs a number of different display technologies to interact with the visitor and improve the understanding of the benefits of Earth Observation for monitoring global change.

The Φ-Experience has four main exhibition elements:

1. The building of satellites, from their design to their launch and deployment in orbit carried by Ariane or Vega rockets.
2. Earth Observation data collection and application examples.
3. Global data for a global view, which only satellites are able to provide.
4. Regional aspect representation (of Central Italy in this case) to make people aware of application examples that have an impact on their immediate surroundings.

A particularly important element in the Φ-Experience is an elevation model projecting high resolution live satellite images of a part of Central Italy covering from the Mediterranean coast all the way up to the "Gran Sasso" national park. This model supports the visitor in understanding the potentiality of distinct satellite data for different applications such as changes in settlements, or the use of infrared imaging to better plan cultivations.

Designed as a visitor centre, the Φ-Experience aims to take advantage of ESRIN's focal point for both science and industry, as well as for decision makers and politicians, contributing with its intuitive display of data, information and experiences. The centre is host to many educational visits, with the goal of making space topics and the related engineering and technological professions more appealing to youngsters.

The importance of the Φ-Experience as a florid visitor centre is demonstrated by its numbers. Since its opening in September 2018, the visit centre welcomed more than eight thousand visitors, many of them from the Lazio Region. Despite the halt imposed by the Covid-19 pandemic, these numbers are expected to grow in the coming years.

The centre promotes its activities not only within ESRIN. This is possible thanks to a specific technology known as the touch table, which can be carried outside ESRIN's premises to attend science events such as "La notte dei Ricercatori" in Frascati, or exhibitions such as a recent one at the "Museo della Scienza e Tecnologia" in Milan, or at science days events in Naples and the "Parco della Musica" in Rome.

In the longer run, the Φ-Experience aims at building up capacities and partnerships to develop new visualisation techniques for satellite-based and other geographic data in order to help better understand, illustrate and explain the value of data gathered from space.

Fig. 1 - Phi-Experience

(Source: Mario Pietravalle, Ars Electronica/Harald Moser)

In terms of benchmarks with the other ESA sites, the one-to-one comparison is difficult to implement, given the different use of the plants. However, a comparison can be made at a macro level, by considering that ESRIN receives a flow equal to 7% of the total, despite having an incidence of 10% on the surfaces and 15% of the total population. The sector benchmarks show ESRIN's leadership position in all energy performance indicators in 2019, as represented in the table below.

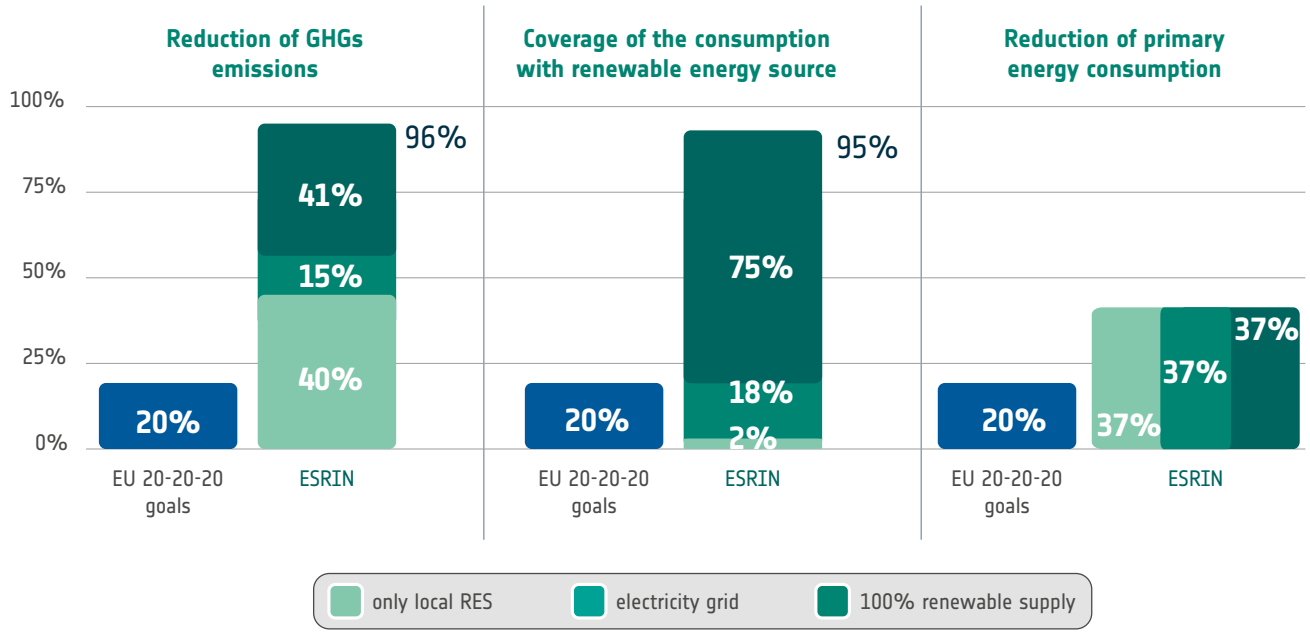
Energy performance index	ESRIN	Benchmark
Electricity per surface unit	146 kWhe/y/m^2	170 kWhe/y/m^2
Electricity per employee	2855 kWhe/y/emp	4379 kWhe/y/emp
Primary energy per surface unit	354 kWhp/y/m^2	453 kWhp/y/m^2
Carbon emissions per surface unit	69.7 kgCO2eq/y/m^2	24-184 kgCO2eq/y/m^2
Carbon emissions per employee	1.32 tCO2eq/y/emp	1.59 tCO2eq/y/emp

The source for the benchmarks are the following:

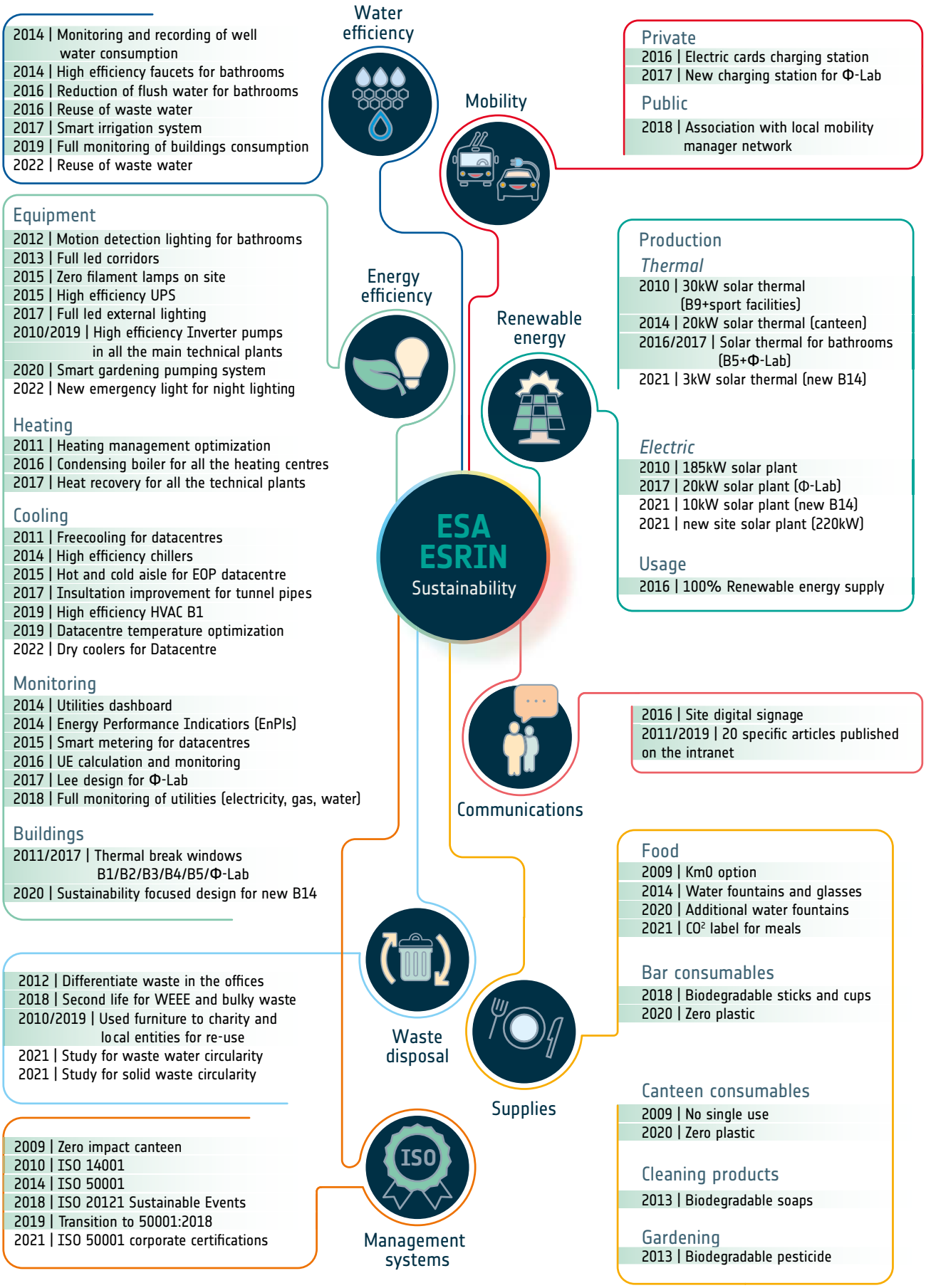
- *Electricity per surface unit – "ENEA and Assoimmobiliare, Benchmark of energy consumption of office building in Italy, Rome, 2019"*
- *Electricity per employee – "ODYSEE_MURE, www.odysseee-mure.eu, 2016"*
- *Primary energy per surface unit – "ENEA and Assoimmobiliare, Benchmark of energy consumption of office building in Italy, Rome, 2019"*
- *Carbon emissions per surface unit – "Technical report by the Joint Research Centre (JRC): Environmental benchmarks for buildings, 2018"*
- *Carbon emissions per employee – "Carbon Footprint Report 2016 – GHG emissions resulting from European Investment Bank Group internal operations"*

Such surprising results have been achieved thanks to the constant commitment shown by ESRIN over time, which go beyond energy efficiency, moving to apply a broader perspective of environmental sustainability. In 2011, ESRIN inaugurated the largest photovoltaic system in the Castelli Romani, today more than duplicated in size, another important action is represented by the green energy purchased.

Furthermore, ESRIN went beyond the goals set at the European level, as shown in the figures below, becoming an example of best practices.



The broad spectrum of actions implemented by ESRIN in support of sustainability can be summarized by the information map in the next page. It is a more than ten-year path conducted according to an ISO 14001 management system.

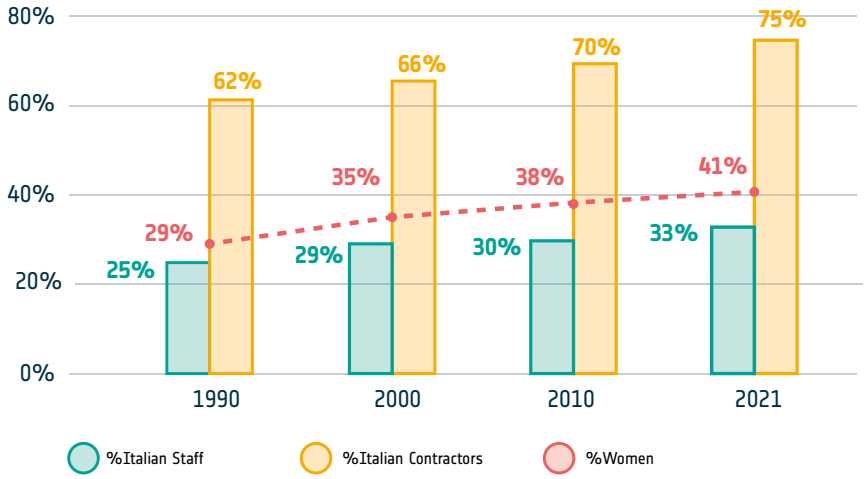

ESA ESRIN
Sustainability
Water efficiency
2014 | Monitoring and recording of well water consumption
2014 | High efficiency faucets for bathrooms
2016 | Reduction of flush water for bathrooms
2016 | Reuse of waste water
2017 | Smart irrigation system
2019 | Full monitoring of buildings consumption
2022 | Reuse of waste water
Mobility
Private
2016 | Electric cards charging station
2017 | New charging station for Φ-Lab
Public
2018 | Association with local mobility manager network
Energy efficiency
Equipment
2012 | Motion detection lighting for bathrooms
2013 | Full led corridors
2015 | Zero filament lamps on site
2015 | High efficiency UPS
2017 | Full led external lighting
2010/2019 | High efficiency Inverter pumps in all the main technical plants
2020 | Smart gardening pumping system
2022 | New emergency light for night lighting
Heating
2011 | Heating management optimization
2016 | Condensing boiler for all the heating centres
2017 | Heat recovery for all the technical plants
Cooling
2011 | Freecooling for datacentres
2014 | High efficiency chillers
2015 | Hot and cold aisle for EOP datacentre
2017 | Insultation improvement for tunnel pipes
2019 | High efficiency HVAC B1
2019 | Datacentre temperature optimization
2022 | Dry coolers for Datacentre
Monitoring
2014 | Utilities dashboard
2014 | Energy Performance Indicatiors (EnPIs)
2015 | Smart metering for datacentres
2016 | UE calculation and monitoring
2017 | Lee design for Φ-Lab
2018 | Full monitoring of utilities (electricity, gas, water)
Buildings
2011/2017 | Thermal break windows B1/B2/B3/B4/B5/Φ-Lab
2020 | Sustainability focused design for new B14
Renewable energy
Production
Thermal
2010 | 30kW solar thermal (B9+sport facilities)
2014 | 20kW solar thermal (canteen)
2016/2017 | Solar thermal for bathrooms (B5+Φ-Lab)
2021 | 3kW solar thermal (new B14)
Electric
2010 | 185kW solar plant
2017 | 20kW solar plant (Φ-Lab)
2021 | 10kW solar plant (new B14)
2021 | new site solar plant (220kW)
Usage
2016 | 100% Renewable energy supply
Communications
2016 | Site digital signage
2011/2019 | 20 specific articles published on the intranet
Waste disposal
2012 | Differentiate waste in the offices
2018 | Second life for WEEE and bulky waste
2010/2019 | Used furniture to charity and local entities for re-use
2021 | Study for waste water circularity
2021 | Study for solid waste circularity
Supplies
Food
2009 | Km0 option
2014 | Water fountains and glasses
2020 | Additional water fountains
2021 | CO² label for meals
Bar consumables
2018 | Biodegradable sticks and cups
2020 | Zero plastic
Canteen consumables
2009 | No single use
2020 | Zero plastic
Cleaning products
2013 | Biodegradable soaps
Gardening
2013 | Biodegradable pesticide
ISO
Management systems
2009 | Zero impact canteen
2010 | ISO 14001
2014 | ISO 50001
2018 | ISO 20121 Sustainable Events
2019 | Transition to 50001:2018
2021 | ISO 50001 corporate certifications

As stands out in the graphs in the previous page, ESRIN has reached the goals defined by ESA in its Agenda 2025, which mandates the reduction of the Agency's greenhouse gas emissions by 46.2% by 2030, compared to 2019. Moreover, an essential element of ESA's Corporate Social Responsibility Principles lies within its focus on diversity. As regards to gender, at present 28.6% of ESA staff are women and at management level only 1 out of 6 managers are women. The Agency will aim for at least 40% of recruitments to be women by 2025, including STEM positions. The significant efforts implemented in ESA for promoting gender equality lead to an important milestone with the EDGE Certification, a leading global assessment methodology and standard related to gender equality, obtained in March 2021. ESRIN, in the meantime, has already achieved this ambitious goal with its 41% of women staff members in 2021. An important achievement considering that in the aerospace industry the average percentage of women is attested at 24%. Historically, the space industry has been a male dominated sector, indeed, "only around 1 in 5 space industry workers are women (UN)". In addition, 80% of ESRIN Staff have a university degree, 40% are under 40 years old and 63% are Italian.

Thus, ESRIN seems today to be well prepared to meet the goal of the ESA Agenda 2025: to become a "greener, younger and more diverse organization… [set to become] a model [for the Agency], the Space community and beyond".

Graph 2 provides evidence of the steady growing commitment of ESRIN, from 1990 to 2021, in supporting the Italian economy by hiring a growing percentage of Italian Staff and Contractors, but also the growing attention in promoting gender equality, by increasing the number of women involved in ESRIN's operations and activities, with a percentage that, at the time of writing, is among the highest of any other ESA site.

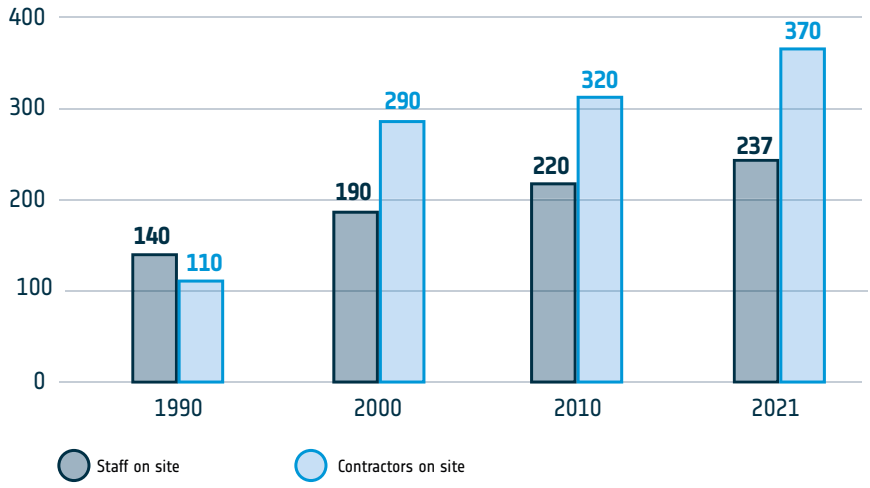
Graph 2. Trend of the percentage of Italian staff, Italian contractors and women in ESRIN (1990–2021)



Source: our elaboration of HIF-EP data (2021)

On the other hand, as shown in Graph 3, it is also worth noting the relevant growth in terms of number of employees in ESRIN (staff and contractors on site), confirming the expansion of activities carried out in ESRIN and its crucial role in the ESA ecosystem.

Graph 3. Trend of Staff and Contractors on site (1990–2021)



Source: our elaboration of HIF-EP data (2021)

2 ESA ESRIN's Programmes and Activities


esa

An introduction of the UN's Sustainable Development Goals in the context of ESRIN's Earth Observation programmes

In the first chapter, ESRIN's significant commitment to developing a sustainable management of its site was shown. As an international organization, ESA has also a responsibility to use its technology for the further development of individuals according to a sustainable development pattern. ESRIN has adhered to the Sustainable Development Goals since September 2015, when the United Nations General Assembly approved the 2030 Agenda and its 17 SDGs. At the time, ESA organized the exhibition "My Planet from Space: Fragility and Beauty" inaugurated by the UN Secretary-General Ban Ki-moon. In 2017, GEO in collaboration with Commitee on Earth Observation Satellites (CEOS) produced a Report to highlight the potential role of EO in supporting the development of the global INDICATOR framework for SDGs. Their conclusion was that almost a half of the SDG targets could be supported by EO. In 2018, CEOS within ESA published an handbook on how the Earth Observation satellite data can sustain SDGs achievement. This work demonstrates the importance of EO for goals 6, 11, 14 and 15. Recently, in May 2020, ESA produced a Compendium of EO contributions to the SDG Targets and Indicators. The aim of this report is a review of EO-derived data sets which are of direct relevance for some of the SDG indicators.

Earth Observation satellites data, once turned into actionable information, can be used to ensure sustainable development, fostering a significant progress in several scientific areas, and laying the basis for the development of new applications. In this chapter, the major achievements, applications and benefits generated by the ESA EOP, and more in general by the EO activities conducted worldwide, are illustrated. Being the ESA Centre for Earth Observation and hosting the EOP Directorate, ESRIN is indeed at the heart of this valuable process.

The power of Earth Observation satellites data can be used to assess the environmental effects of human activities, and to ensure that economic development does not take place at the expense of the environment's irreplaceable resources. This is especially relevant for the developing world, where the pace of change occurs at a considerable speed. At a macro level, Earth Observation provides constant updates, allowing the flagging of regions that are susceptible to floods, landslides or subsidence as unsuitable for building, guiding urban development toward more suitable zones, and defending agricultural lands from urban encroachment. At a micro level, within cities, satellites data support the identification of those hotspots in danger of overcrowding, congestion, pollution and other factors that reduce the quality of life of their residents.

The connection between ESRIN's EO programmes and the achievement of the UN's SDGs will be highlighted by means of the relevant SDG icons.

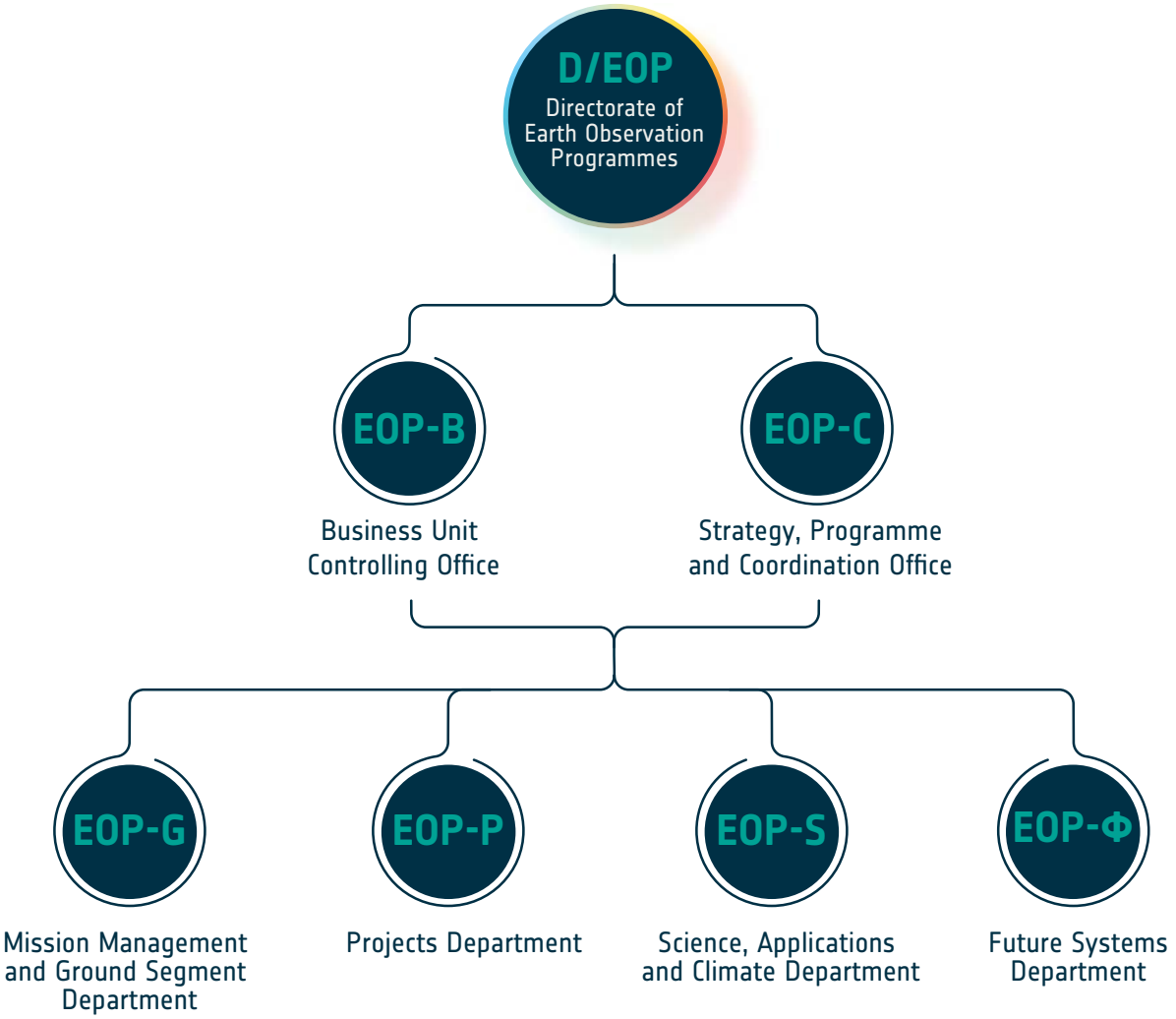
1. An in-depth analysis of Earth Observation Programmes

1.1 Mission Management and Ground Segment

ESRIN, ESA's Centre for Earth Observation, hosts the Director of the Earth Observation Programmes (D/EOP) and some key strategic functions of the ESA-EO programme. The EOP Director is also the Head of ESRIN. Since July 2017, the EOP Directorate has been supported by the Business Unit Controlling Office and the Strategy, Programme and Coordination Office and by four Departments:

- the Mission Management and Ground Segment Department (EOP-G);
- the Projects Department (EOP-P);
- the Science, Applications and Climate Department (EOP-S);
- the Future Systems Department (EOP-Φ).

EOP-G and EOP-S are both located in ESRIN. Under the authority of the Director of Earth Observation Programmes, the Heads of the above Departments and Offices, as members of the Earth Observation Management Board (EMB), are collectively responsible for ensuring the coherent preparation, planning, implementation, resource management and review of all ESA Earth Observation Programmes.

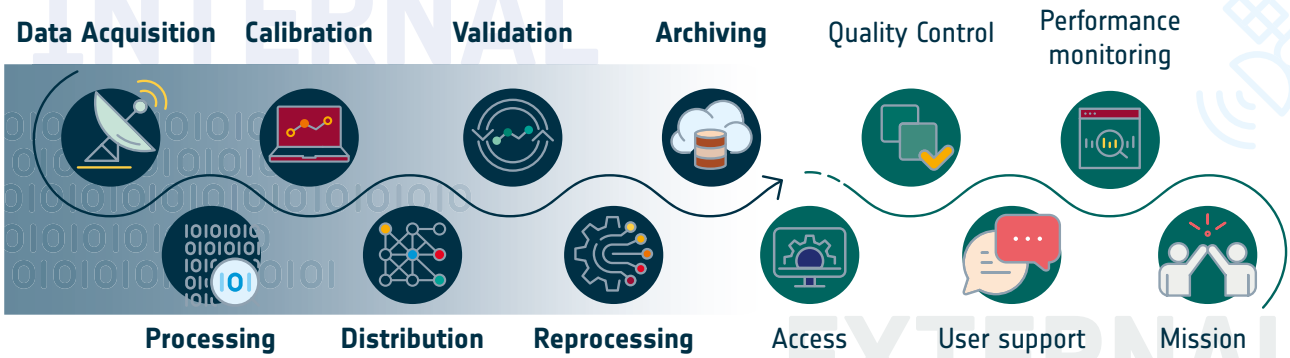


Stucture of the Directorate of Earth Observation Programmes (Source: ESA/ESRIN)

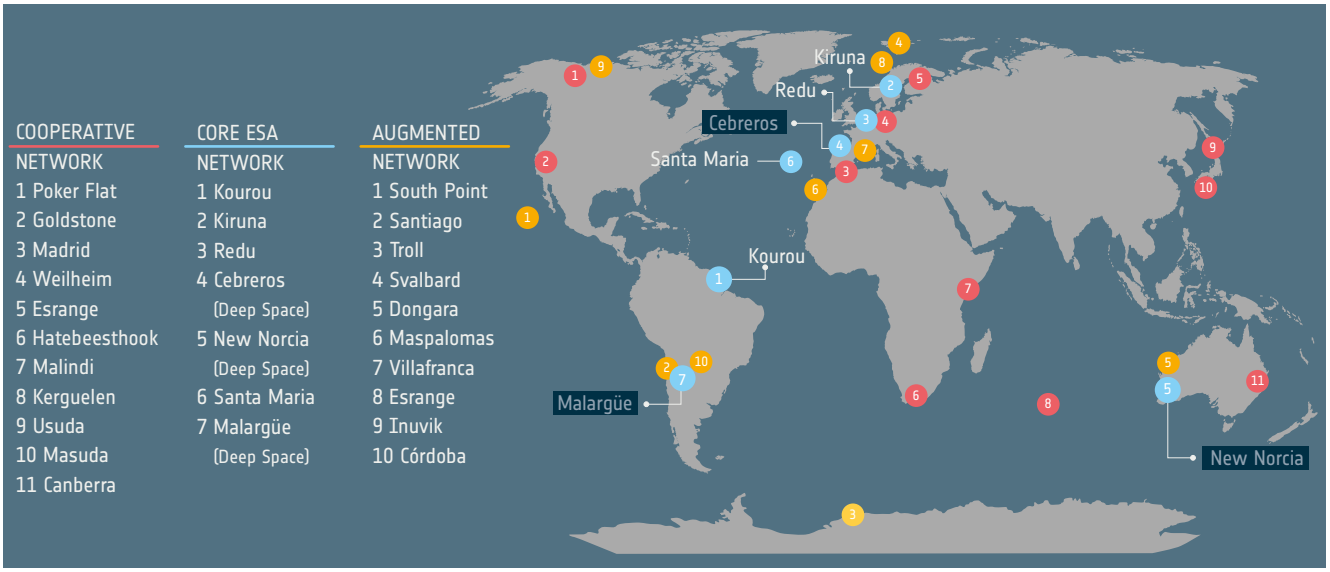
In ESRIN, the Mission Management and Ground Segment department is responsible for the management, operations and ground segments functions for ESA satellites and for a major portion of the Copernicus Sentinel satellites of the EU devoted to Earth Observation.

The department is in charge of the entire satellite data value chain of all of these missions. In fact, huge data streams need to be properly acquired, processed, converted into information, and made accessible through various access points such as data platforms or hubs.

This value chain includes the following functions:



The goal is to ensure the ground segment is operationally available to acquire and process data once a satellite is in orbit and operational. In addition, the department procures large volumes of data from commercial and national missions to provide them to scientific users and institutional services as well as for developing commercial applications. In order to carry out this duty, ESRIN manages a complex, worldwide distributed ground segment that uses public and industrial facilities. One example is the global network of ground stations (see figure below). ESA ground stations, national ground stations and commercial ground stations form a seamless network. The EOP-G department ensures that for each mission the optimal combination of ground stations, in terms of reliability and cost efficiency,



The Network of ESA Ground Stations

is implemented. In some cases, ground-breaking technologies, such as EDRS – an optical space-based data relay system - are used.

The department also oversees the satellite flight operations, which are carried out by ESA/ESOC in Darmstadt, Germany. The data are uploaded on a continuous basis in the ESA's Earth Observation archive data systems which constitutes a unique source of environmental information that serves as the basis for a steadily widening range of applications, and provides vital feedback for current and future programmes.

In quantitative terms, ESA/ESRIN produces 30 to 40 TB of Earth Observation data per day, serving more than 500,000 registered users. Data are distributed on a scale of about 300 TB per day. Thus, ESA is disseminating roughly 1 PB of data every 3 days, which is approaching comparability with the 4 PB per day of Facebook. Therefore, ESRIN handles the largest data management facility for Earth Observation in the world. In comparison, NASA EO data dissemination reaches only about 50% of the volume. When it comes to the overall scale and capacity of the EO space infrastructure and data management, Europe has gained global leadership and is increasingly showing a consistent return of investment of its EO space programmes[1]. ESRIN EO Data Management was key in obtaining this leadership role.

ESA provides the entirety of this data collection according to the **ESA Data Policy which mandates a free and open use of the data so that any entity or individual can download and integrate these into their products or services.**

Overall, there is no other entity in the world, neither private nor public, which is managing a comparable volume and various communities of users (scientific, institutional and commercial) benefit from such a data policy for Earth Observation data as ESA.

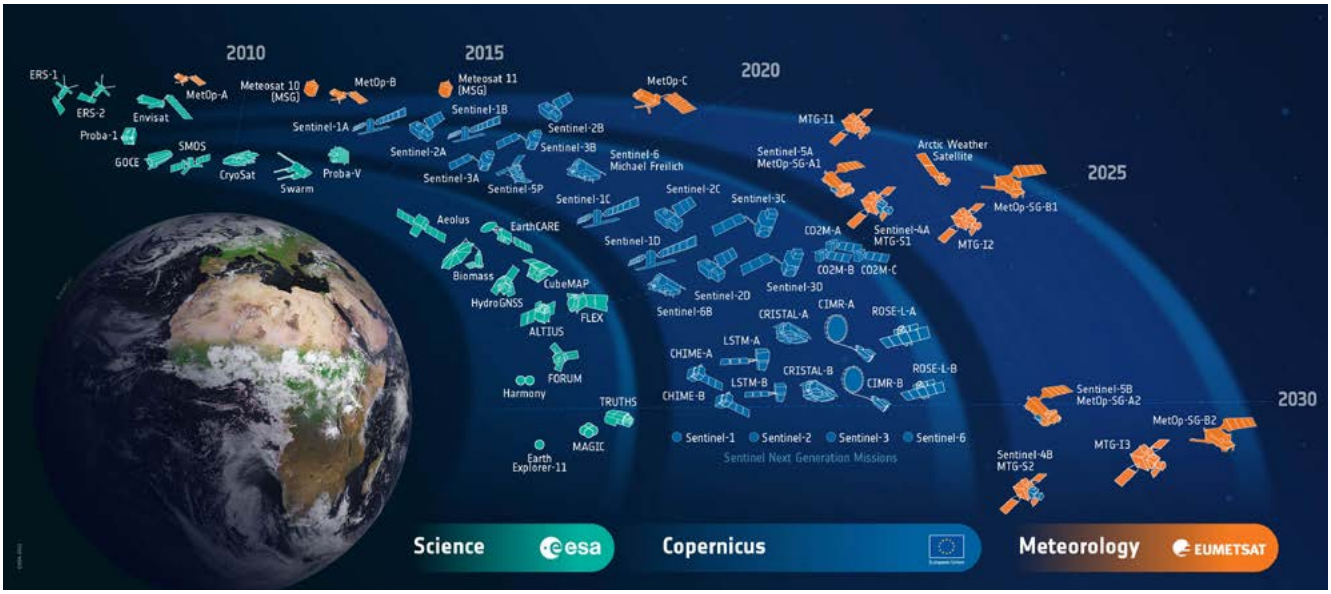
1.1.1 EO Mission Management

ESRIN is responsible for managing the operations of ESA-EO Earth Explorers and EU Copernicus Sentinel satellites once they are in orbit. Each satellite has a Mission Manager that ensures mission objectives are met and addresses users' requirements. To achieve their goals, ESRIN's Mission Managers work in close contact with the entities that are responsible for planning and supervising data acquisition and archiving, as well as with the entities that are responsible for product generation and dissemination. Mission Managers also cooperate with several counterparts at ESTEC and ESOC to resolve unexpected technical problems and to request potential adjustments to the spacecraft and/or its instruments to meet requests for specific data.

Once a mission is completed and the satellite is no longer transmitting data, Mission Managers must ensure data accessibility for long-term exploitation. Finally, they provide an ex-post assessment of the mission, in order to facilitate and promote the definition of new mission scenarios for the future.

[1] *The commitment in Europe provides a strong contrast; the European Union formally committed in 2014 to Copernicus, a long term, user-driven Earth observation and monitoring program focused on the delivery of near-real-time products and services to meet a broad range of societal needs. This is a commitment not just by a nation, but by the European Union, recognizing that the investment is many times over in the values it provides to its population and business community."*

Source: National Academies of Sciences, Engineering, and Medicine. 2018. Thriving on Our Changing Planet: A Decadal Strategy for Earth Observation from Space. Washington, DC: The National Academies Press



Past and Future Earth Observation Missions

ESA EOP has 42 satellites in development and 16 in operations (latest launch: Sentinel-6 on 21 November 2020).

Generally, the EO missions can be divided into:

- Scientific Missions;
- Copernicus Sentinel Missions;
- Meteorological Missions (operated by EUMETSAT);
- Third Party and Contributing Missions.

The currently active **Scientific Missions** include the Earth Explorers ADM-Aeolus, SMOS, Cryosat and Swarm; EarthCARE, Biomass and Flex will follow shortly. A new Earth Explorer mission, FORUM, has been selected, and an additional three missions the Daedalus, Hydroterra and Harmony were chosen to enter pre-feasibility study and compete to be the tenth Earth Explorer mission. In February 2021, ESA selected Harmony to go forward to Phase-A for further design consolidation and feasibility assessment.

During the Call for Ideas for Earth Explorer 11, in May 2020, four mission ideas (Cairt, Nitrosat, Wivern and Seastar) were selected to enter pre-feasibility study in June 2021. Further selections will be made in 2023 and 2025.

Copernicus Sentinel Missions comprise two satellites and carry state-of-the-art technology to deliver a continuous stream of diverse data sets, which are tailored to the needs of the programme and a broad user community.

Roughly €300 million were spent by ESRIN over the last 4 years in Copernicus missions. This was complemented by a budget of around €15 million for scientific applications.

Meteorological Missions include Meteosat Second Generation (MSG) missions and the Meteorological Operational satellite programme (MetOp). ESA develops the innovative satellites for the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) and procures the recurrent versions on its behalf. EUMETSAT is responsible for the overall user and mission requirements, the development of the ground segment (including data dissemination) and the satellite operations.

Furthermore, ESA uses its multi-mission ground systems to acquire, process, archive and distribute data from other commercial and national missions, the so-

called **Third Party and Contributing Missions**. More than 70% of the data is now obtained from European satellites and several initiatives are under way to increase the contribution from European systems even further. These initiatives have a special focus on fostering so-called "New Space Companies" to establish new agile and competitive companies in Europe.

1.1.2 Ground Segment

The Ground Segment and Data Management activities in ESRIN have directly engaged more than 700 companies in Europe. Globally, a considerable number of large corporations integrate Earth Observation data into their services and products including Airbus, SAP, IBM and Google.

Italian companies have been involved by ESA/ESRIN in the provision of the Ground Segment and Data Management services with contracts worth more than 200 million euro over the last five years. This value is higher than the industrial benefits obtained by larger contributors to the ESA EO programme, such as Germany and the UK. Thus investments in ESRIN are fostering Italian industrial competences in the ever more important domain of applying IT technology to generate products and services from increasingly sophisticated EO missions.

Therefore, the Earth Observation activities performed at ESRIN have **a triple application rationale that targets: Science, Public Institutional entities and Commercial entities**.

Finally, international cooperation is a significant way of leveraging the returns from ESA EO activities. ESRIN liaises with several international bodies including the Committee on Earth Observing Satellites (CEOS) that coordinates space agencies' mission planning, data products and policies in the field of planetary monitoring. In addition, ESRIN is the centre managing the secretarial of the **International Charter Space and Major Disasters**, which puts EO resources of its member space agencies at the disposal of civil protection authorities in the event of a natural or man-made disaster. The centre also provides support to various international ESA initiatives including the **Tiger Initiative**, which supplies satellite data to African users in support of sustainable water management, and the **Dragon Programme**, an initiative between China and ESA to encourage joint research across a number of thematic areas, concentrating on Chinese territory. Additionally, **ESRIN cooperates with EUMESAT, ECMWF, NASA, as well as with the Member States' National Space Agencies, including ASI.**

17 PARTNERSHIPS FOR THE GOALS

1.1.3 A focus on Earth Explorers

The Earth Explorers (EEs) are targeted research missions meant to explore a specific aspect of the Earth environment, proving the potential for new technologies development. Whereas the Satellites development is in ESTEC, the Frascati establishment is responsible for the entire mission and data management. In fact, beside presiding over the operational and programmatic functions while in orbit, ESRIN also handles the related scientific and commercial data flows.

Earth Explorer current and future missions

The EEs always entail new measurement technologies that need to be matched by the appropriate ground segment functions. Below we present a brief description of the missions and their goals for science activity and studies.

13 CLIMATE ACTION

14 LIFE BELOW WATER

aeolus

ESA'S WIND MISSION

2018 - ongoing

First ever spatial mission addressing the need for more accurate wind measurements for improving the capacity of weather forecasting.

goce

ESA'S GRAVITY MISSION

2009 - 2013

Understand the interaction that the Earth's gravity field has on the ocean currents and sea level, using more homogenous and high resolution set of gravity data.

Earth Explorer Missions

swarm

ESA'S MAGNETIC FIELD MISSION

2013 - ongoing

Achieve a deeper understanding of the interaction between meteorological processes and climate change conditions, by looking at the processes which govern the interior of the Earth, in particular focusing on the strength and the direction of the Earth's magnetic field.

smos

ESA'S WATER MISSION

2009 - ongoing

Evaluate the effects of the soil moisture and the ocean salinity on water cycle acceleration.

cryosat

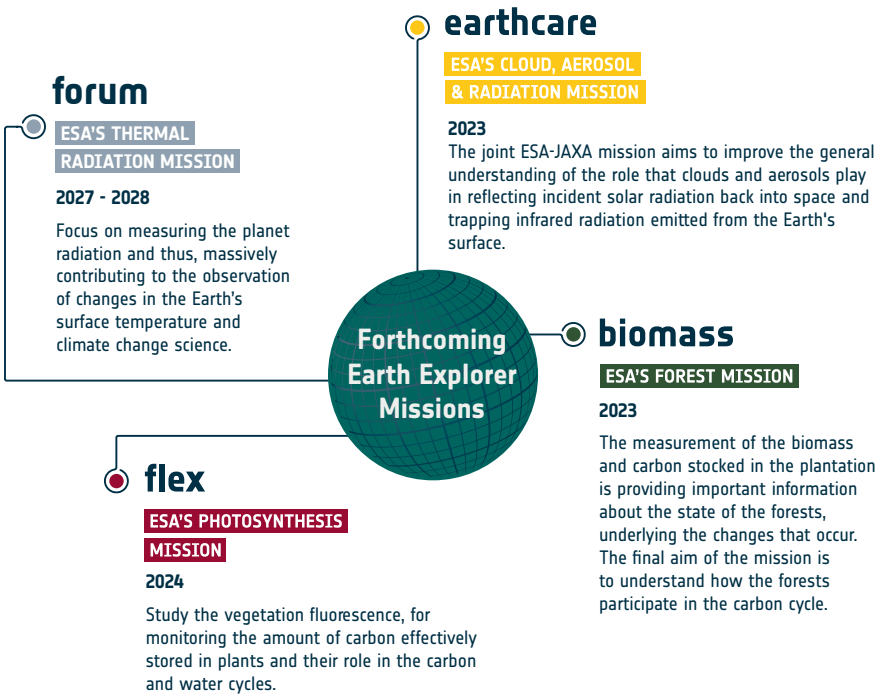
ESA'S ICE MISSION

2010 - ongoing

Measure the changes and predict the implication in terms of future trends in ice caps shrinking.

The Earth Explorer missions have already produced significant scientific impacts also in support of the fight against climate change. For example, CryoSat data revealed that, over the last seven years, Antarctica has lost an area of underwater ice equal to the size of Greater London. The three Swarm satellites have led the discovery of a jet stream in the liquid iron part of Earth's core 3000 km beneath the surface. Finally, the Aeolus Data became systematically integrated in ECMWF's Weather Prediction models.

ESA develops on average one mission every two years. The following table summarizes the forthcoming four Earth Observation Missions.

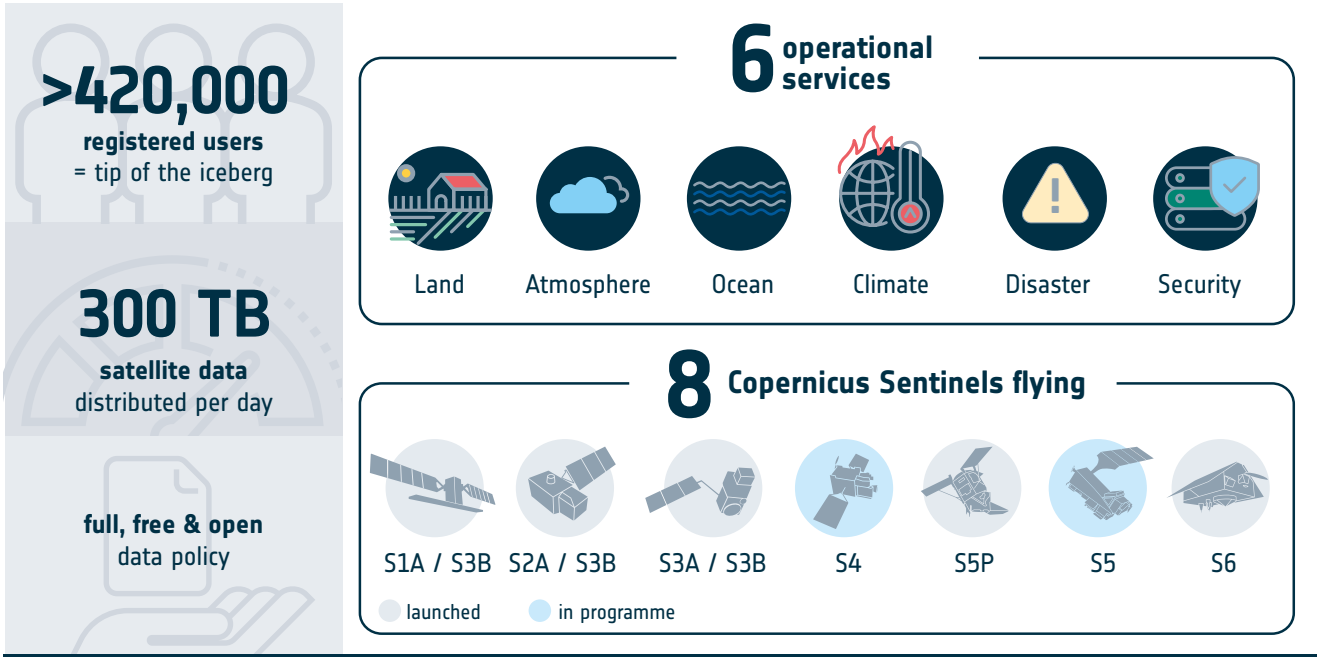


1.2 Copernicus

Copernicus is the **most important programme for data space as support to enviromental and climate change in the world**. It guarantees free, full and open access to data and services to its users. Copernicus data and services support the development of many applications that create added value in several non-space domains, for several different user segments.

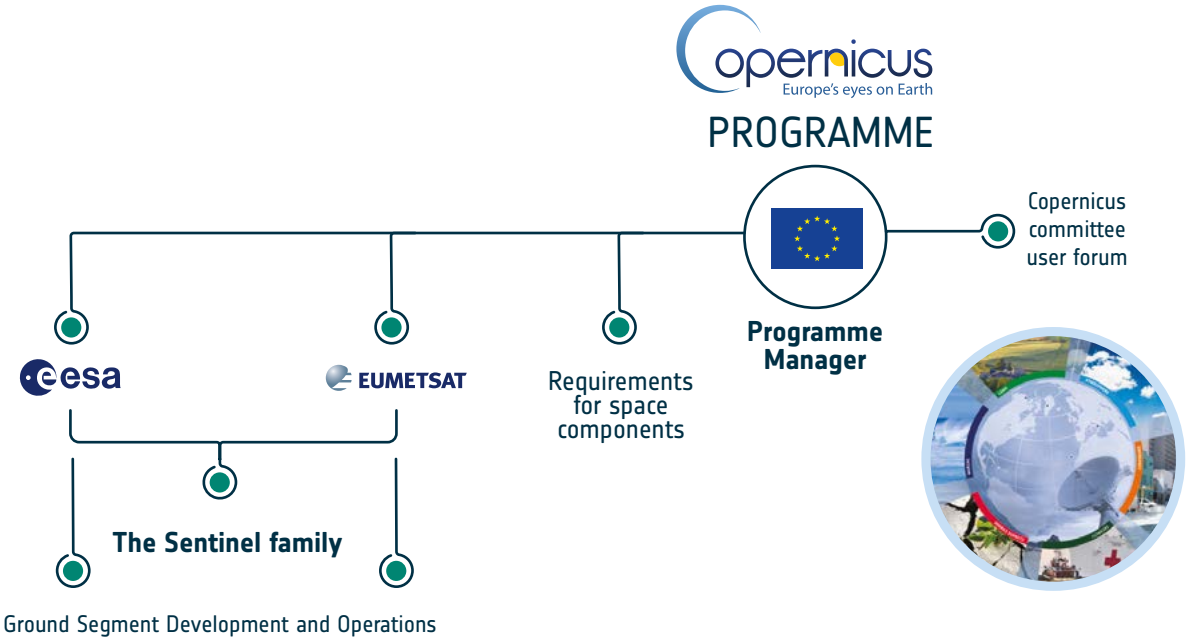
The Copernicus services process the environmental data collected from Earth observation satellites and in situ sensors. These Copernicus services are split into two groups of missions:

- **The Sentinels**, which are developed for the specific needs of the Copernicus programme. Sentinel-1, 2, 3 and 6 are dedicated satellites, while Sentinel-4 and 5 are instruments onboard EUMETSAT's weather satellites.
- **The Contributing Missions**, which are independent missions operated by National, European or International organisations and already provide a wealth of data for Copernicus services.



Last update 2021

ESA is responsible for the development of the **Space Segment Component** of the Copernicus programme and operates the Sentinel-1, Sentinel-2 and Sentinel-5P satellites (which is a precursor to Sentinel-5). ESA also delivers the land mission from Sentinel-3. ESA and EUMETSAT coordinate the delivery of data from more than 30 satellites that form the Contributing Missions.



The Space Component serves users with remote sensing data from the Sentinels and the Copernicus Contributing Missions. Furthermore, Space Component forms the European contribution to the worldwide **Global Earth Observation System of Systems** (GEOSS).

The **ground segment**, which facilitates access to Sentinel and Contributing Mission data completes the Copernicus Space Component.

The Service Component provides a unified system through which vast amounts of data are fed into a range of thematic information services. These are designed to benefit the environment, living standards, humanitarian needs and to support effective policy-making for a more sustainable future. Copernicus services fall into six main categories: **land management, marine environment, atmosphere, emergency response, security and climate change.**

Some of them were already declared operational several years ago such as: the Land Monitoring Service and the Emergency Management Service Mapping in 2012, and the Atmosphere Monitoring Service and the Marine Environment Monitoring Service in 2015. Others were declared operational more recently such as: the Border Surveillance and the Maritime Surveillance components of the Security service in 2016 and the Support to External Action Component in May 2017, and in October 2018, the assessment of the program Climate Change Impact and Biodiversity.

The range of the information services provided by Copernicus satellites produce data as well as the development of a variety of EU-ESA programmes targeting the achievement of the UN 2030 SDGs. For example, the identification of hotspots in danger of overcrowding, congestion, pollution and other factors that reduce the quality of life of their residents. Furthermore, Copernicus programmes can support the protection of historical heritages similarly to the 2003 ESA Open Initiative launched with UNESCO, using Earth Observation to help developing countries protect their World Heritage sites more effectively.

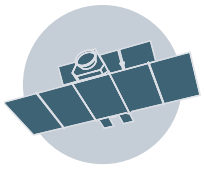
Finally, Earth Observation can be a powerful tool to combat the most pressing world challenges, such as the prevention of the spread of epidemics, or the partnership with the World Health Organization in the *Epidemio* project against malaria, or the most recent roll-out of the RACE Dashboard with the European Commission to address the recent Covid-19 crisis.

In the coming years, six high-priority missions are being studied to address EU policy and gaps in Copernicus user needs, and to expand the current capabilities of the Copernicus space component.

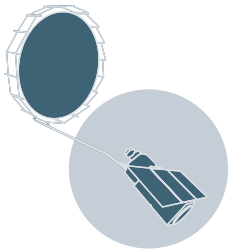
The **new missions developed by ESA** aim to provide data from the Copernicus Sentinels which help address challenges such as urbanisation, food security, rising sea levels, diminishing polar ice, natural disasters and, of course, climate change **in accordance with the objectives pursued by the EU's Green Deal of December 2019 and the ESA Agenda 2025.** In particular:

CRISTAL | for polar regions, provides continuity measures and monitors sea-ice thickness and overlying snow depth. Since inter-annual sea-ice variability is sensitive to climate change, the mission would contribute to a better understanding of climate processes.

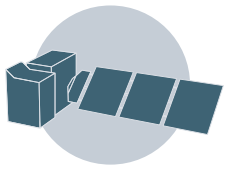
ROSE-L SAR | for coastal regions would carry an L-band SAR. The mission will fill measurement and information gaps not addressed by other Sentinels and provide enhanced continuity of Copernicus SAR observations. It would be used in support of forest management, to monitor subsidence and soil moisture and to discriminate crop types for precision farming and food security. In addition, the mission would contribute to the monitoring of polar ice sheets and ice caps, sea-ice extent in the polar region, and of seasonal snow. Space Segment Consortium with 29 companies from 15 countries is led by Thales Alenia Space Italy (TAS-I) as Prime Contractor.



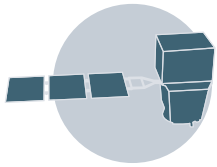
CIMR | Copernicus Imaging Microwave Radiometer, monitors climate changes through a number of different climate variables such as the observation of sea surface temperature, sea ice concentration and sea-surface salinity. The industrial consortium with 60+ companies from 17 countries is led by Thales Alenia Space Italy (TAS-I) as Prime Contractor.



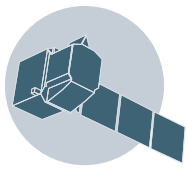
CO2M | is the first mission attempting to measure the man-made (anthropogenic) carbon dioxide in the atmosphere with unprecedented accuracy. It will be used to monitor the compliance with the Paris Treaty commitments. The principal goals are: detection and monitoring of emitting hot spots such as megacities or power plants; assessing emission changes at country level; assessing the changes in 5-year time steps to estimate the global stock take.



LSTM | main objective is to deliver global high spatio-temporal day- and night-time Land Surface Temperature (LST) measurements in order to monitor changes in the observed landscape. These will support the water, agriculture and food security communities with evapotranspiration measurements, reflecting peak vegetation water stress worldwide, with a priority over Europe and Africa.



CHIME | Copernicus Hyperspectral Imaging Mission for the Environment, is aiming to obtain a more accurate determination of biochemical and biophysical variables in support of EU and related policies for the management of natural resources and assets. The resulting products and services are expected to be used in a variety of domains ranging from agriculture, food security, to the monitoring of coastal waters and forestry.



National governments own and operate the *In Situ* component that includes contributions of the Member States to the Copernicus Programme, as a significant

part of the data and monitoring infrastructure. The Copernicus *In Situ* Component also benefits from international efforts to collect and share data, in many cases from research infrastructures. The Copernicus *In Situ* Component's main goal, therefore, is to map the in situ data landscape, comparing what is available against requirements to identify gaps, support the provision of cross-cutting data and manage partnerships with data providers to improve access and usage.

Table 1. A summary of Data Access points, policies and providers

	Access point	Data policy	Providers
 Satellite Data	Sentinel Scientific Data Hub (SCI-Hub)	Free, full and open data policy	ESA
	Copernicus Space Component Data Access (CSCDA)	Access limitations apply	ESA
	EUMETCAST	Access requires specific equipment	EUMETSAT
	CODA	Free, full and open data policy	EUMETSAT
 Service Data and Information	Copernicus Atmosphere Monitoring Service (CAMS)	Free, full and open data policy	ECMWF
	Copernicus Marine Monitoring Service (CMEMS)	Free, full and open data policy	Mercator
	Copernicus Climate Change Service (C3S)	Free, full and open data policy	ECMWF
	Copernicus Land Monitoring Service (CLMS)	Free, full and open data policy	EEA and EC
	Emergency Management Service (EMS)	Activation by authorised users	EC
	Security	Access restricted	FRONTEX, EMSA, EU SatCEN

As already mentioned, Copernicus space infrastructure and **Copernicus service data and information are free and open both for people and institutions**. Specifically, they are accessible through a series of access points, whose characteristics are summarized in Table 1.

Secondly, the Copernicus Programme, in accordance with ESA Agenda 2025, intends to boost innovation and economic growth. In this, the commercial downstream sector plays a key role in maximising the achievable benefits. To facilitate this task, the EU and several public and private institutions have designed a set of financial instruments and platforms to support SMEs and start-ups in developing Copernicus-related businesses. The Graph 1 in the following page provides an overview of the instruments activated by the public sector.

Thirdly, Copernicus follows a user uptake strategy. Copernicus data, like most space data, cannot be used directly by end users. The key objective of the strategy is therefore to support an ecosystem of service providers (public or private) that transform space data into accessible and usable information.

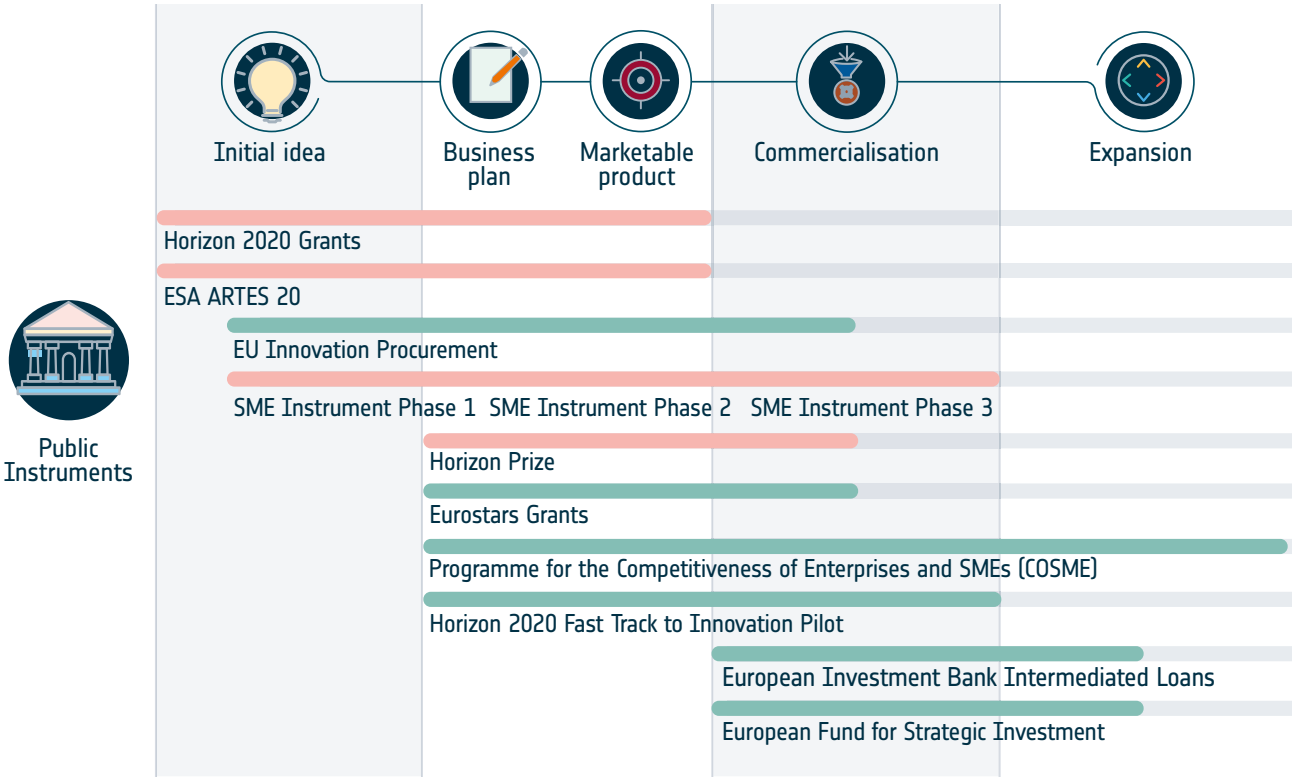
The strategy focuses on three actions:

- increase awareness about Copernicus;
- facilitate access to Copernicus data and services;
- support downstream sectors.

For the first action, two networks (Copernicus Relays and Academy) have been set up, with more than 170 members acting as multipliers in all European Regions.

For the second action, beyond the ESA Copernicus Open Access Hub and the EUMETSAT Copernicus Online Data Access point, from June 2018 the data are delivered by five new cloud-based platforms called DIAS (Data and Information Access Services).

Graph 1. Public financial instruments (in green those specifically relevant for Copernicus downstream)



source: www.copernicus.eu

They provide centralised access to Copernicus data and information, as well as to processing tools. All DIAS platforms provide access to Copernicus Sentinel data, and to the information products from the six operational services of Copernicus, together with cloud-based tools (open source and/or on a pay-per-use basis).

Finally, the following initiatives are part of the third action: Copernicus Masters and Accelerator, Copernicus Incubation Programme, Copernicus Hackaton Programme, COSME, Copernicus Prize, and Copernicus Skills Programme.

A focus on Mirror Copernicus

In 2016, the Italian government drafted the "Space Economy Strategic Plan", which allocated an overall investment of about 4.7 billion euro for different space programmes related to the activities carried out by ASI and ESA.

In the context of Copernicus, the Italian Government launched in 2019 the programme Mirror Copernicus, which is the national support programme to Copernicus. Mirror Copernicus aims to strengthen the positioning of Italian and European geospatial services based on Copernicus services in the national community, and to create an open, scalable and interoperable infrastructure to enable and promote the adoption of these services.

ESA, and in particular ESRIN, provides technical and managerial support to this programme.

The programme has four main goals:

1. Host and allow the access to satellite and non-satellite data targeting the building of applications and services.
2. Ease the access to Italian companies, not only in the space domain, but also to cutting-edge data technologies (e.g. Big data analytics and HPC).
3. Create the Copernicus Marketplace, a brokering platform between the demand and supply of geospatial applications and services, which will follow the functioning of traditional platforms in financial markets.
4. Provide the final users with the data linked to their operational needs.

Moreover, the Italian government has established 8 services, identified according to the needs of the final users:

1. Coastal and marine monitoring
2. Air Quality
3. Ground movements (e.g. volcanic or seismic)
4. Ground coverage and usage monitoring
5. Hydro-weather-climate
6. Water resources
7. Emergency
8. Security

1.2.1 Copernicus service for Security

Earth Observation can contribute to supporting several security areas at European level.

In the area of border surveillance, the main goals are to reduce the number of illegal immigrants entering the EU undetected, to reduce the death toll of illegal immigrants by rescuing more lives at sea, and to increase the internal security of the European Union as a whole by contributing to the prevention of cross-border crime.

In the area of maritime surveillance, the EU aims to support Europe's maritime security objectives and related activities. The corresponding challenges mainly relate to safety of navigation, support to fisheries control, combat marine pollution, and law enforcement.

Finally, a main objective of the EU is to assist third-party countries in a situation of crisis or emerging crisis and to prevent global and trans-regional threats having a destabilising effect. The Support to External Action (SEA) component of the Copernicus Security Service will assist the EU in its operations outside EU territory, providing decision makers with geo-information on remote, difficult to access areas, where security issues are at stake.

1.3 Earth Observation: from Climate Change to Climate Crisis

The overall effort of observing the Earth with the use of satellites has resulted in significant progress in several scientific areas, laying the basis for the development of new applications. In the remainder of the paragraph, the major achievements, applications and benefits generated by the ESA EOP and more in general by the EO activities conducted worldwide are illustrated. Being the ESA Centre for Earth Observation and hosting the EOP Directorate, **ESRIN is at the heart of this valuable process.**

As previously mentioned, ESRIN has been committed to the Sustainable Development Goals since September 2015, when the United Nations General Assembly approved the 2030 Agenda. ESA delivers a suite of datasets provided by Earth Observation satellites including the key components of the climate system, known as "Essential Climate Variables" (ECVs). Information derived from satellite data can contribute to more than half of the 54 ECVs identified by the **Global Climate Observing System** (GCOS) to support the **United Nations Framework Convention on Climate Change** (UNFCCC) and the **International Panel on Climate Change** (IPCC), and they are a major contribution to the evidence base used to understand climate change and to predict the future.

Furthermore, the **ESA Agenda 2025** declared that the Agency will appoint a Senior Climate and Sustainability Adviser to the Director General to ensure that ESA and European space programmes can support the implementation of the Paris Agreement and the European Green Deal to the fullest extent. The Agency will improve its own environmental responsibility, to contribute to the climate neutrality of Europe.

In the last decade, international institutions have focused increasingly on the transition **from climate change to climate crisis** and the direct impact on the human population in terms of loss of life, economic loss and irreversible destruction of the environment.

The supply of a consistent set of continuously updated global satellite data can be turned into actionable information for decision making on various environmental issues thus, **strengthening public safety**. Specifically, satellite-based rapid mapping

services can support civil defence and humanitarian aid activities during crises as well as supporting risk assessment and prevention efforts in the long term. Within this context, as already mentioned, ESA co-founded in 1999 the **International Charter Space and Major Disasters**, an agreement between space agencies to make near-real time satellite data available to worldwide civil protection agencies. Following the Charter's roll-out, space-acquired data products and associated resources are made directly available to the civil protection agencies concerned. Services are not limited to supplying data but include processing and interpretation as well. Furthermore, Earth Observation has the potential to overcome the lack of territorial data, yielding satellite imagery with high levels of both spatial and temporal resolution. In poor and remote areas, these images can serve as a source of reliable baseline geographical products suitable for operational planning, such as the speedy distribution of emergency food and medicine or deciding emergency evacuation routes for personnel. Satellite imagery can also be integrated within standardised **geographical information systems (GIS)** software, to be supplemented with local knowledge gathered on the ground – such as road conditions, warehouse stocks or the current battlefronts within war zones. Finally, satellite data are also a valuable support for the aid of authorities working **to prevent the spread of epidemics**, as they have the potential to help forecast disease outbreaks. Three recent dramatic events describe well how the EO data can support the climate crises:

Wildfires in Canada – June 2021

In June 2021, Wildfires have been raging in Canada's Alberta province causing widespread destruction and forcing thousands of people from their homes. Satellites from numerous space agencies across the globe have imaged the fires, including the recently launched Sentinel-3A for Europe's Copernicus programme. The ESA satellite launched in February 2021 is not completely operative but once the satellite is in service, images will help to assess the size and power of a wildfire, provide an indication of how the fire front is developing and the course it may be taking, giving important information for firefighting and planning evacuations.

Rainfall in Western Europe – July 2021

The torrential rainfall in July 2021 caused swollen rivers to burst their banks and wash away homes and other buildings in western Europe, leading to more than 90 casualties and over 1000 people missing. The data from the Copernicus Sentinel-1 implemented in Copernicus Emergency Mapping Service are being used to map flooded areas to help relief efforts.

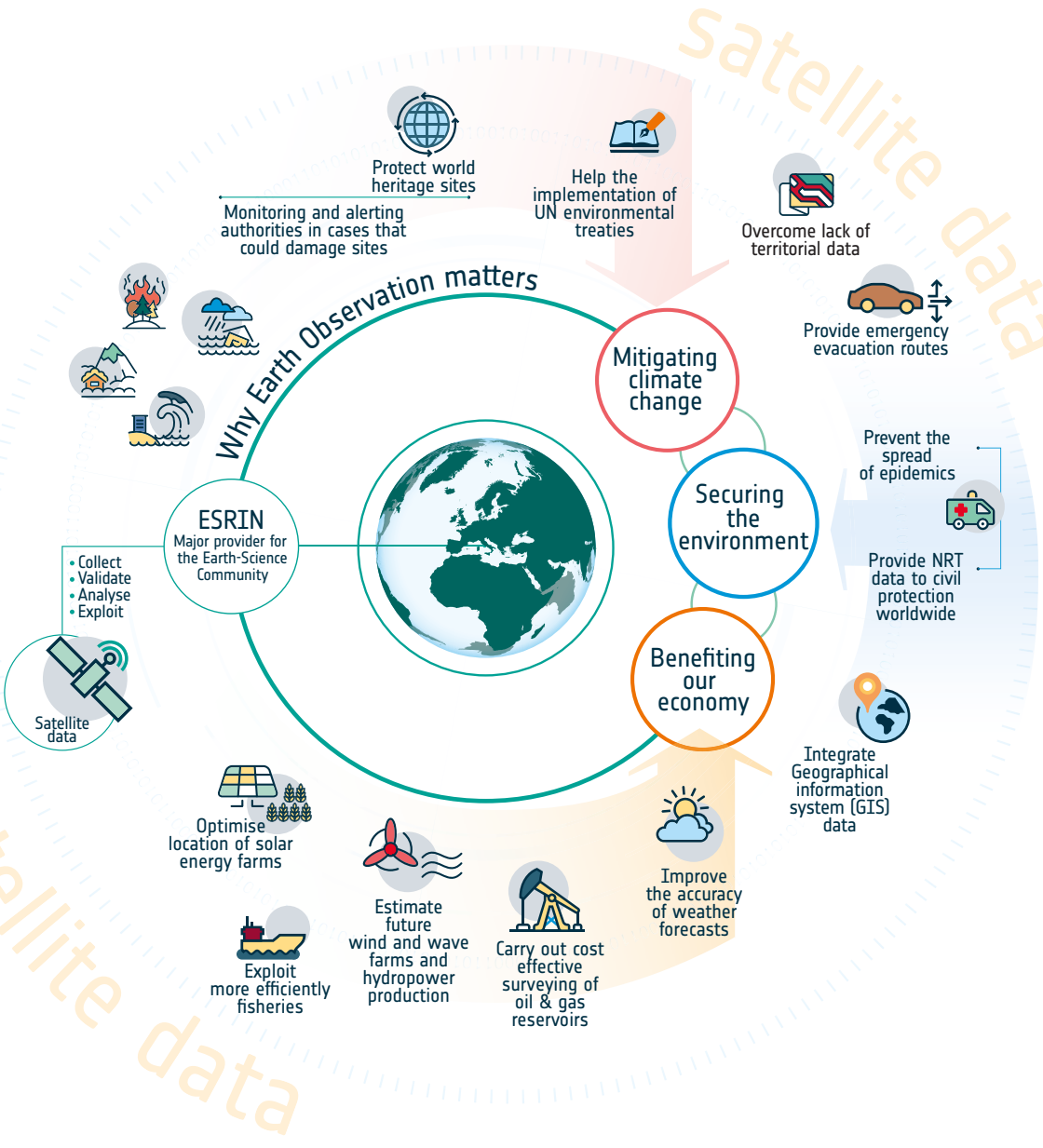
Global Ice loss – 2021

A recent research "Earth's ice imbalance" published in The Cryosphere (15, 233–246, 2021), uses satellite observations from ESA's ERS, Envisat and CryoSat satellites as well as the Copernicus Sentinel-1 and Sentinel-2 missions to estimate that the rate at which Earth has lost ice has increased markedly within the past three decades, from 0.8 trillion tonnes per year in the 1990s to 1.3 trillion tonnes per year in 2017. The authors show that overall, there has been a 65% increase in the rate of ice loss over the 23-year survey. This has been driven mainly by steep rises in losses from the polar ice sheets in Antarctica and Greenland.

A recent example is the platform "**COVID-19 Earth Observation Dashboard**" that presents the results of the joint cooperation between ESA, the European Commission, NASA and JAXA. The platform is a tangible example of how the use of Earth observation data can help shed new light on societal and economic changes currently taking place owing to the coronavirus pandemic.

Space-derived information provides a whole new dimension of knowledge and services which can benefit human daily life. As an example, satellite data have radically improved the accuracy of weather forecasts, generating practical benefits in many sectors of economic activity. Furthermore, **the Earth offers a wide array of resources with the potential to create wealth, and satellite data reveal these resources**. For instance, by returning data on hilltop snow cover or precipitation amount, satellite images capture an entire river basin within a single acquisition so enabling accurate, advanced **estimates of future reservoir depth and hydropower production**. Space-based instruments also make possible the creation of wide-ranging **"sunshine indexes"** for the **optimal location of solar energy farms**, and by recording the incoming solar energy amount they provide an

7 AFFORDABLE AND CLEAN ENERGY



objective yardstick for testing if existing farms are functioning efficiently. Another example are orbital sensors recording wind and wave parameters, which allow to provide the equivalent service for wind and wave farms. The latter are especially useful for **positioning offshore facilities where meteorological statistics are not usually gathered**. For example, in commercial fishing, ocean current and sea temperature data returned from satellites may serve to exploit fisheries more efficiently by guiding fishing fleets to areas where the catch is likely to be the highest. Because the oil and gas reserves dwindle, offshore frontier areas such as the Arctic and south-east Asia have come under an increased focus of interest for energy companies and the exploration managers are making increasing use of satellite data as a cost-effective mean of carrying out large-scale surveying of unexplored areas. Finally, wide-area satellite images have the potential to identify the **distinctive geological structures associated with oil and gas reservoirs and also mineral deposits.**

Within cities, satellites can help identify **overdeveloped "hotspots"** in danger of overcrowding, congestion and other factors that reduce the quality of life of their residents. They can also monitor air quality and trace pollution sources. Finally, Earth Observation is a particularly useful means of studying cities within the context of the wider landscape, checking on the continued **sustainability of natural resources** essential for urban living such as dependable energy sources and clean water. Long-term monitoring of Earth from space helps to assess the **environmental effects of human activities** on a systematic basis, and provides an extensive time series of data for the projection of current environmental trends into the future.

2. EO for society

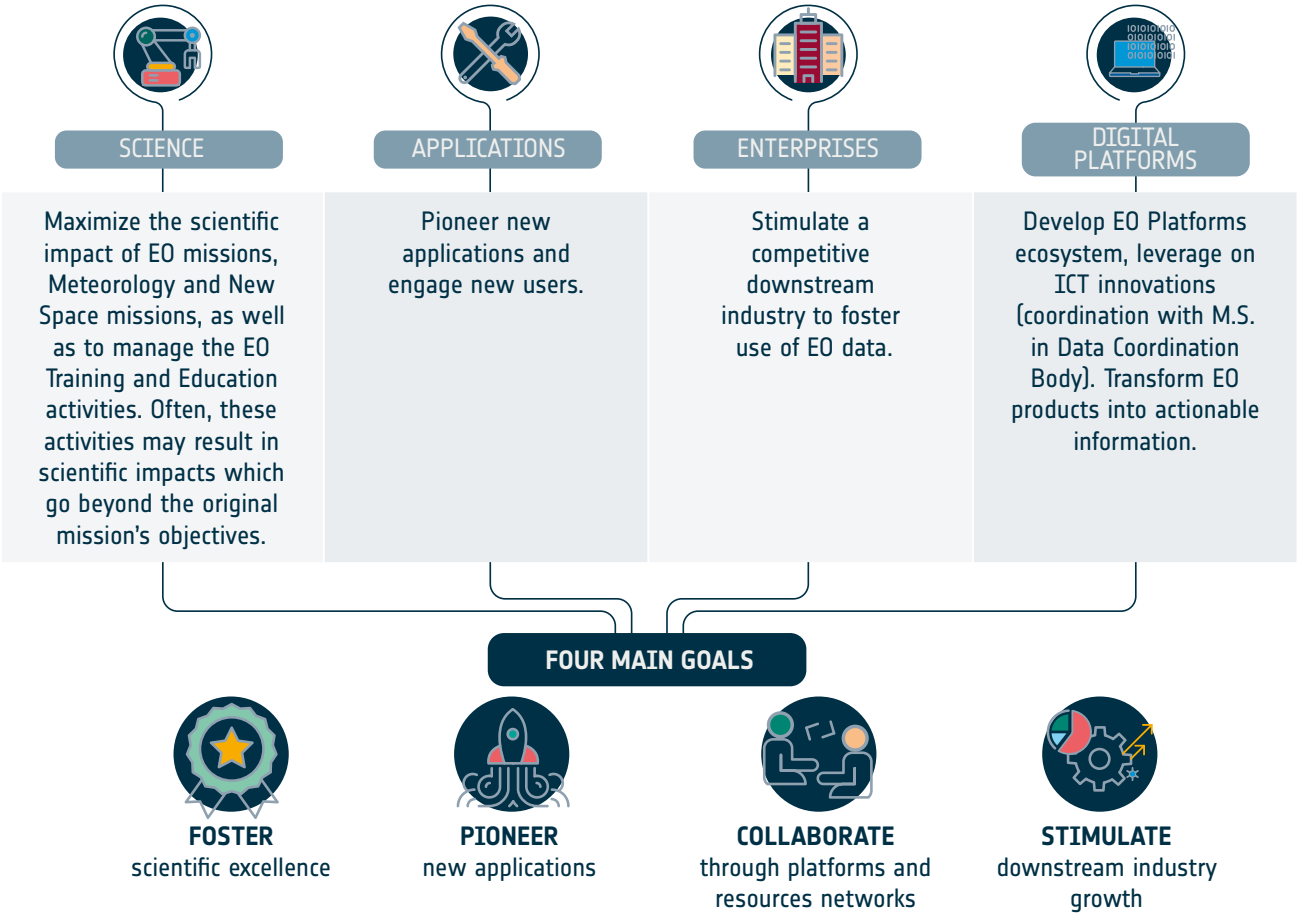
2.1 About EO for society

The Earth Observation Envelope Programme (EOEP) is the backbone for implementing the ESA Earth Observation Strategy 2040, whose prime objective is to help society to monitor the health of the Earth, to understand the physical interaction of society with the Earth system, and to inform decision makers and citizens on scenarios and consequences of political and economic decisions regarding our home planet.

The vision behind the EO Strategy 2040 is to foster the **maximum benefit of Earth observation for science, society and economic growth in Europe**. EO for Society represents the current main effort by ESA in fostering EO data exploitation to advance earth science, pioneer new applications, develop the downstream sector using the latest ICT tools and collaborative platforms in the Space 4.0 era.

In particular, the programme is developed across four main sections: **Science, Applications, Enterprises and Digital Platforms.**

The mission of the EO for Society can be summarized in four main goals: **scientific excellence, new applications, collaborate through platforms and resources networks, stimulate downstream industry growth.**



2.1.1 Foster: scientific excellence

Scientific Data Exploitation is the programmatic element that addresses the needs of the EO and Earth-system science communities in terms of new methods, advanced tools, innovative products and Earth-system science results. This programmatic element aims at ensuring that ESA scientific activities remain main catalysts for innovation which may provide the baseline for novel mission concepts and future observational principles, and thereby stimulate ideas for future generation EO missions.

All the activities related to the scientific exploitation (including the platforms) are entirely developed in ESRIN. In this regard, within the end of 2021, a new research lab will be inaugurated in ESRIN, the *Earth System science lab*, which will make the Frascati's facilities as **the ESA's hub for Earth System Science**. The lab will host the EO scientific community to work around the relevant EO programmes and topics.

2.1.2 Pioneer: new EO applications to support International Policies

The Applications Section develops innovative solutions to address the main societal challenges concerning sustainable development and the protection of the environment. The solutions support the monitoring and the implementation of international policies by policy makers and public stakeholders.

In particular, based on a policy-driven roadmap, the Applications Section ensures that the development of EO-based products and services is performed with the

engagement of the key relevant stakeholders. The definition, implementation, integration, validation and qualification of these products and services is carried out by the EO value-adding industry and academia in close collaboration with the end-user organisations. In this framework, ESA implements demonstrators linking the EO industry with policy makers and related stakeholders. Through ESA contracts, the EO industry enables users to have direct experience with the products and/or services developed, so that they can appreciate the benefits and advantages of EO technology.

ESA's objective is to generate an operational long-term commitment in the usage of the EO data from these public organizations. In parallel, this mechanism generates future business opportunities. In a second step, the demonstrators are translated in mainstream applications, for example, supporting the programmes of international development organizations, or fully integrated into commercial services.

Clearly, the pioneering activities of EO for Society are able to generate added value for the industry and the research environment and in particular **for the Italian environment which is favoured by the existence of ESA's facilities within the Italian premises**.

In particular, the awareness activities that ESRIN hosts on its premises, such as open-door events or industry days, often attract the interest of different Italian research groups. This initial interest may translate into spin-offs, which, in turn, may trigger partnerships or even acquisitions by established firms. Finally, these small and new ventures may also use the ESA's first customer reference to scale up even beyond the R&D activities, as well as to expand their operations to other public or private bodies.

2.1.3 Collaborate: through platforms and resources networks

Digital Platforms are a game-changer in scientific mission and value-adding. The cloud-based platforms represent a critical enabler in supporting and facilitating the research community in the take-up of the constantly growing volume of environmental data from ESA's missions like Sentinel, without the need for a physical infrastructure of their own. This new attitude, defined as "bring the user to the data" approach, **will create a *democratization* of the downstream usage of EO data using a fraction of the time and investment that was required before and thus, avoiding the need to download the data**.

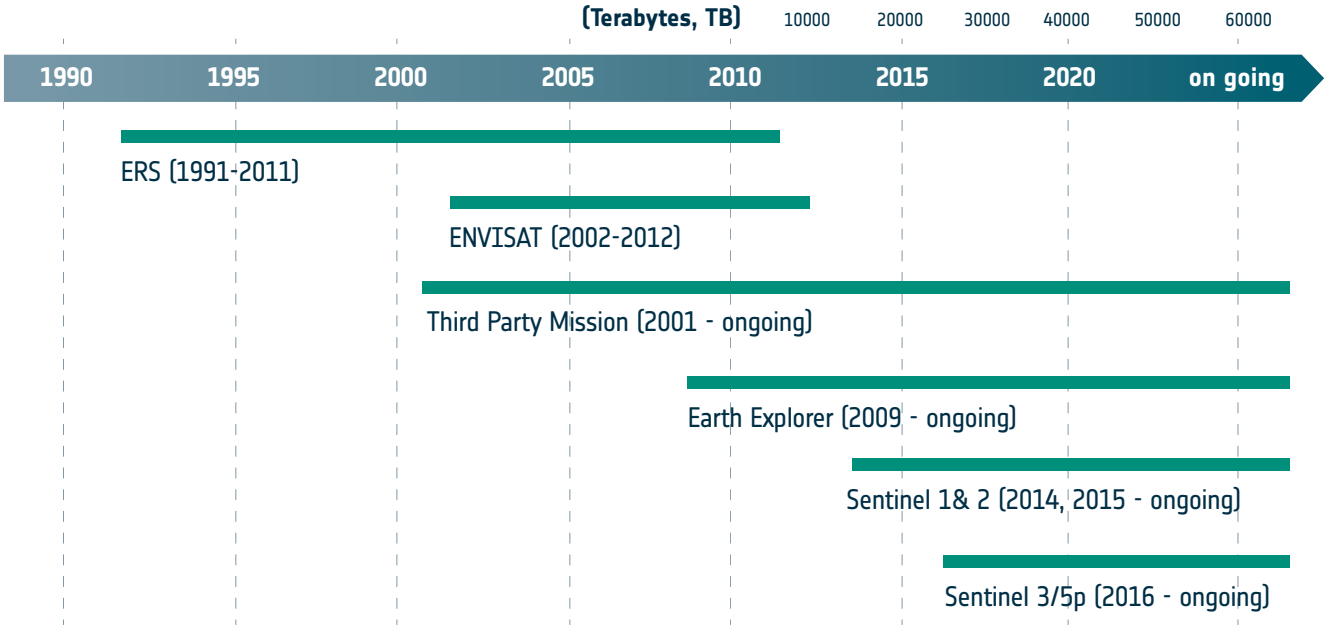
In this centralized environment, ESA's facilities in Frascati play a critical role as the "(virtual) place to go" for EO Big Data analytics and paired to others collaboration and supporting tools.

This generates a huge, although difficult to measure, value created for the benefits of the public and private sector of the Member States. In fact, while data are often referred to as the "new oil"[2], data intelligence represents the new digital currency around the world.

As previously mentioned, ESRIN's EO data archive is the largest of its kind in the world. ESRIN's EO data volume, and therefore its value, has recently started to grow exponentially, as shown in Graph 2.

[2] *"Data is the new oil" was firstly coined by Clive Humby in 2006, the concept has been taken back and confirmed by many authoritative sources such as the European Parliament, Forbes, The Economist*

Graph 2. ESA Earth Observation Archives Volume



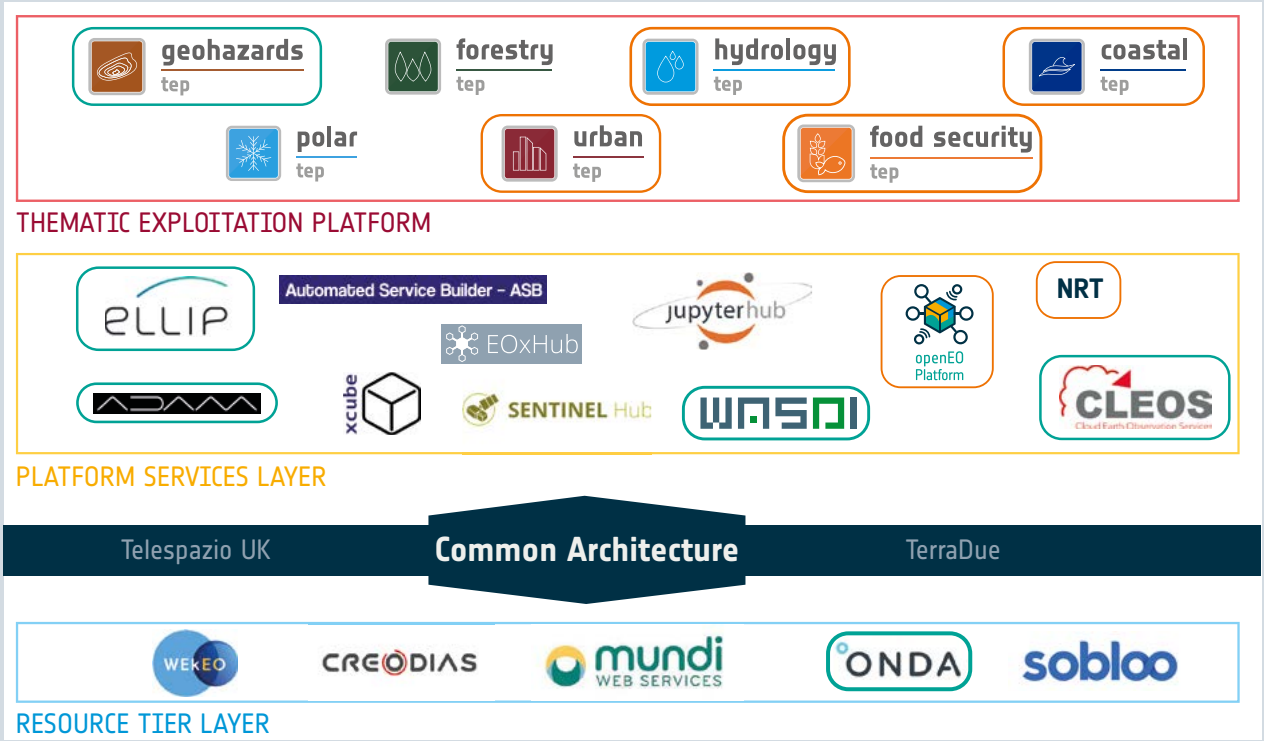
In this regard, in order to increase and integrate its exploitation activities, from 2019 ESA started to procure processing services from various existing European Earth Observation Resource Providers and to incentivise a **'Network of EO Resources'** to contribute to a common framework which aims at harmonising their service offerings to users. The Network of EO Resources eases the uptake of the ecosystem by the science community, providing vouchers to consume the services of the Platform Services Layer and the Resources Tier Layer "free-at-point-of-use". The *Resource Tier Layer* consists of cloud providers which host Earth Observation data. These services are procured from the Member States and the European Commission. One of the most notable example, is the Data and Information Access Services (DIAS) platform, which stores the Copernicus Programme data.

Digital platforms surely represent an important effort to ensure state of the art capabilities for creating science and applications for European providers. Nevertheless, they also represent a valuable market opportunity, currently dominated by American and Chinese providers. In this domain, defined as Platform Service Layer, the European capabilities still lag behind their main international competitors, as there is a considerable technological gap in both cloud computing and space data. Therefore, the Application sector in ESRIN represents **a major enabler to steer and support the European platform industry so that it can compete on a level playing field with other countries.**

In this framework, Europe is investing in a federated ecosystem with contributions from ESA, Eumetsat, National missions, the European Commission, as well as from local cloud and platform capabilities. This requires a strong effort on architectural coherence, where ESA has a leading role due to its unique ability to ensure programmatic continuity and availability of staff. The goal of the Network of resources is to create this federation of different players to link the Common Architecture/Open Interfaces together.

A focus on the Italian role in the digital platform economy

The figure below identifies the Italian role in the European EO Platform Ecosystem. At the top, there are the thematic areas, while the rest highlights the private players in the common architecture. The green boxes are led by Italian players. The orange boxes have participations of Italian players.



In this framework, two Italian companies play a major role: Telespazio UK, a Leonardo and Thales company, which is the world leader in building these types of interfaces such as the common architecture; TerraDue is a small company which has been empowered by the Open Geo Space consortium to define the best practices for hosting Earth Observation applications on the Cloud. TerraDue is currently considered the undisputed world-champion driving industrial standardisation of EO platform architecture in the cloud and is operating the "Geohazard TEP" and the "Ellip" platform.

2.1.4 Stimulate: downstream industry growth

Expanding emerging demand

The objective is to embed EO analytics to the maximum extent possible within the information and analysis flows of the target demand sector so that the full value from geospatial information can be generated. This will enable a wide range of added value dimensions, such as detecting spatial variation and elaborating disaggregation of core business information, characterizing environmental or situational risks on core business and integrating geospatial statistics with conventional strategic intelligence. This will support enhanced decision making, operational responsiveness to emerging issues and long term strategic planning, catalyzing new opportunities and the emergence of new actors.

This line of action addresses two main categories of emerging new opportunities:

- bringing new technologies and tools together with EO datasets, opening up new markets, new approaches to creating and delivering information

- working with small satellites and other novel data collection platform developers/ operators to augment existing operational geo-information services

In addition, a range of studies are being carried out to assess the potential for new EO exploitation opportunities from a range of new developments including Blockchain, AI, quantum computing, Internet of Things as well as data processing paradigms such as TensorFlow.

Consolidating industrial best practices for EO

This line consists of a set of activities to address factors that inhibit wider uptake of EO derived information in priority market sectors. For each market sector:

- the range of situations will be elaborated where EO derived information can be used
- best practice guidelines will be tested and examples to support these guidelines will be generated

The output is a comprehensive characterization of best practices for using EO derived information within that market sector. At present, contracts have been started for the extractives industry and the agrichemical sector. It is planned that two market sectors each year will be addressed.

3. The new Earth Observation Programmes

3.1 The Φ-Lab

The European Green Deal and Digital Agenda as well as similar national policies of ESA members can be served by competitive and innovative commercial space companies, transforming big data and connectivity into smart information products, knowledge and commercial services. This context represents a perfect environment for advances in AI-based data analytics and prototyping quantum computing and quantum communication technologies.

ESA will offer its expertise as technical partner/adviser in new cooperative schemes with funding entities like venture capital funds and business angels to facilitate access to private capital. Coherently with the ESA Agenda 2025, the ESA Φ-Lab was created in 2017 as a Division in the Future Systems Department of the EO Programmes Directorate in ESRIN. ***The ESA Φ-Lab is considered as the transformative innovation engine***, namely, hosting those innovations able to completely transform or create entire industries via new technologies, of the European Earth Observation ecosystem. The Φ-Lab's mission is to accelerate the future of Earth Observation via transformational innovation, to strengthen European competitiveness and to become the reference and key influencer for innovations in Earth Observation.

The Φ-Lab is also the home of the ESA EO commercialization programme, investing in Industrial Innovation (InCubed), to support innovative entrepreneurs as they develop and deliver to the market new commercially viable products and services. The programme has been subscribed by 18 Countries, with Italy ranking first in terms of contribution, followed by Germany, Spain and United Kingdom. As of 2021, Φ-Lab has a size of 103M€, 29 activities have been already funded, 4 have been completed, and 3 are already generating revenues.

The Φ-Lab identifies, supports and scales innovative EO-based solutions and business

models harnessing the power of these transformative digital technologies. In particular, the lab acts as a:

- **Catalyst for innovative ideas and solutions** by providing know-how, guidance, and an experimentation open space;
- **Bridge among industry, academia, innovation leaders and start-ups** to better understand, explore and scale up new technologies and solutions for the market.

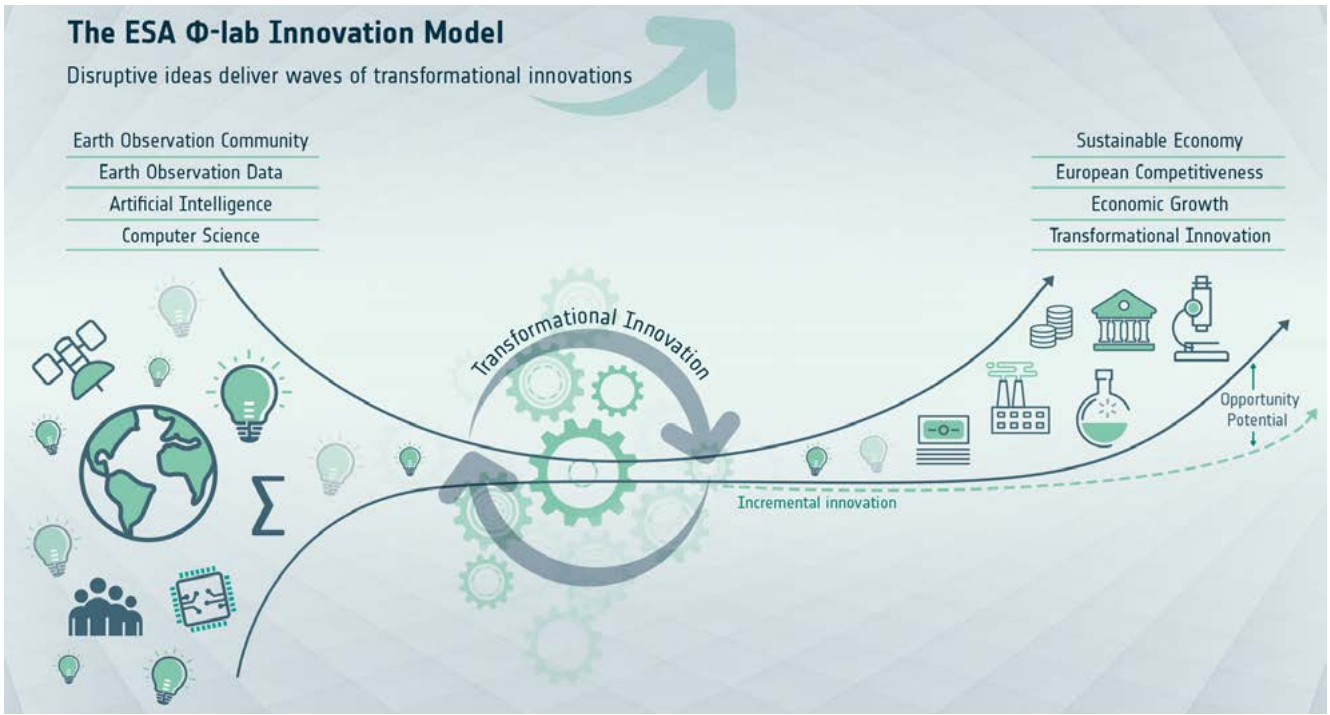
The Φ-Lab has a small group of researchers, from inside and outside ESA, mainly active along three technology axes that are applied to all elements of the Earth Observation value chain: **Artificial Intelligence and Machine learning; Quantum Computing; Internet of Things, Blockchain, Cognitive Space.**

Considering all the activities managed and so including the InCubed programme, about 50% of the budget is allocated to Flight Hardware and Software activities, about 40% to downstream applications, while the remaining are innovative business models or complete space systems.

The Φ-Lab is a new model in the Agency, created to have *"under the same roof"* the entire innovation pipeline which covers not only basic and applied science, but also all the activities which scale an idea or a solution up to its commercialization. For this reason, the Φ-Lab is organized in two distinct offices: **the Explore Office** (TRL 1-3) and **the Invest Office** (from TRL 4 to commercialization). While the Explore Office operates in the early stages of innovation, and in particular, connecting various disruptive actors, the Invest Office focuses stimulating and developing innovative companies and their ideas by acting as a de-risking partner and facilitator.

Very recently the new ESA DG has announced, via its Agenda 2025, the intention to replicate this innovation model in other ESA sites and also at regional level in Europe, in order to foster the growth and competitiveness of the entire European space industrial ecosystem via innovation.

The Φ-Lab is an open lab, as it welcomes partnerships with industry, research



centres and institutions, without exchange of funding, and it offers talented visitors the possibility to be hosted for an agreed timeframe. In particular companies can cooperate with the Φ-Lab according to three modalities:

1. Research activity, based on a topic of common interest and without any exchange of funding, usually with "visiting researchers" hosted at the Φ-Lab, or co-funded PhD or post-doc.
2. Development activity based on a specific plan offered by the companies in reply to a Φ-Lab need, and followed by the signature of a contractual agreement.
3. Offering an entrepreneur initiative to InCubed program, and receiving co-funding and support for commercially viable product and services.

The Φ-Lab is also collaborating with ESTEC to bring innovation not only to demonstration satellite missions, but also to future operational satellites. In this regard, the Φ-Lab participated in the development of the satellite Φ-sat-1 (launched on September 2020), contributing to the artificial intelligence parts and to the hyperspectral payload. A similar contribution is also expected in the development of the satellite Φ-sat-2, currently under development. Finally, it provides support to those undergoing assessments for the implementation of Machine Learning functionalities in future Copernicus missions.

At the time of writing, the Φ-Lab has already started **12 partnerships** and others are in preparation. Partnerships with industries are typically focused on co-development of innovative use cases, or support to business definition based on transformative innovation. With research centres the outcome is joint applied research and outreach, and with private investors Φ-Lab shares information about the respective cohort of companies, discussing potential co-funding initiatives, and having support from private investors on assessing proposed entrepreneur business plans for InCubed.

Besides the industrial impacts, the Φ-Lab is also a scientific engine which hosts members of academia and of industry. The Φ-Lab research team in cooperation with 10 Visiting Professors and 12 Visiting Researchers, and with co-funded PhDs has already produced about 30 scientific publications in peer-reviewed journals and conferences. One of the most notable examples of scientific partnerships is the ESA-CERN co-funded PhD around the topic of quantum computing for EO.

Last update May 2021

At present, the Φ-Lab Explore office runs about 15 research activities divided in three categories:

- Exploratory: basic research to expand knowledge
- Ecosystem development & Capacity Building: development of toolbox and algorithms as well as of the EO innovative industrial and research ecosystem
- Impact and Adoption: aiming at transformative innovation user uptake

The Φ-Lab is very active within the Italian ecosystem, key examples are:

- hosting staff of the Italian Space Agency (ASI), working on Artificial Intelligence applied to the PRISMA mission products
- hosting postdocs from various Italian universities and personnel from EO industries
- collaborating with Fondazione Amaldi supporting the expansion of InCubed impact onto the Italian ecosystem

3.1.1 A focus on Incubed

The Invest Office supports EO innovative entrepreneurs through several initiatives, such as the co-investment program InCubed, facilitating access to private investors, proactive networking between corporate, private investors and entrepreneurs, as well as industry-to-industry and industry-to-academia synergies.

The industrial innovation programme, also know as **InCubed**, which stands for 'Investing in Industrial Innovation', is an industry-led partnership between Industry, National Delegations and ESA, focusing on co-funding and supporting innovative and commercially viable products and services development for the Earth Observation sector.

The goal of this programme is to bring innovative ideas and R&D activities to the market, reaching at least the minimum viable product stage. It de-risks entrepreneur initiative by delivering a sound and resilient development programme from a technical, commercial, programmatic and financial point of view. In this regard, entrepreneurs admitted to the programme receive extensive support during the whole innovation development, as summarized in the table below.

Type of support	The Incubed offer
Financial	Equity-free and Intellectual Property Right-free co-founding support (from 50% to 80% of the eligible costs)
Technical	Technical expertise and guidance
	Access to ESA's EO facilities and to the Φ-Lab
Commercial	Commercial, business development support and facilitating start-ups access to funding opportunities
	Validating entrepreneur initiative, hence offering a kind of ESA stamps of credibility
	Membership of the Φ-Lab community with access to networks and dedicated events

- partnering with the Italian Venture Capitalist Primo Space focused on investment in the space industry sector
- exploring the possibility to support Mirror Copernicus Italian initiative

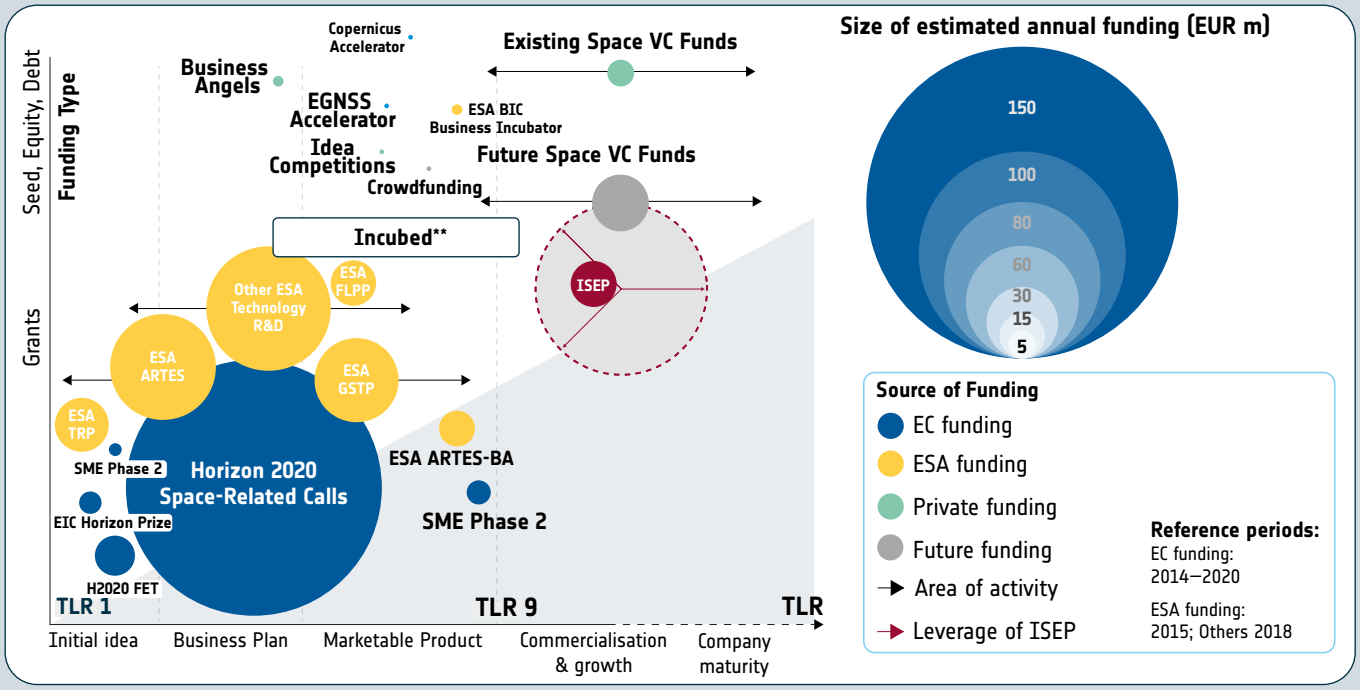
In the coming years, the Φ-Lab will strengthen the cooperation with investors and Venture Capital to ease access to EO entrepreneurs to this critical growth funding instrument.

In this regard, Φ-Lab has created a partnership with Primo Space, an Italian seed and early stage venture capital fund focused on Space Tech projects.

Working with Primo Space, the Φ-Lab aims at boosting its InCubed program adding the competences and capabilities of professional investors in support to new ventures which could have great space technologies but limited commercial, financial and business capabilities.

Finally, the Φ-Lab is currently working to also create for its community a marketplace in which investors and space companies can meet and match.

Figure 1. Overview of space-focused financial instruments in Europe and position of InCubed



source: EIB and ESA

The objective of InCubed is to foster the competitiveness and the growth of the industrial capabilities in Earth Observation. Therefore, the co-funding is equity and IPR free and with a wide scope including instruments, complete satellite or downstream applications. The three criteria for successful access to InCubed are: an innovative idea, commercially credible and within the Earth Observation sector.

The position of InCubed in terms of type of funding and maturity of the invested solutions compared to other known instruments is highlighted in Figure 1.

At the time of writing and after only 3.5 years of existence, the program has co-funded 29 activities for a value close to €47 million, exploiting about a third of the available budget of €103 million. On average the activities have been co-funded at 59%, amounting to an average value of about €806,947. Four projects have been completed, and three of them already generate revenues.

3.2 Destination Earth (DestinE)

Destination Earth is an ambitious project commissioned by the European Commission (DG CNECT) in collaboration with ESA/ESRIN, ECMWF (European Centre for Medium-Range Weather Forecasts) and EUMETSAT (European Organisation for the Exploitation of Meteorological Satellites) to create a detailed high-precision and constantly evolving model of the Earth which includes and predicts the impact of human activities. This new model targets to reach an astonishing 1-kilometre resolution compared to the traditional 50 or 100 kilometre resolution. DestinE leverages on new measurements and data sets to obtain predictive models for many EO applications beyond weather and climate. Destination Earth will also take advantage of Artificial Intelligence and new advanced weather prediction methodologies in order to estimate the impact of climate change on society and how human behaviours may affect this through early detection and interventions. Destination Earth's three most important enablers are:

- **Open Core Platform**: a cloud-based platform allowing for modelling and open simulation and able to reach a wider spectrum of stakeholders thanks to the user-friendly design.
- **DestinE Data Lake**: a specific and dedicated data lake for merging a variety of data coming from the federation of distributed data sources.
- **Digital Twins**: virtual high-precision replicas of reality, fed and adjourned on a real time basis. DestinE digital twins will be developed under thematic categorisations from the different domains of Earth science. The final purpose will be to merge all the Digital Twins to create a complete digital twin representing the entire Earth system.

The project will be developed under different phases, starting from 2021. The first milestone should be completed before the end of 2023 with the launch of the core platform and the development of the first two digital twins. The first **Digital Twin on Weather-Induced and Geophysical Extremes** should improve the capability to embrace a more proactive approach with respect to environmental extremes phenomena. The second is the **Digital Twin on Climate Change Adaptation**, which will play an important role in providing analytical data and testing of predictive scenarios for supporting climate policies elaboration. By 2025 at least 4 others digital twins should be developed supporting the public sector in elaborating, monitoring and evaluating the impact of environmental and climate policies and legislative measures. By 2030, a digital twin of the entire Planet is expected to be fully developed.

The expected benefits of the project can be summarised as follows.

Evidence-based policy. DestinE will provide important data for supporting the twin digital and green transitions, embracing a data-driven and customer-centric approach into policy formulation. High-quality information, models, services, scenarios, forecasts and visualisations related to expected changes in the environmental or societal frameworks will also be made available to non expert users.

European Green Deal. The possibility to predict future scenarios in climate change will be the basis not only for mitigation policies but also for climate resilience. Policy makers have the possibility to test the expected impact that a specific legislation may have so as to introduce changes for maximizing the mitigation effects.

Accessing data and benchmarking models. The user-friendly core platform provided on a cloud-basis will enable a wide access of DestinE models, algorithms, applications and data, giving to anyone the possibility to develop and test its own model.

User-Specific and Actionable Predictions. The new information can feed existing expert systems to provide additional knowledge essential for a more proactive approach.

3.3 Global Development Assistance

If in the past Space technology was greatly undervalued in its crucial role for empowering humanitarian and development activities, a more recent tendency has completely revised the role of ESA's Satellite Earth Observation capabilities, leading to it being considered as a major enabler in promoting and supporting international development work. Indeed, Earth observation by satellites provides a wide range of global, comprehensive, accurate, repeatable and timely environmental information that is key to effectively planning and implementing development and humanitarian activities. In the last decade, ESA has worked closely together with International Financial Institutions (IFIs) such as World Bank, Asian Development Bank, Inter-American Development Bank, and the International Fund for Agricultural Development (IFAD) and their client countries to harness the benefits of EO in their operations and resources management. The most recent result of this cooperation is the Global Development Assistance (GDA) initiative, the first-ever ESA dedicated programme targeting sustainable development, **which has been established in ESRIN as part of the Sustainable Initiatives Office** and included in a broader initiative called the Space for International Development Assistance (Space4IDA).

The aforementioned programme was built on a long heritage of previous programmes and initiatives, the former Earth Observation for Sustainable Development or EO4SD initiative, which comprised several projects divided by thematic areas, laid the foundation for GDA.

If EO4SD focused on strengthening the alliance between ESA and IFIs by increasing their engagement and supporting them in selecting the more strategic projects

and initiatives, GDA can be considered a step forward, aiming to transfer a more programmatic ownership to the IFIs. The initiative was subscribed by 13 Member States at Space19+ in November 2019, at an initial level of €30 million for the period 2020-2024. **Italy is the third largest subscriber.**

This programme will develop knowledge sharing materials as well as EO data products and services that have not previously been investigated within the context of development assistance, and will also explore new products of interest to national development aid agencies, which may be considered too ambitious for a single aid agency to address acting alone.

Initial sectors to be addressed include: *Disaster Resilience, Urban Sustainability, Climate Resilience, Fragility, Conflict & Security.*

The main aim of this programme is to grow the wide-scale, systematic use of EO satellite as a 'best-practice' source of environmental information, integrated into work practices and finances for all phases and activities of development assistance operations. Therefore, the GDA programme creates powerful synergies between ESA which delivers the technologies and the data, and the IFIs which take advantage of these to improve their efforts along the entire assistance project cycle.

Furthermore, the GDA mission encompasses a larger policy picture which aims to promote the data from Copernicus missions, as well as to display and position the

GDA three main objectives

European and Italian industrial capabilities in the development finance market. In this regard, the GDA programme represents a unique opportunity not only to enhance and display the international cooperation capabilities of the Member States, but also for the Italian and European industries to position themselves in a growing market estimated to be worth close to several hundreds of millions dollars per year.

One of the main differences compared to previous efforts in this context is the goal of stimulating in the long run the uptake of the EO services by the IFIs themselves, without ESA funding. In fact, differently from its precursor initiatives, in which ESA funded all the related projects, the GDA programme is designed as just one component of a larger cooperation framework in which ESA provides the capabilities and focuses on new technical pre-operational developments which target direct needs or requests collected from the IFIs. In this framework, the IFIs mobilize complementary resources to build on this effort with associated capacity building and skills transfer efforts in the developing countries. Part of these resources will be provided through dedicated Trust Funds set up by WB and ADB, financed by Official Development Assistance (ODA) sources. Indeed, a point worth noticing is that the Space4IDA initiative has been accredited by the OECD as ODA compliant and therefore, donors can invest into that initiative and account for it as ODA. The funds will support activities in the domains of Capacity Building (training for the use of EO-based environmental information) and Skills Transfer (training for the production of EO-based information) in developing countries. Integrating development finance and more traditional 'space budget' as provided through ESA, this innovative approach represents an entirely different sourcing setting compared to any other ESA programmes. At the moment the Banks have already programmatically committed more than $50 million to complement GDA services and developments.

The Sustainable Initiatives Office is currently working to expand this programme to include other international development organizations such as the African Development Bank, the International Fund for Agriculture Development and the Inter-American Development Bank.

3.4 The fight against Covid-19 and the Rapid Action Coronavirus Earth observation platform (RACE)

Data from space are pivotal in supporting governments in crisis management in different scenarios. The Copernicus programme, together with ESA Earth observation programmes, is fundamental to tackle these diverse challenges.

At the moment of writing, the 2020 Covid-19 pandemic is still raging across the world, proving one of the greatest challenges humanity has had to face since World War II, both from a health and an economic perspective.

In order to counteract the spread of the virus, ESA and the European Commission have jointly created the Rapid Action Coronavirus Earth observation (or simply RACE) dashboard. The platform was time-record developed in the very early stages of the pandemic thanks to the participation of over 35 European companies and research entities, and by capitalising on the unique potential of ESRIN's Earth observation capabilities.

The platform makes use of Artificial Intelligence data in conjunction with ESA

Earthnet Programme, Copernicus, and Third Party Missions data, to measure not only the impact of the coronavirus lockdown and monitor post-lockdown recovery and reboot, but also allows for the monitoring of key environmental parameters such as air, water pollution and quality changes and the monitoring of socio-economic activities including industry, shipping, construction, traffic, as well as agricultural productivity.

Across all European countries and ESA Member States, the dashboard showcases examples of how Earth observation data can illustrate both socio-economic and environmental changes. In addition, the dashboard shows the role that the EU Space Programme can play for Europe's sustainable and long-term recovery. For example, using the combination of artificial intelligence along with commercial satellite data, it is possible to watch production changes in the volume of cars produced by a specific car manufacturer, or to monitor plane traffic of an airport or the quality of the water in an exact part of the sea.

The fight against COVID-19 includes not only the ESA RACE platform, but also the Trilateral Earth observation data-driven (EOD) dashboard, jointly developed by ESA, NASA and JAXA. The goal of the dashboard is to observe the environmental and socio-economic impacts of COVID-19 from space and to highlight the value of data-driven dashboards to clearly communicate indicators to the general public and decision makers.

4. An in-depth analysis of the Vega Programme

4.1 The Vega launch vehicle

VEGA is a launch system commercialized by Arianespace and developed by ESA. Italy is the leading contributor to ESA's Vega Programme. Preparatory studies on a European small launcher were performed during the 90s in several European countries, capitalizing on previous experience. In the same period, ASI and the Italian space industry not only developed concepts, but also began pre-development work based on their established know-how in solid propulsion. The Vega programme approved as an ESA programme in 1998 was based on the Italian industry experience on solid propulsion and on the European background of Ariane industrial framework. The full development was subscribed by ESA participating states in December 2000, with an Italian share of more than 50%. Vega was the first launcher programme fully under ESA management.

Indeed, Vega introduces key innovation among launcher technologies particularly in the solid-propulsion, materials and avionics fields. Furthermore, Vega offers and improves launch flexibility by providing launch services for a wide range of institutional and commercial missions especially for small payloads. Specifically, the launcher can deliver a reference payload mass of up to about 1,500kg into a Polar Earth orbit of 700km altitude. In operation, with 14 perfect launches in a row, Vega scored a record which was interrupted by the failure of VV15. After that, some corrective actions were put in place and Vega flew again on 2 September 2020 and orbited 53 satellites on the Small Spacecraft Mission Service (SSMS) Proof of Concept flight, performed on behalf of 21 customers. Few months after, an anomaly led to the premature end of the VV17 mission in November 2020. An

independent enquiry commission investigated the causes of the failure providing Avio all recommendations on launch vehicle production and launch preparations: Vega returned to flight in April 2021 with VV18, a flawless mission. Two more Vega flight have been succesfully made in 2021, namely VV19 and VV20, preceding the Vega-C maiden flight planned in Q2 2022.

4.2 The Vega launchers family in brief

Vega is a single-body launcher approximately 30 metres high, with a maximum diameter of 3 metres, and a weight of 139 tonnes at lift-off. It has three main sections, namely the Lower Composite, the Restartable Upper Module and the Payload Composite.

The Lower Composite consists of three solid-propellant stages or solid rocket motors (SRM): the P80, the Z23 (Zefiro23), and Z9 (Zefiro9) plus the four stage-interfacing structures.

The Restartable Upper Module or 4th stage is known as AVUM (Altitude and Vernier Upper Module). The AVUM provides attitude control and axial thrust during the final phases of Vega's flight to allow the correct orientation and orbit injection of multiple payloads.

The **Payload Composite** that accommodates the satellite(s) is composed of the fairing and the payload/launcher interface structure. It is worth mentioning that Vega can deliver multiple payloads into different orbits. The Vega Secondary Payload Adapter (VESPA), housed in the fairing at the top of the rocket, can carry a 1000kg main satellite on top, and either a secondary payload of 600kg in the internal cone, or several auxiliary payloads totalling 600kg distributed on a platform.

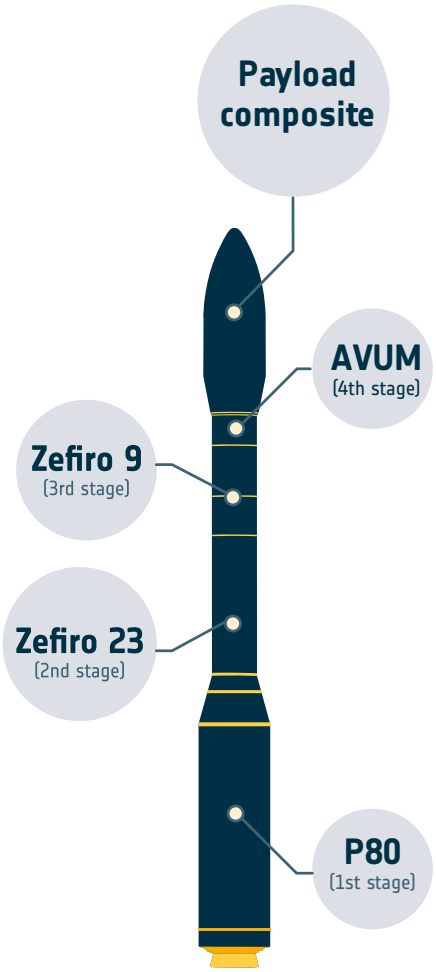
Additionally, SSMS (Small Spacecraft Service Module) expands further the Vega flexbility allowing for very flexible multi-payload configurations for rideshare or piggyback missions for small sat, from mini-sat to cubesat class satellites.

Vega benefits from the existing launch infrastructure of the European Spaceport at Kourou in French Guiana, where Vega's dedicated ground infrastructure comprises the Launch Zone (ZLV: Zone de Lancement Vega) and the Operational Control Centre.

The **first of the twenty Vega flights** designated as VV01 (Volo Vega 01), took place on 13 February 2012 from Kourou in French Guiana. The primary scientific payload was LARES (LAser RElativity Satellite) from ASI. The secondary payload consisted of 7 CubeSats and 1 microsatellite, AlmaSat, of the University of Bologna, Italy.

To allow a smooth transition between development and exploitation (after the maiden flight), the **VERTA (Vega Research and Technology Accompaniment)** programme undertook five flexibility demonstrations flights primarily for ESA missions (ADM- Aeolus, Swarm, LISA Pathfinder, PROBA-3, and the IXV re-entry demonstrator). The VERTA programme had three main components:

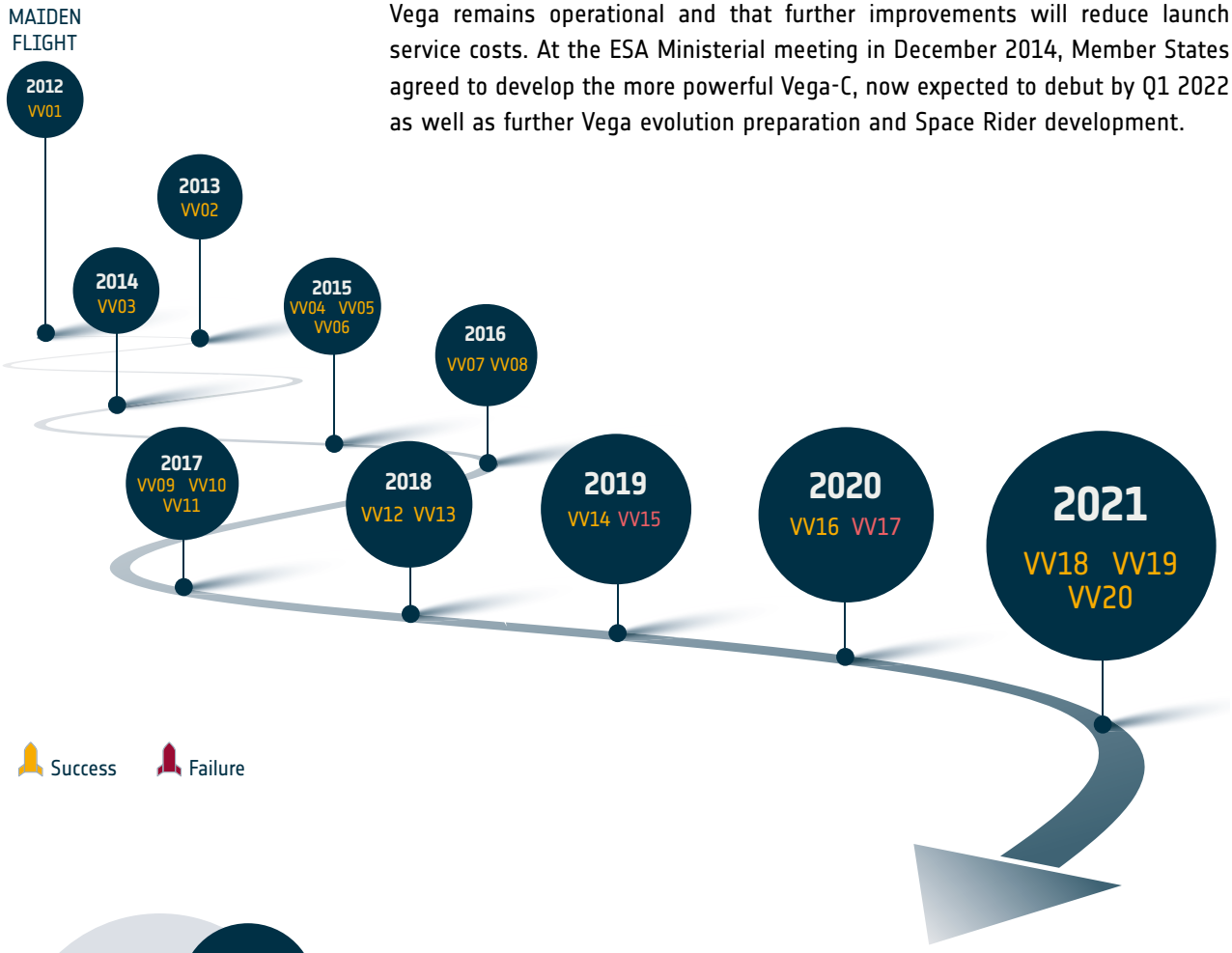
- Procurement of five launches (VERTA demonstration flights)
- Customer Service Improvement activities



- Production accompaniment and technological activities.

The VERTA Programme was successfully completed on 3 December 2015 with the launch of LISA Pathfinder on Vega's sixth flight. Arianespace is now fully responsible for the commercial operation of Vega.

To support Vega's full commercial exploitation, ESA refined and improved the launch system configuration and operations. This lowered costs mainly by speeding up the launch campaign. The Vega launches in 2015 (VV04, VV05 and VV06) displayed the capacity of the system to reach three missions per year. ESA's Launchers Exploitation Accompaniment Programme (LEAP) ensures that Vega remains operational and that further improvements will reduce launch service costs. At the ESA Ministerial meeting in December 2014, Member States agreed to develop the more powerful Vega-C, now expected to debut by Q1 2022 as well as further Vega evolution preparation and Space Rider development.



4.3 The Vega and Space Rider Development

The **Vega and Space Rider Development Programme** is strengthening Vega's competitiveness to expand its success in the available worldwide markets by introducing the Vega-C, developing the Vega-E family of launchers, and a series of spin-off products.

4.3.1 The Vega-C

The new configuration of the Vega launcher is called the Vega-C (Consolidation). Vega-C will increase the performance from Vega's current 1,500kg to about 2,200kg in a reference 700km polar orbit, covering identified European institutional users' mission needs, with no increase in launch service and operating costs. The total length of Vega-C is about 35m with a mass at liftoff of 210 tonnes.

Vega-C is based on the existing Vega launcher and comprises four stages. The first stage is based on the P120C, the largest monolithic carbon fibre solid-propellant rocket motor ever built. Its development relies on new technologies derived from those of P80 Vega's current first stage motor. The second stage is the new Zefiro-40 (Z40) motor. The third stage is the Zefiro-9 currently used on Vega. Finally, the AVUM+ upper stage is derived from the current Vega AVUM but has a lighter structure, carries more propellant inside larger tanks and features several new European-developed components.

In October 2020, all the new solid motors for Vega-C have completed qualification testing. The Zefiro-40 solid rocket motor for Vega-C completed qualification tests in 2019. The final test of the P120C took place successfully on 7 October.

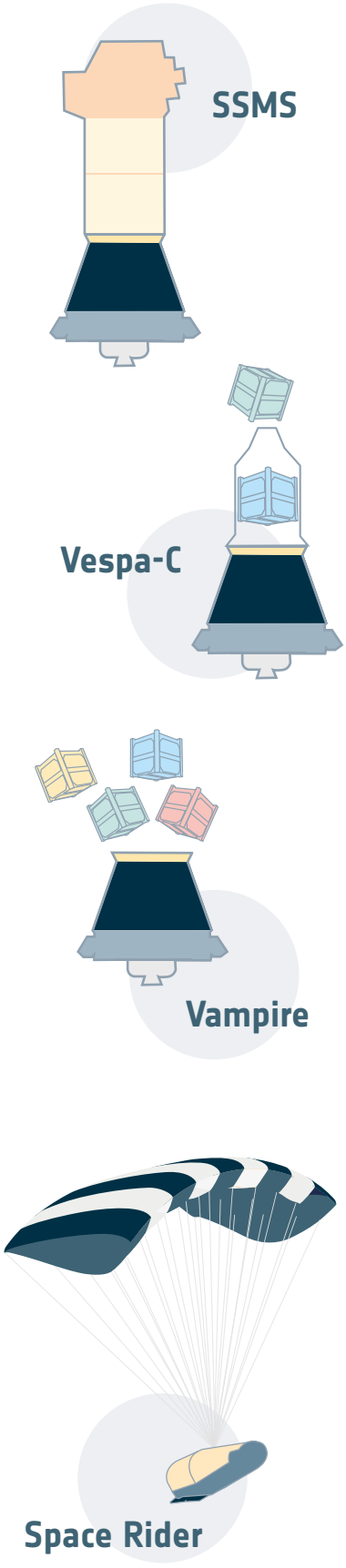
A larger fairing with an increased payload envelope to accommodate larger satellites is also being developed to host Earth Observation satellites of more than two tonnes, and the Space Rider re-entry vehicle. Vega-C's range of adapters makes this a very flexible launch vehicle capable of responding to market needs:

- **Routine dedicated rideshares to space for small satellites**. The Small Spacecraft Mission Service (SSMS) dispenser will allow dedicated rideshares to space. The SSMS can be configured to accommodate any combination of 1 kg CubeSats up to 400 kg mini satellites; from a main large satellite with smaller companions, to multiple small satellites, or dozens of individual CubeSats.
- **Dual passengers**. The Vespa-C payload adapter, used for dual passengers with a mass above 400 kg, takes advantage of the larger volume available in the Vega-C fairing.
- **Single large passenger**. The Vampire will be used for single large payloads with possible combination with the smaller payloads on the SSMS multiple payload dispenser.
- **Return missions**. The Space Rider system will be launched on Vega-C and use the AVUM+ upper stage capabilities to provide in-orbit operations for payload return capability.

ESA is overseeing procurement and the architecture of the overall Vega-C launch system, while industry is building the rocket with Avio as prime contractor and design authority.

The P120C solid rocket motor is co-developed by ArianeGroup and Avio, on behalf of their 50/50 joint venture Europropulsion. France's space agency, CNES, is preparing the Vega-C launch facilities at Europe's Spaceport in French Guiana. Arianespace will be responsible for Vega-C commercial operations from Europe's Spaceport.

The final review step, the Ground Qualification Review, has started in december 2020, and will be finalized before the maiden flight in Q1 2022.



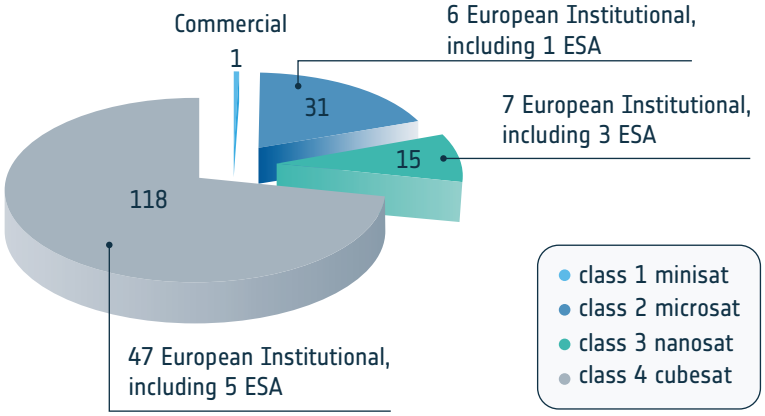
4.3.2 Light satellite, Low-cost Launch opportunity (LLL or L3) and the Small Spacecraft Mission Service (SSMS)

The ESA LLL (Light satellite, Low cost, Launch opportunities) and SSMS (Small Satellite Mission Service) proof of concept flight goal is to demonstrate achievement of the capability to aggregate, prepare, launch and deliver into orbit a set of Light Sats; enabling timely, standardized and guaranteed access to space to the Light Sats Institutional and commercial User community by means of a dedicated and optimized European launch service. The SSMS dispenser with its modular design enables Vega to provide launch opportunities for light satellites with masses ranging from 1kg up to 400kg, with different configurations and relevant combinations under a "rideshare" and piggyback concept.

To prepare for the Vega PoC flight – which took place in September 2020 - the first step jointly performed by ESA and the European Commission, in collaboration with Arianespace, was to issue an Announcement of Opportunity to collect User community feedback on the initiative and probe the Light Sat market status to corroborate the forecasted rise in launch demand on such Spacecraft classes. The following chart shows the outcome of the AO: 70 responses of Notice of Interest corresponding to 101 individual projects and to 165 spacecraft overall were received from the light satellite worldwide community (figure below)

Vega Proof of Concept (PoC) flight

AO outcome: **101 projects** for a total of **165 S/C**



Customers **s/c compatible** (by schedule) with **PoC end 2018**:
33 Institutional and **87** commercial

The SSMS PoC Rideshare mission on Vega VV16 embarked a total of 53 Small S/C:

- 7 Micro and NanoS/C on the top central column, deck#1 (towers) and deck#2 (main deck),
- 46 Cubesats in Deployers located on the hexagonal module.

The sequence of these satellites as well as their main features are summarized in Table 2 (see next page).

The fully-booked VV18 "piggyback mission" successfully performed in April 2021, demonstrated how attractive the SSMS technology is for users and customers.

Table 2. Satellite involved in SSMS PoC Rideshare mission on Vega VV16

Position	Quantity	Customer	Project	Country	Interface	Mass (kg)
Top	1	SPACEFLIGHT	SFL-1	USA	MLB 15"	138
Deck #1	1	SPACE-SI	NEMO-HD	SLO	MLB 11,732"	60
Deck #1	1	ESA (for UPM)	UPMSAT-2	EU	MLB 13"	45
Deck #1	1	SFL	GHGSAT-C1	CAN	4 bolts	33
Deck #2	1	D-ORBIT Srl	IN ORBIT NOW Mk1	ITA	MLB 13"	145
Deck #2	1	SPACEFLIGHT	SFL2	USA	MLB 13"	43
Deck #2	1	ESA/ExactEarth	ESAIL SAT-AIS	EU	MLB 15"	112
Hexa	4 x 12U Deployers	SPACEFLIGHT (14 x Flock 4V for Planet Lab & 12 x Spacebee for Swarm Technologies)	ISIS Quadpack	USA	8 bolts	118
Hexa	2 x 12U Deployers	SPIRE (8 x Lemur-2)	ASTROFEIN PSL-P	USA	16 bolts	60
Hexa	1 x 12U Deployers	ISL (NAPA-1 & TARS)	ISIS Quadpack	NL	8 bolts	30
Hexa	1 x 12U Deployers	SAB LS (TRISAT, DIDO-3, SIMBA, PICASSO)	ISIS Quadpack XL	EU	8 bolts	25
Hexa	1 equi 12U Deployers	D-ORBIT Srl FSSCAT-A & FASSCAT-B)	Stack of two Tyvak DS-6U with bracket	EU	6 bolts	33
Hexa	1 equi 12U Deployers	TYVAK (Tyvak-0171 & OSM-1 CICERO)	Stack of two Tyvak DS-6U with bracket	USA	6 bolts	36
Hexa	2 Deployers	SAB LS TTU100 & AMICal SAT)	ISIS Isipod 1U & ISIS Isipod 2U	EU	4 bolts	15

With the goal of further benefiting the small satellite community, the SSMS configuration for Vega-C launch system has improved capabilities compared to Vega: higher performance (60% more), larger fairing, improved versatility (3 different orbits can be targeted) and a wider spectrum of payload accommodations for any S/C. This will allow even more Small S/C to be embraked at the same time and will always make life easier to any entities that want to take advantage of affordable access to space.

4.3.3 Space Rider

Inheriting technologies from the Intermediate eXperimental Vehicle (IXV) experience, launched on 11 February 2015 on VV04, ESA is developing the Space Rider service, a two minivan sized re-entry module powered in orbit by Vega-C's upper stage AVUM+ aiming to provide Europe with an affordable, independent, reusable end-to-end integrated space transportation system for routine access and return from low-earth orbit. Specifically, the Space Rider enables users to "access to", "operate in" and "return from" low Earth orbits for a wide variety of applications such as (but without being limited to):

- Free Flying applications (e.g. microgravity);
- In Orbit Demonstration and Validation;

- Robotics for IOO/IOS;
- Earth Observation instrumentation;
- Earth Science;
- Telecommunication;
- Technologies for exploration;
- Surveillance applications (e.g. Earth monitoring, satellites inspection);
- Educational missions;
- In-space manufacturing.

The operational missions for Space Rider include a wide spectrum of orbital altitudes and inclinations in low-earth orbit, compatible with the performance of the Vega-C launch system and its future evolutions.

With a cargo bay offering a 1200 litre volume more than 600 Kg of net payloads mass seated on a high-technology platform that supplies power along with thermal, control, data-handling and telemetry capability. The spacecraft will stay in orbit as required by its payloads (for 2 months or more), and then it will perform a ground landing.

At the end of the mission, a final burn of the Space Rider orbital module will send the re-entry module with its user payloads towards the re-entry trajectory for a smooth ride back to Earth with a soft precision landing on the ground. After payload recovery and minimal refurbishment, the Space Rider re-entry module will be ready to take its next set of payloads on its follow-on mission.

Three landing sites are being studied: Kourou in French Guyana, Santa Maria in the Azores archipelago (Portugal) and Grottaglie spaceport in south Italy. Kourou will be the landing site for the maiden flight foreseen by the end of 2023.

The Space Rider programme achieved major success at the **Space19+ ESA Ministerial Council** attracting ten participating States and exceeding funding expectations, enabling ESA to close a successful negotiation with industry leading to the signature of 2 contracts in December 2020: the first one for the delivery of the Space Rider flight model including the re-entry module and the AVUM orbital service module, **by co-prime contractors Thales Alenia Space Italy and Avio and the second contract to cover the delivery of the ground segment by Italian co-prime contractors Telespazio and Altec.**

Phase C of the development activities is about to be completed paving the way for the ground qualification within 2022 which will, then, lead to the inaugural flight on board Vega-C in the second half of 2023. Space Rider will be then operated commercially, complementing Vega and Ariane launch services at Europe's Spaceport and opening the door for capturing new market opportunities.

4.3.4 A focus on the P120 C booster

The P120 C solid propellant motor derives from the first stage of the Vega Launcher P80. Capitalising on the major investments required for building solid-propellant engines, the P120 C (Common) is an engine that can serve both as the first stage of the Vega-C and as the booster of the future Ariane 6.

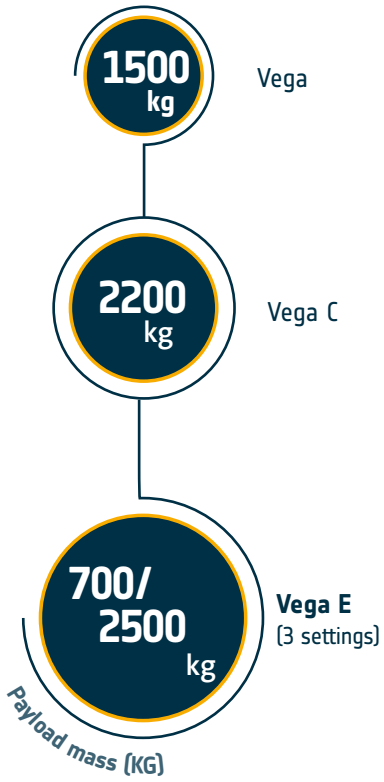
Ariane 6 launcher for GTO payloads will have the maiden flight in 2022 and will replace the Ariane 5 in 2023. The launcher will be equipped with two or four P120C solid rocket motors respectively for Ariane 62 and Ariane 64 configurations. This evolution provides high economies of scale in the field of launcher production, thus growing the competitiveness of European launchers.

4.3.5 The Vega-E

Preparatory activities are under way for Vega's evolution into a family of configurations beyond 2025. A European cryogenic upper stage powered by a 10t-class liquid oxygen and methane expander cycle engine, tested at NASA Marshall Space Flight Centre in March 2020 and to be tested in Q1 2022 in the new Sardinia Propulsion Test Facility (SPTF) in Italy, will replace the current Zefiro-9 and AVUM. The other elements will be based on existing and still developing building blocks (P120C, Z40, VUS). New technologies such as 3D printing are implemented in VUS design and development with the scope to possible ways to reduce the cost of the engine and other subsystems. To reduce the environmental impact, improve the safety of the ground processes and reduce costs, a new "green" roll and altitude control system using hydrogen peroxide will be developed, with potential earlier applications on Vega-C and Space Rider.

The Vega-E family will improve the system's competitiveness for the normal Vega-C payload class in the small–satellite market. In addition, efforts are being aimed at widening the Vega market. These include creating opportunities for small spacecraft mission services and for reaching geostationary orbit and beyond with the use of the flexible VENUS (Vega New Upper Stage) electric propulsion module, while keeping the cost competitive on the world market.

The evolution of Vega payload



4.4 Future evolution and applications of the Vega

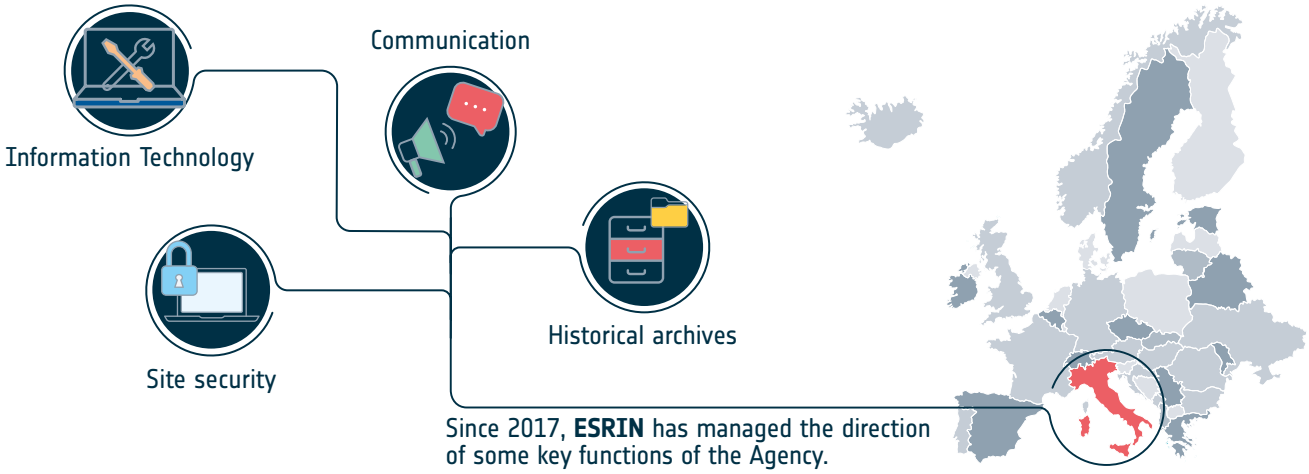
Together with the use of electrical propulsion modules, Vega will enable economically accessible solar system exploration projects to NEOs (Near-Earth Objects), the Moon, Mars and its satellites, Venus, and the moons of Jupiter.

AVIO has also carried out feasibility studies and simulations for In-Orbit Servicing missions. For example, Vega could transport new materials and bring used materials and modules from the International Space Station. It could also be used for SDM (Space Debris Mitigation) activities for the recovery of defunct satellites.

Vega is also an ideal environment for conducting low cost experiments for educational and scientific purposes, and for the qualification of technological systems and components in orbital conditions. In short, the Vega-E family will be even more flexible and versatile, and will further broaden the horizon of potential applications.

5. ESA ESRIN's centralised corporate and operational services and activities

Since 2017, the managerial direction of some key functions of the Agency has been centralized in ESRIN. These are key corporate activities generating benefits for all the 22 ESA Member States and leading the site to become a focal point in the management of these activities.



5.1 ESA Information Technology activities carried out at ESA ESRIN

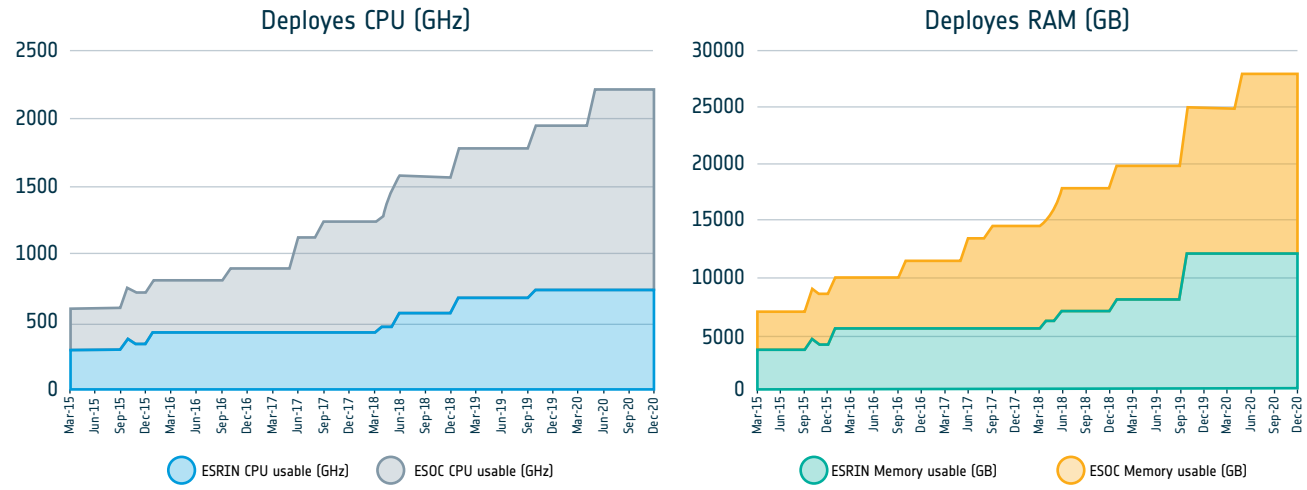
The strategic objectives of ESA's main scientific programmes respond to recent advances in ICT and new digital technologies, combined with a growing demand for science in society. On the opposite side, the fragmentation of resources and proliferation of standards are major threats to several Information Technology (IT) -related fields. In this context, IT services have acquired a key role in boosting innovation in support to the success of ESA, EU and Member States' Digital Agendas and National Space Plans.

Despite the fact that all ESA establishments have corporate and programmatic IT staff, ESRIN leads the entire Agency's corporate IT activities. For this reason, **the Information Technology represents the most staffed department** in ESRIN after the EOP department, handling a budget of approximately €90 million per year. As highlighted before, in recent years there has been a consistent ESA shift towards the more data-driven approach and towards the adoption of shared services provided by the IT department. Moreover, the added value of cooperation among directorate domains, external and IT infrastructure specialists has reinforced the professional IT connective tissue and led to the emergence of new roles for technical IT in multiple domains of expertise.

The IT department operates across three main areas: End user services, Security and Infrastructure, and Application services.

The first area provides the main IT user-driven corporate services to ESA's users such as provision and servicing of laptops, fixed and mobile phones, personal and large videoconference systems, productivity and collaboration application suites and identity and access management tools. These services cover a population of ESA staff and contractors in the range of 7,000 people distributed across more than 12 sites worldwide.

Graph 3. Adoption evolution for general nodes (2015-2020)



In the IT Infrastructure area, ESRIN is home to the main EsaCloud facilities, a private cloud service which provides computing and storage services to all ESA's users. This service has been growing exponentially in the last years (see Graph 3). This part of the IT department also manages all communication, security and computing infrastructures and data centres for corporate use across the establishments of ESA.

ESRIN also houses the cybersecurity emergency response and awareness centre for the whole Agency, the ESACERT. As a matter of fact, the IT department is the main one responsible for implementing the security policies and directives established (and enforced) with Member States by the ESA Security Office. The ESACERT service provides risk and threat assessment, security and cybersecurity reactive and preventive IT security services.

The IT department in ESRIN is also on the forefront of the development and servicing of all corporate applications for Enterprise Resource and Planning (ERP) and is progressively digitalising and automating multiple corporate processes in areas such as human resources management, procurement, finance, facility management, stakeholders management, etc.

The IT department has various contracts with external IT providers from which it draws expertise and resources for its services and projects, many of which have established local support entities close to ESRIN.

The IT Department also provides support for Agency-wide IT related infrastructure and services in accordance with ESA's IT Strategy and with the new Agenda 2025 in support to multi-directorate initiatives and to Agency-wide digitalization projects.

5.2 ESA ESRIN Communications: The Production and Management Support Division

ESRIN hosts one of the 2 Divisions of the ESA Communication Department: The Production and Management Support Division, whose main purpose is to oversee the development and management of all ESA communication channels, including online, video and print publications. It also manages the implementation

of communication partnerships, ESA merchandising and the deployment of the ESA brand and corporate identity. Finally, this Division is also responsible for the coordination of outreach communication activities through the Agency in close collaboration with the respective heads of ESA establishments and ESA Member State space agencies, and for coordinating the deployment of the Department's budget and manpower resources plan.

To achieve its objectives, the Division is supported by four offices:

- **The Digital Media Production Office** responsible for carrying out and coordinating the planning, technical management, implementation, and publishing of ESA's digital media and online channels such as the ESA Web Portal and all its sub channels such as ESA Web TV, Videos and Images Distribution and any ESA web streaming activities, but also the four ESA Social Media channels: You Tube, Instagram, Facebook and Twitter;
- **The Print Media and Merchandising Office** responsible for the production of printed materials for the Communication Department, as well as print services for other ESA departments. This office also manages the production of ESA's merchandising online and its retail outlets, providing design and support for the marketing of ESA merchandise accessible through the ESA Space Shop: **https://www.esaspaceshop.com**;
- **The Branding & Partnership Office** responsible for the implementation of communication partnerships and the deployment of the ESA brand. It acts as a central point of reference for all ESA brand development, its derivatives and its application accessible through the ESA Brand Centre: **https://brand.esa.int**;
- **The Outreach Coordination Office** responsible for the coordination, harmonization and implementation of the outreach communication activities carried out across the various ESA establishments and Member States. It coordinates in particular the ESA Director General Member States Advisory Group on Communication. It also played a key role in the move towards Digital Outreach and the ESA/ASI Digital School Days[3] with more than 15,000 students connected, and the development of the Discover ESA Platform[4] are only two of the numerous examples of this digital transformation.

The results of these important efforts are confirmed by the excellent recognition recorded by the ESA brand, standing out in the second position, after NASA, in terms of most recognised brand involved in space & space exploration activities, in almost all the 5G nations, except for the United Kingdom.

As such with a 50+ members team dispatched all across Europe, the Division located at ESRIN develops all the ESA Communications tools, channel, partnerships, branding and merchandising aspects as well as outreach activities with the aim to give the widest and clearest message as to why Europe must invest in space activities and to ensure that ESA is duly recognised by the Public as the main actor to achieve this goal.

5.3 The European Centre for Space Records and the ESA Archives

The European Centre for Space Records (ECSR) was established at ESRIN in 2002.

[3] *https://www.esa.int/Space_in_Member_States/Italy/ESA_ASI_School_Days_2021*
[4] *https://discover.esa.int*

Its original purpose was to house a large collection of technical archives material originating from ESTEC, but it soon established itself as the main repository for documentation of all ESA establishments.

Currently, the centre is part of the DG-OM office within the Cabinet of the Director General.

DG-OM operates three services:

1. The Records Management, which coordinates with the Directorates to create a framework for a strategic information management in ESA, involving both technical and administrative documentations.
2. The evolution of the newly established official document system ("Blue-docs").
3. The ESA Archives, where the documentation of all the ESA establishments is stored. In these archives 70% of the information regards programmes and 30% concerns the administration, which was once stored in ESA HQ in Paris.

Regarding the ESA archives, the centre is currently taking on a massive venture of transferring a large part of its data and documentation, which accounts for almost 10 km of paper archives, to digital form. Currently, the digital information represents 20% of all the ESA's data.

Most of the non-digital documentation is in paper form, without counting the data stored in obsolete media (e.g. CDs), between 500,000 and 800,000 references, and 300,000 photo negatives.

The archives represent an effort to achieve a complete digitalisation of the Agency, which can be cost efficient, and, at the same time, to create a unique, centralised and protected access point for the ESA's information and data. Therefore, the ESA Archives are the custodian of the Agency's heritage, as well as the main point of user access to trustworthy information directly from ESRIN.

The digitalisation of the archives requires a long-term and complex endeavour. For this reason, DG-OM has contracted out these activities in the so-called "ECSR Digitisation and Operations" contract. **Through this contract, the Agency will progressively open its data archives to the public.** In the meantime, the digitalisation will allow a better internal access to the data also taking advantage of Artificial Intelligence technologies.

Nevertheless, the protection of ESA's heritage and legacy by the centre in ESRIN is also devoted to displaying the technical and scientific historical excellence of the Agency, in Europe and around the world. For this reason, the centre also has a "deposit agreement" with the Historical Archives of the European Union (EUI/HAEU) since 1989 which founded the ESA Historical Archives, whose mission is to provide the academia and the wider public with access to several historical documents of the Agency. In May 2019, ESA with HAEU opened to the public the digitised files of the collections of the precursors of ESA, ESRO and ELDO and also the European Space Conference (ESC) which was the authority creating the ESA Convention. In December 2020, ESA and EUI/HAEU signed a "revised contract" to reinforce the interoperability of the IT systems, the security of the Information and the implementation of the European Regulations related to Personal Data.

From 2018, the ESA Archives in partnership with the ESA "Long Term Data Preservation" Programme decided to digitise three main collections: ERS-1 and

ERS-2 (Earth Observation), SOHO (Science), and Human Space Flight. The result of the digitisation is today in the OMNES (IT System created by an Italian company) system, a data lake system preserving digital files in PDF-A and FITS. The FITS format is considered a fundamental opportunity in terms of virtual storage. Created thanks to cooperation between NASA and ESA in the 1970s, it is the only format capable of ensuring very long-term data preservation. Another important characteristic is the possibility to make the information immediately retrievable without the need for conversion, thus preventing the risk that eventual incompatibility with other future systems may generate a loss of information. Even the Vatican Apostolic Library in 2016 decided to exploit the potential of FITS for preserving, managing and exploiting the Vatican Library heritage, so guaranteeing access to the future generation.

5.4 The Security Office

Security is a top priority in ESA, and should be intended as a wider concept. If this term normally refers to both internal corporate security and security for the space projects, this activity also necessarily encompasses the activities dedicated to ensuring the safety of the European citizens.

The Security Office in ESA, under the Director General authority, deals with the security of the entire European Space system in terms of availability, integrity and confidentiality.

The Security Office grounds its activities on four main pillars:

- **Security Strategy**
- **Security Policy & Standard**
- **Security Accreditation Engineering**
- **Cyber Security**

This crucial role was also confirmed during the last update of the Security Regulation in July 2020, in which the Security Office in ESRIN was identified as the Security Authority and the Cyber Security Authority for the entire Agency. Compared to a few years ago, the Security Office in ESRIN is a well established office and crucial reference point for all the security activities in ESA. The progressive process of centralisation and expansion of the Security activities in ESRIN also entailed a significant increase in terms of personnel employed as staff and contractors since 2018.

The Office periodically updates the Security Strategy for the entire Agency, updating the changing trends and the evolution of the threats for the space activities. In addition, the Office also drafts the policies and regulation for the space and corporate security in ESA. Finally, in conjunction with the relative procurement departments, the Security Office coordinates the procurement of all the services and works related to security.

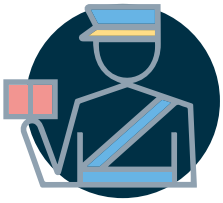
5.5 A need for security

Europe is facing a slew of new, changing, and interconnected dangers from both within and beyond its borders.

- Areas near Europe that are presently facing or are expected to endure climate-driven or induced stresses, such as exposure to endemic and infectious illness

- Areas at danger of political upheaval
- Economic dependency on long supply networks that pass through unstable/under-governed areas
- Growing reliance on physical and digital key infrastructures that can be abused or disrupted for criminal or terrorist objectives
- Organized criminal syndicates engaged in human trafficking, cybercrime, environmental crime, and corruption

Maritime surveillance



Border surveillance

support to EU External Action

Moreover, the evolving geopolitical environment can amplify the impact of many of these threats.

As such, the higher level of capability, accessibility and openness that now characterizes Earth Observation and Earth Sciences in general must be complemented by a higher level of security.

To this extent, ESRIN is actively working to balance the necessary and economically valuable exposure to disruptive innovation and the need to protect more than fifty years of effort and success in pushing forward the technological frontier in space research, and more specifically in the field of Earth Observation.

The security activities managed by ESRIN for all the ESA's member states cover a threefold need:

- The civil security application and the use of Earth Observation data to support services and products and also the demonstration of the use of Earth Observation data in response to users' requirements such as EMSA, or Satellites Centre or NEVI
- The security of infrastructures, sites and cybersecurity
- The safety from natural hazards originating in space covered by the recently inaugurated NEO Coordination Centre (NEOCC).

ESRIN also cooperates with a wide array of stakeholders to guarantee the security of European citizens and of global society by providing the data distributed through the Copernicus Security Service.

5.5.1 Civilian Security

There is strong interest in the development of expanded Earth Observation based capabilities among stakeholders such as the law enforcement community, the civil protection and public health community, as well as critical infrastructure operators.

However, while satellite data collection capabilities currently ensure rapid situation

awareness after an event has occurred, the increasing variety and intensity of risks and threats necessitates going beyond the state-of-the-art in order to develop a better understanding of the underlying processes associated with the evolution of priority threats. In fact, a variety of technological and organizational barriers continue to obstruct successful blending, integration, and interoperability with other information sources.

The Agency, and in particular the Directorate of EO Programmes and the Directorate of Telecommunications and Integrated Applications, are actively working to address these challenges.

To this extent, ESRIN is working to implement a combination of innovative analytics and platform-based environments that integrate both existing space and non-space data, as well as data from small satellites and cutting-edge ground networks (e.g. IoT), to provide enhanced monitoring and analysis capability when integrated within existing systems operated by the target user communities. This will improve routine monitoring, the early discovery of crises, and the planning and execution of appropriate mitigation or reaction activities.

The objective is for space and ground based technologies to progressively become an integral part of the monitoring, analysis and response processes, and consequently to develop an expanded portfolio which will enable a more resilient response to emerging issues affecting the European and international security community. This will also be possible thanks to the emergence of the "NewSpace" sector related capacity evolution which enables small, low cost demonstrator technologies to be developed and put into operations on significantly shorter timescales than was previously possible.

Building on initial consultations with stakeholders already working with ESA, the priority functionalities to be developed within this portfolio of services will include:

- Tactical intervention support
- Crisis response situational awareness including geospatial components, infrastructure status (eg. network situation), citizen situation
- Routine monitoring and anomaly detection
- Extended monitoring of priority processes/threats
- Offline investigation which may be stand alone major investigations or support to routine/extended monitoring activities

5.5.2 Cyber security

ESA has established in ESRIN the cybersecurity authority of the Agency; its strategic allocation is further strengthening the possibility to create virtuous synergies with the Italian Government on cyber security topics.

In this regard, in 2021 the Security Office has launched four procurements in support of cybersecurity activities: a cyber system supporting the design and development of space systems (expected deployment in 2023), a cyber system for space operation (expected deployment in 2025), plus two tools for the development of risk analysis and new technologies devoted to security. The capabilities of these new cybersecurity systems will not only serve the corporate and space needs of the Agency, but they will be also made available to all the contributing Member

States, including Italy. In this regard, **the Security Office is currently working closely with the Italian government to build synergies which will expand the Italian capabilities in the protection of the safety of both the civilian and defence domains**. ESRIN will develop, in the coming years, into an important Cyber HUB in Italy, with potential links to the Italian Cyber External Entities such as the Security Operation Centre (SOC) of the Italian Government for information sharing. The vision for ESRIN is to make the establishment become an holistic ESA security focal point, cooperating with the Italian Cyber excellence, able to work in synergy with other ESA establishment (ESOC and ESEC), and in close contact with security authorities in Germany and Belgium.

5.5.3 ESA Near Earth Objects (NEO) Office based at ESRIN

The **ESA NEO Coordination Centre** (NEOCC) is the operational centre of ESA's Planetary Defence Office (PDO) within the Space Safety Programme (S2P). It is located at ESA's establishment ESRIN. Its aim is to monitor the threat coming from Near-Earth Objects carrying out daily NEO orbit determination and impact monitoring as well as coordinating and contributing to the worldwide observational effort needed to improve the accuracy of their orbits. The results of this activity, together with other relevant data on NEOs is disseminated through the NEOCC web portal.

Near-Earth Objects (NEAs) are small solar system bodies mostly of asteroidal origin of sizes ranging from metres to tens of kilometres that orbit the Sun and whose orbits come close to that of Earth. Of the more than 600,000 known asteroids in our Solar System, more than 20,000 are NEOs.

The NEO monitoring programmes are necessary to constantly increase the knowledge of the NEO population which is still incomplete. To date, thanks to US telescopes, more than 90% of objects with diameters larger than 1 km have been discovered, which represents a sizable increase from 2013 when only 50% were identified. However, this figure drops to only 10% when considering 100 m sized objects. NEOs could potentially hit our planet and, depending on their size, produce considerable damage. While the chance of a large object hitting Earth is very small, it would produce a great deal of destruction.

NEOCC is a knowledge-based system with unique orbit determination and impact monitoring algorithms running at its core. **It is worth noting that there are only two facilities of this kind in the world: one is located at the NASA Jet Propulsion Laboratory in California, and the other is indeed the Near Earth Objects Coordination Centre in Frascati.** NEOCC is the central access point to an entire network of European near-Earth object data sources and information providers. Every day, the coordination centre uses this information, gathered from across the globe, to provide orbital information, impact monitoring, data provision and risk analysis.

The NEOCC has three main activities:

1. **Observation** - the centre keeps monitoring both the known and the newly discovered NEOs; it also contributes to the discovery of new NEOs via its Optical Ground Station in Spain and will soon use its first facility fully dedicated to NEO survey, the Flyeye telescope.

NEAs in Risk List

1,336
objects

Current NEAs

28,230
objects

Current NECs

117
objects

Last update February 2022

2. **Orbit calculation** – this activity is handled by dedicated software which is able to determine the orbit of these objects and to predict their presence in a time range of 100 years, thus, anticipating potential risks for the Earth. This software owes much to NEODyS, the first impact monitoring system entered into operation, originally developed by the University of Pisa and the "Istituto Nazionale di Astrofisica" (the Italian Institute for Astrophysics).
3. **Mitigation** – prevention and mitigation response related to the specific risk. In this regard, the Coordination Centre is also the focus point for studies aiming to improve near-Earth object warning services, needed to give near-real-time data and alerts to European and international customers, including scientific bodies, international organisations and decision-makers. The NEOCC is currently working closely with the International Asteroid Warning Network (IAWN) and the United Nations Office for Outer Space Affairs (UNOOSA) to create a worldwide network for emergency coordination.

In addition, the forthcoming construction of the first NEO Survey Telescope, dubbed 'fly-eye' owing to its multilens design, in Sicily, in Italy, will add to the existing infrastructure capabilities of the centre. Another important step forward has been reached in June 2021 with the new Financial Framework Partnership Agreement (FFPA) signed between ESA and EU. The new programme will strengthen the global leading role of Europe in Earth observation and navigation. The FFPA agreement includes additional components under ESA's responsibility, such as In-Orbit demonstration/Validation service and space safety activities to monitor space hazards. The valuable contribution of the NEOCC has been confirmed during the "G20 Space Economy Leaders Meeting" organized by ASI in Rome in September 2021.

Clearly, in this context ESRIN will play a pivotal role in the coming years.

Table 3 (see next page) summarizes the present knowledge of the impact hazard, including the frequency of occurrence of selected events and their consequences, as well as the references to recorded events.

One of the most important outputs of the NEOCC is the so-called "Risk List", which catalogues the objects with a non-zero impact probability. Each entry contains details on the particular Earth approach which poses the highest risk of impact together with data regarding the date, size, velocity and probability.

Clearly, the science behind NEO intrigues not only scientists but is also able to reach the wider public, due to its potential although negligible level of hazard. This often brings unnecessary attention from the media, generating unjustified alarms. Therefore, the services provided by the centre are open to scientists, journalists and the public at large willing to better understand the NEO threat and get access in real time to reliable, up to date and verified information.

Finally, the NEOCC has two main future objectives: to discover more than 90% of the NEOs larger than 150 metres, and to extend the discovery times for 20-metre objects to at least 72 hours.

At the moment, an important achievement of the centre is the capability to computationally cope with the doubling of the number of detected NEOs every 1-2 years.

Table 3. Impact hazard, frequency of occurrence and selected consequences

Diameter of impactor	Event type	Effect	Energy (MT=Megatons TNT)	Timescale (years)	Examples	Notes
> 1 km	Impact	Global (climate change)	> 1,000,000 MT	> 1,000,000	Chicxulub	Chicxulub is a 170km crater whose formation is thought to have been responsible for the Cretaceous / Tertiary mass extinction (K/T boundary)
150 m	Impact	Local (earthquakes, tsunamis)	100 MT	~10,000	Iso Naakkima Zhamanshin	Craters of the order of 10 km can be considered as limiting cases between local and global consequences.
50 m	Impact	Local (earthquakes, storms)	1 MT	~1,000	Tunguska Meteor Crater	Outcome depends on the impactor composition and dynamics. Tunguska was a large airburst producing no crater, the Meteor Crater was formed by a metallic impactor.
10 m	Impact/ Superbolide	Local (craters, blast waves)	< 1 MT	~10	Kamil Carancas Chelyabinsk	Carancas was a slow high altitude event producing a 12 m crater. Kamil crater (40 m) was originated by a 1 m iron impactor. In the Chelyabinsk event, the meteorid exploded before reaching the ground.
1 m	Bolide	Local (local flash, meteorites)	10 kT	~1	Revelstoke 2008 TC3	The Revelstoke fireball led to the recovery of meteorite grains, 2008 TC3 was the first meteorite fall observed prior to atmospheric entry.
1 cm <	Meteor	Upper atmosphere / near earth environment (shooting stars, spacecraft damages)	Negligible	hourly rates	Perseids, Leonids, Geminids etc.	Sporadic meteors and meteor showers (shooting stars) can be of cometary or asteroidal origin. Since these bodies completely burn in the upper atmosphere, damage is limited to orbiting infrastructures.

(Source: NEOCC 2021)

3 ESA ESRIN's economic benefits for Italy

There is plenty of evidence that the space industry generates ample returns for nations that invest in it. Since 2016, the Space economy has seen investments quadruple with the entry of many new private companies that contain the race towards the space business. In 2020, private investments in space reached 6.7 B € (+30% compared to 2019) of which 7.5% in Europe and public investments amounted to 76.2 B € of which 15% in Europe. These are very important numbers that candidate the space sector to become a reference for the economy of the future. Space Foundation has estimated that in about 10 years the revenues in global space economy have grown by 70%. Also in Europe, in 2020 the Upstream market value reached 7.7 B € (28% of the global one), while the Downstream one reached 65.9 B€ (equal to a quarter of the global market). It should be emphasized that the worldwide public budgets for space investments were not affected by the pandemic event in 2020. All activities related to the space economy benefited in this particular historical period.

The Regulation (EU) 2021/696 of the European Parliament and of the Council of 28 April 2021, establishing the Union Space Program, sets a budget for the space sector for the period 2021-27 of € 14.88 billion (9.0 B€ for Galileo and EGNOS; 5.4 B€ for Copernicus; 0.4 B€ for SSA and GOVSATCOM), more than 30% growth compared to the 2014-20 period. Italy is obviously not excluded from this trend. Through the National Recovery and Resilience Plan (NRRP) and other national budget resources for the period 2022-2026, 1287.5 M € have been allocated to ESA for the assistance to be provided to the Italian National Project concerning Earth Observation (IRIDE Constellation) and Space Transportation. The Italian Government's investments in ESA via ASI are a driving force of this mechanism. Through its close and coordinated link with ESA, ASI allows the latter to flourish. This generates returns for both ESA Member States at large and Italy itself. Indeed, ESA's action cross-fertilizes all countries involved in its governance, and one of ESA's key institutional engines is its Italian-based ESRIN. In fact, as highlighted multiple times in Chapter 2, the role of Earth Observation's activities and services are becoming more and more strategic in the Space Economy. In this context, as the ESA's main centre for Earth Observation, the advantaged position of ESRIN at the core of this chain of value creates far-reaching social-economic benefits for its surrounding territory and for the entire national economy.

In this chapter, we try to define ESRIN's value for Italy according to several methods of analysis.

In section 1 we illustrate ESRIN's economic and strategic value for Italy. Specifically, in the first part of the section we illustrate the Italian return coefficients computed by the Industrial Policy Committee (IPC) by comparing the Italian investment in ESA with the industrial commitments signed by ESA with Italian companies. In the second part of the section, we analyse the Italian industrial returns related to the programmes hosted in ESRIN such as the Earth Observation Programmes, the Vega and related exploitation activities, as well as a focus on its economic, human and infrastructural resources.

In section 2 we provide an overview of ESRIN's economic impact on the Italian economy. In the first part of the section, we illustrate ESRIN's economic impact on a local level in terms of employment and tourism. We examine the economic impact of ESRIN's personnel, and we emphasize the role of the site as a "visitor hub" for the local territory. Specifically, we illustrate how ESRIN generates a consistent impact on the local and regional economy in terms of added value, i.e. additional demand of final goods and services, most of them produced locally.

In the second part of the section we illustrate the main figures related to ESRIN's procurement, focusing on the Italian contractors, stressing the role of ESRIN as an industrial catalyst for space and especially non-space economy.

Finally, in the last part of the section, we present the results of a scenario analysis aimed at disentangling the direct, indirect and induced benefits for Italy generated by each euro invested in ESA. We show how benefits overcome costs for a wide array of private stakeholders and for the public sector.

In section 3 we investigate the scientific and relational value of ESRIN's activities. In the first part, we illustrate ESRIN's scientific value and achievement related to Earth Observation and launchers programmes. We show the constant and exponential increase of this qualitative value, especially following the entry into services of the last generation of Sentinels.

In the second part of the section, we briefly illustrate ESRIN's national context. We focus on the national and international space research centres located in Italy and provide an overview of the Italian space industry. In the third part of the chapter, we illustrate the relational role of ESRIN in the local context, revealing its role in the local research district which is at the heart of a technological revolution. In particular, we summarize the most important agreements with the neighbouring institutions.

1. The economic and strategic value for ESRIN to Italy

At the beginning of the joint European space research collaboration, the European Space Research Organisation (ESRO), there was no specific provision to distribute industrial commitments on a geographical basis. It was Austria that suggested that some attempt should be made to ensure that all Member States had a guaranteed return from the effort. The principle was accepted within ESRO in 1962, but several years of discussion were necessary to clarify its interpretation. Finally, the principle adopted was that the distribution of contracts by value should be proportional to the Member States' contribution to the overall budget, the so-called principle of just return. By the end of 1966, weighting factors distinguishing technically relevant contracts (WF=1) from contracts for lands and buildings, as well as administration and transport equipment (WF=0.25) were introduced in ESRO's industrial policy. No limit to the excess of expenditure over contribution was fixed, in order to retain flexibility in the award of contracts, though it was agreed that as soon as possible no Member State should be more than 100% above its ideal share. In 1967, ESRO's industrial policy was reoriented to ensure that by 1971 each Member State would have achieved a return coefficient of at least 0.7, using the weighting factors for the value of contracts agreed. Whereas until this time the idea had always been to penalise Member States which were performing 'too well', now the aim was to encourage those who were performing badly. Even now, far from having achieved a stable equilibrium, the long running economic debate over the geographical distribution of contracts is of strategic importance for most ESA Member States.

1.1 Analysis of the Italian return coefficients

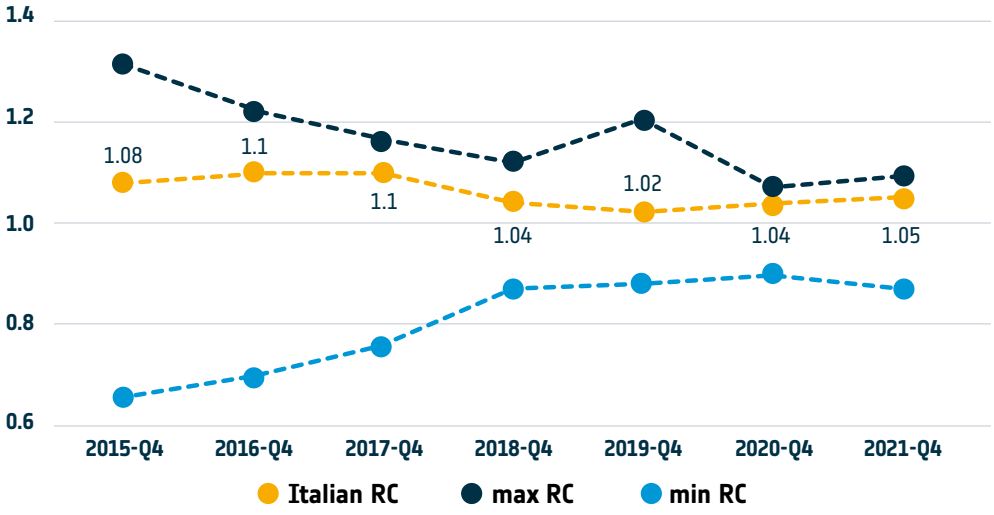
The ESA Industrial Policy Committee (IPC) calculates quarterly the ESA Member States' return coefficients. The return coefficient (RC) is a measure that compares the economic benefits obtained by each Member State in terms of industrial

commitments with the share of its contribution to ESA programmes. The Member State return coefficients are analysed cumulatively, i.e. with respect to the overall industrial commitments and national contribution accounted since the last date in which the time series was "discontinued"[5] (restarted) and calculated only for the contribution of ESA Member States in Mandatory and Optional Programmes. The last update runs to the end of December 2021 and refers to the third cumulative geographical return statistics, which began in 2015. The next formal review of the geographical distribution of contracts is set for the end of 2024, with an interim review by the end of 2022.

The formal reviews verify that the measures used to target a return coefficient of 1[6], and the lower limits for the overall return coefficient, are adequate and effective. For the third statistical period, from 2015 to 2024, the Council decided to adopt the following lower limits[7] for the cumulative return coefficient for all Member States, except for those still benefitting from transitional measures under their Accession Agreements: 0.91 at end-2019; 0.93 at end-2024.

Graph 1 illustrates the evolution of the minimum and maximum return coefficients over a 6-year period (2015 Q4-2021 Q4). The data show that a converging trend started in 2015 stabilizing around 2018 until the last quarter of 2021. Even if Italy is still currently benefiting from a return coefficient greater than 1, the cumulative value will eventually converge to 1 by 2024.

Graph 1. Evolution of minimum and maximum overall return coefficients for ESA Member States (2015–2021)

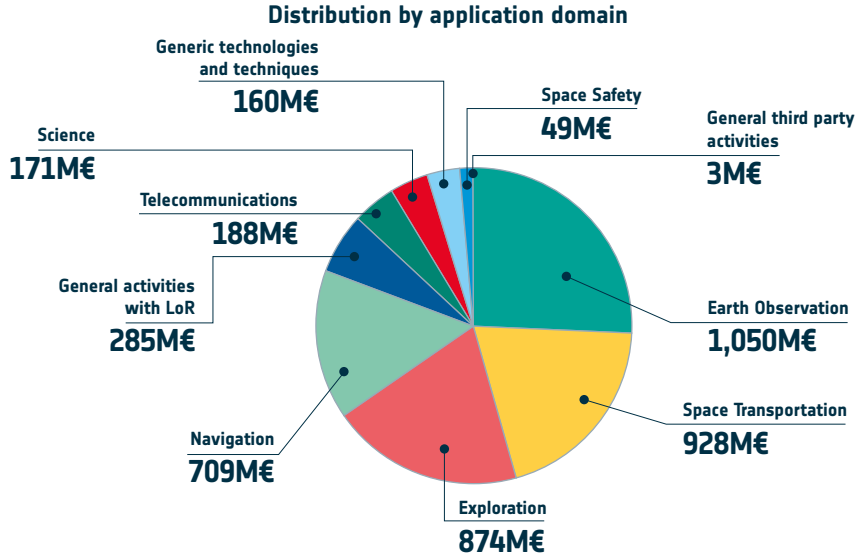


Source: our elaboration on ESA/ IPC (2021)13 data. Data refers to annual intervals

Looking at the period between January and December 2021, ESA committed an unweighted (UW[8]) value of 2,224 M€, distributed mainly in ESA Programmes and Third Party Programmes, with 5% allocated in indirectly attributed contracts. It should be noticed that General Procurement and Purchase orders are not included in the previous amount, accounting for approximately 92 M€.

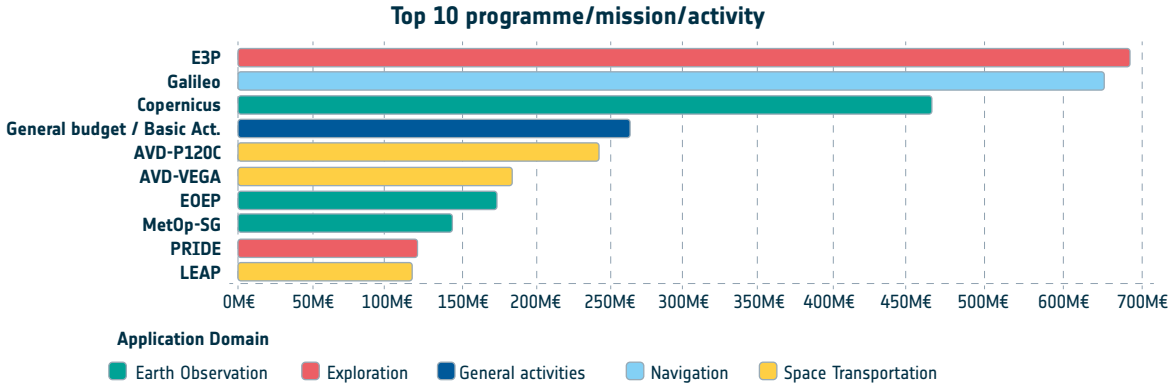
[5] The discontinuation of the return coefficient means the interruption of the time series. Specifically, the new return coefficients are computed on the overall value of contracts measured after the discontinuation date.
[6] For a Participating State, it means that the industrial commitments are equal to the ideal share of contracts that it should receive according to its contribution in ESA.
[7] The minimum amount of industrial commitments with respect to the ideal share of contracts that the Participating State should receive according to its contribution.
[8] UW stands for unweighted value of contracts, that is to say the value before being weighted by using the technological weighting factors established by the IPC and underlined in the ESA Chart of Accounts (ESA/AF (2015)31)

Graph 2. ESA contracts awarded to Italian industry by application domain (2015–2021)



Source: DG Country Report Q4-2021 ESA

Graph 2 provides, differently from ESA/IPC, a new overview of all ESA managed activities in a given timeframe (2015-2021). Indeed, while the Geo-Return computed in ESA/IPC is exclusively based on contracts financed by ESA Member States, the DG Briefing comprises all ESA managed activities, also including programmes not funded by ESA Member States (hence not part of the geo-return), plus all contracts funded by common cost holders not directly linked to a certain programme. The overall value of ESA contracts awarded to Italian industry was 4,417 M€. It was mostly associated with the Earth Observation, followed by Space Transportation and Human and Robotic Exploration. In particular, the programmes and missions that developed the most contracts were Galileo, European Exploration Envelope Programme (E3P) and Copernicus.



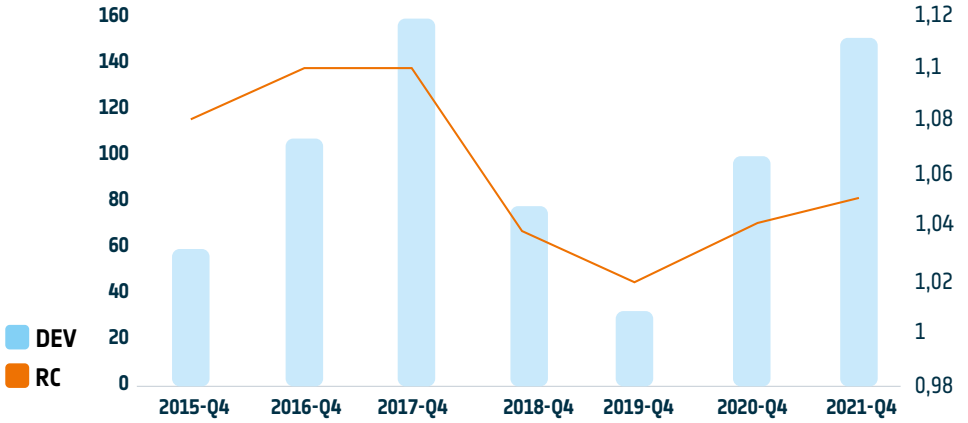
Source: DG Country Report Q4-2021 ESA

By taking into account the boundaries within which return coefficients are calculated and their implications, it is possible to illustrate in more detail the economic value of the Italian returns.

The value of the overall Italian return coefficient is illustrated in Graph 3. Since the discontinuation of the time series in 2014, Italy has been in over-return, and only recently it began to converge to 1. Measured in euro, the Deviation, i.e. the Italian over-return with respect to the ideal share of the weighted value of contracts signed between ESA and Italian contractors, is worth cumulatively €149 million.

As in the case of Italy, if the return coefficient was significantly greater than 1, there are two alternatives to make it converge to:

Graph 3. Italian Deviation (DEV - left scale M€) from the ideal share and Return Coefficient (RC - right scale) (2015–2021)



Source: our elaboration of ESA/IPC (2021)13 data

- increase the denominator: the Participating Country invests more, therefore the scale of contribution rises and the ideal share decreases accordingly;
- reduce the numerator: the value of ESA industrial commitments with contractors of the Participating country in severe over-return decreases.

Although in the years under analysis the Italian Return Coefficient decreased, it remained steadily above 1, showing a slightly but valuable growth with respect of 2019.

A share of value that does not need to decrease is the value of contracts with negligible scientific content signed by Italian companies (DW). DW can be considered as a non-space co-production of the technologically relevant industrial commitments and this figure is by construction excluded by the computation of the return coefficients. As of December 2021, the value of contracts with non scientific content, obtained as the difference, the difference between the unweighted and weighted cumulative value of contracts is worth almost 736 million euro for Italy, therefore about 18% of the unweighted value of the Italian industrial commitments.

Table 1 briefly summarizes the relevant figures needed to assess the unweighted Italian over-return, according to the new Domain structure proposed for the period 2020-2024. Italy benefits from a consistent over-return in Mandatory Programmes[9]. Within the Optional Programmes of interest for ESRIN, Italy has a return coefficient which remains stable around 1 in Earth Observation and a decreasing RC in Space Transportation, which still remains at a value slightly greater than 1. However, there are new segments of investment in which Italy is obtaining significant results, in particular Human and Robotic Exploration and Space Safety, the new basic pillar of ESA's activities, which represent the maximum RC obtained by Italy with a value attested at 1.41.

Furthermore, the Ministerial Council Space 19+ has been characterized by a 30% increase of the budget intended to support the Telecommunications Domain, having as its main objective the development of "fully flexible satellite systems" which

[9] ESA's activities can be divided into two categories, mandatory programmes carried out under the General Budget and the Space Science programme budget, including basic Agency activities such as studies on future projects, technology research, information systems and so on, and optional programmes which cover areas such as Earth observation, telecommunications, satellite navigation and space transportation, including also International Space Station and microgravity research. The former should be financed by each Member State on a specific scale computed according to their Gross National Product (GNP), while the latter programmes can be freely joined, letting each State decide the level of commitment.

can be integrated with 5G networks. In line with this trend, Italy also included this segment in its investments. It is worth noticing how the share of the non-scientific contracts (DW) compared to the overall unweighted amount of the Italian industrial commitments is higher for the Mandatory Programmes (19.6%), while is fluctuating compared to the Optional Programmes hosted at ESRIN, ranging between 5.9% for Telecommunications to 23.1% for Space Transportation. In correspondence of Earth Observation, even if the DW is lower than the overall value, a growing trend for 2017 can be noticed, moving from 8% to 10.2%.

Table 1. The Italian over-return in brief as update in December 2021

	UW (M€)	W (M€)	Deviation (M€)	RC	DW (%)
Overall	4011.8	3275.8	149.0	1.05	18.3%
Mandatory	524.0	421.3	72.8	1.21	19.6%
EO	520.0	466.8	-1.6	1.00	10.2%
Space Transportation	1221.2	939.1	22.7	1.02	23.1%
Human and Robotic Exploration	1419.5	1147.4	77.2	1.07	19.2%
Telecommunications	212.9	200.3	-8.6	0.96	5.9%
Space Safety	50.4	45.0	13.2	1.41	10.8%
Other Programmes and Activities	63.8	55.9	-26.8	0.68	12.3%
Consolidation for programme for Ariane and Vega development	478.9	398.7	-8.7	0.98	16.7%

Source: our elaboration of ESA/IPC (2021)13 data

***UW** | unweighted value of contracts | **W** | weighted value of contracts | **RC** | Return coefficient | **DW** | % of the value of non-scientific contracts compared to the total amount of unweighted value of the contracts.*

The consideration according to which the resources invested by the Italian Government ranked third among the ESA's five largest national contributors is worthy of mention with a total amount that compared to the Ministerial Council of 2016 almost doubled. In particular, looking at the unweighted value of contracts (UW), this increase is reflected in both the mandatory and optional programmes, with the amount of resources dedicated to EO Domain which tripled.

The strategic choice of such expansion seems to be perfectly in line with the European goals to address environmental challenges, recognizing that Copernicus is providing the largest Earth observation satellite data in the world.

While the EOP Directorate is at ESRIN, and consequently the aggregate return coefficient fits the purpose of this research, the aggregate "Space Transportation" refers to several programmes that include Vega, Ariane, FLPP and others, therefore we have analysed the Italian returns for Vega programmes accounted in the period 2015-2021. Furthermore, we have added an analysis of Italian returns for the Space Situational Awareness (SSA) Programmes 1, 2 and 3, as they should include the industrial commitments for NEOCC. Table 2 illustrates the results.

The data show heterogeneous returns from 0.53 to 1.39 in the Launchers programmes, and consistently higher in the Space Safety programme although the latter generates an unweighted amount of industrial commitments equal to almost 36 million euro, against an overall figure for Vega of more than 900 million euro. Also, the share of the non-scientific contracts, DW, exhibits a high degree of heterogeneity among programmes.

Table 2. An in-depth analysis of the Italian return in Transportation and SSA programmes (2015-2021)

	Programme	UW	W	RC	DW (%)
Vega	LEAP (2013-14) - VEGA Classical & MCO	29,387	26,938	1	8.3%
	LEAP (2015-16) - VEGA Classical & MCO	31,951	26,356	1	17.5%
	LEAP (2015-16) - VEGA Supplementary	8,563	2,139	1	75.0%
	LEAP (2017-19) VEGA Classical & MCO	47,411	34,653	1	26.9%
	LEAP (2020-22) - VEGA/VEGA C Transition Accompaniment	19,127	19,099	1	0.1%
	Reusable In-Orbit Demonstrator For Europe	138,948	138,373	0.95	0.4%
	Ariane and Vega Development (Vega Element)	185,981	173,796	1.03	6.6%
	Ariane and Vega Development (P120C element)	236,611	179,802	0.89	24.0%
	Ariane and Vega Development (Launchers Evolution Element)	229	184	0.53	19.7%
	VEGA Consolidation and Evolution Preparation Programme	41,738	40,887	0.97	2.0%
	VEGA Research & Technology Accompaniment Programme	2,544	636	1	75.0%
	VEGA Slice 5	41,195	40,032	1	2.8%
	VEGA Competitiveness Improvements Element	112,874	112,829	1.39	0.0%
	Commercial Space Transportation Services and Support Programme - Element 1	10	2	1	80.0%
	Commercial Space Transportation Services and Support Programme - Element 2	4	1		75.0%
SSA	Space Situational Awareness Programme - Period 3	10,838	8,882	1.06	18.0%
	Space Safety Programme	35,955	33,087	1.52	8.0%

***UW** | unweighted value of contracts | **W** | weighted value of contracts | **RC** | Return coefficient | **DW** | % of the value of non-scientific contracts compared to the total amount of unweighted value of the contracts.*

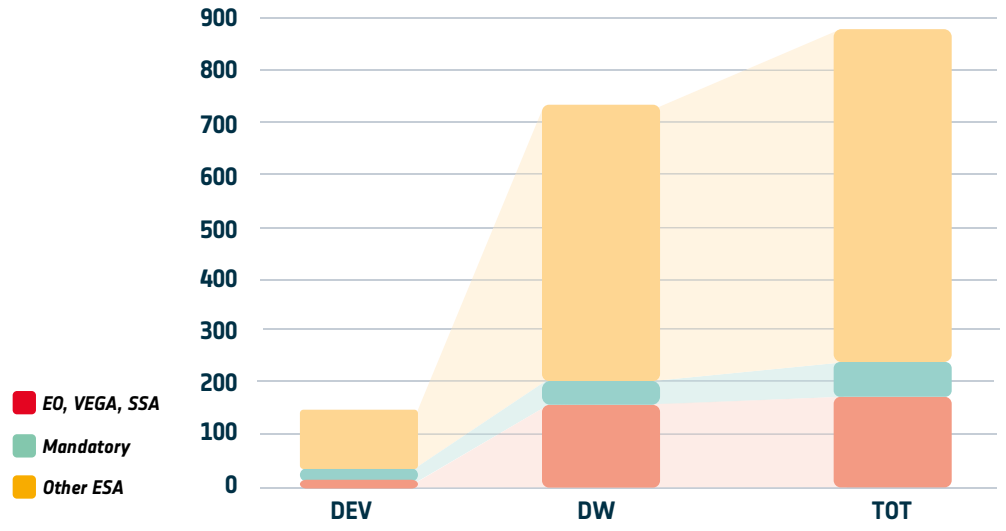
Source: our elaboration of ESA/IPC (2021)13 data

To conclude, Graph 4 provides a measure of the Italian over-return generated by its industrial commitments with ESA with respect to several aggregates of interest:

- Optional Programmes hosted in ESRIN (Vega, EO and NEOCC, approximated to SSA),
- Mandatory Programmes,
- Others ESA programmes.

The amount of the positive deviation (DEV) from the value connected to the ideal share of Italy's scientific commitments (left bar) compared to the total value of scientific contracts "in excess" and the value of non-scientific contracts for Italy (right column, obtained as the sum of DEV and the value of non-scientific contracts, DW) is very relevant when accounting for Mandatory programs and becomes irrelevant when referring to ESRIN (EO, VEGA, SSA) programmes and other ESA programmes.

Graph 4. Italian deviation (DEV) and value of non-scientific contracts (DW) (M€) (2015–2021)



Source: our elaboration of ESA/IPC (2021)13 data

1.2 An in-depth analysis of the Italian industrial returns for EOP and Vega

The Space19+ Ministerial Council and the Italian contribution to EOP

At the occasion of the Council meeting at ministerial level on 27 - 28 November 2019 in Seville, Spain, ("Space19+") a number of optional programmes were submitted for subscription, for a total amount of 14.4 B€, where Italy with 2.28 B€ is the third contributor (15.9%) after Germany (22.9%) and France (18.5%).

Table 3 shows that more than 75% of Italy's Budget established in 2019 for the space sector is concerning programmes in the area of Earth Observation (27.3%), Space Transportation (25.6%) and Exploration (24.7%).

Table 3. Italian Budget according to the Ministerial Council Space19+

Programme	Ammount (M€)	%
Other	22.7	1.3%
EO	490.0	27.3%
Exploration	443.5	24.7%
Space Safety	46.0	2.6%
Telecom	213.0	11.9%
Navigation	15.0	0.8%
Space Transp	459.1	25.6%
Technology	105.0	5.9%
Total	1794.3	100.0%

Source: our elaboration of ESA Ministerial Council Space19+

As illustrated in Table 4, the Italian contribution to the EOP is consistent yet varies according to the selected programme. Compared to the past performance in which Italy had registered, in comparative terms, a subscription lower than the French or German ones and in most programmes also than the UK contribution, Italy subscribed a consistent share at Space 19+, becoming the second largest contributor to EO, after Germany.

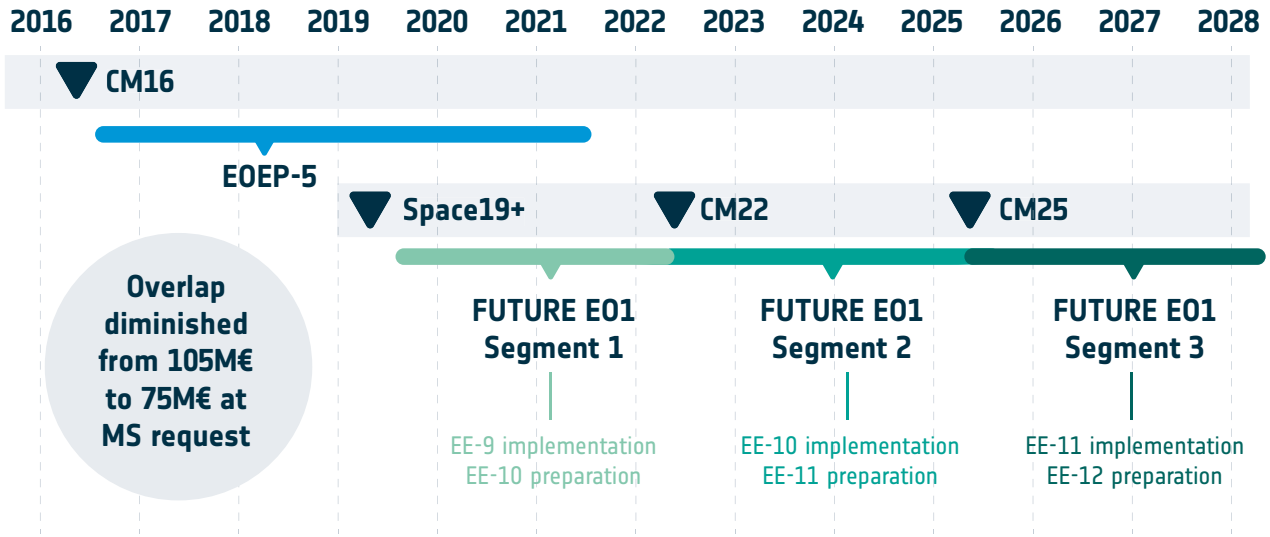
Before providing more details about the measures approved in the Ministerial Council of 2019, we give a brief overview of the other EO programmes discussed in Table 4.

Table 4. The Italian contribution in EO programmes – comparison with France, Germany and UK

Programme	Total subscr. env. (M€)	Economic Conditions	Italy	France	Germany	UK
Future EO	650	2019	15%	7.7%	24%	8%
CSC-4	1402	2019	26.4%	25%	30%	12%
InCubed+	150	2019	10%	/	10%	/
GDA	50	2019	10%	/	20%	4%
ALTIUS	152	2016	/	/	/	/
TRUTHS	32	2019	/	/	/	84%
AWS	42	2019	/	16.7%	17%	/
Proba-V Exploitation	43.4	2012	/	/	/	/
Tot. Subscription in EO	**2478**		**487.6**	**407.6**	**607.44**	**249**

Source: our elaboration of ESA Ministerial Council Space19+

In the Space19+ Ministerial Council EO activities remain the backbone of ESA programmes. Indeed, having a better understanding of our planet means acquiring great potential in terms of inspiring science to address new challenges, supporting European competitiveness towards an innovative growth, but also taking on a formal responsibility in empowering sustainability strategies and practices. Among other programmes, Future EO is leveraging on the strong foundation established by the Earth Observation Envelope Programmes (EOEPs) to improve the results already obtained. The Future EO is divided into 3-year segments, each covering in priority the entire development of a new Explorer mission. The new Future-EO-1 period will cover the 3 segments, with segment-1 tabled for subscription during Space 19+. The graph below shows the synchronization of EO programmes with the Ministerial Council cycle.



Clearly, as ESRIN is ESA's centre for Earth Observation, its role not only within the Agency but also in the entire European space domain will be progressively and steadily empowered in the forthcoming years.

The most important Italian financial subscription in EO is for the Copernicus Space Component-4 (CSC-4), a new segment of existing programmes and Space19+ is the first (2020-2029) of three phases that will follow missions CO2M, CIMR, CHIME, CRISTAL, LST, ROSE-L (see chapter 2). The continuation of the programme previously known as InCubed Private Public Partnership, with the new programme InCubed+ is worth a mention.

In addition, ESA has set up a new Global Development Assistance (GDA) programme. Over the period 2020-2024, GDA will carry out the technical Knowledge Developments useful for new types of environmental information arising from development operational needs. Initial sectors to be addressed include: Climate Resilience, Disaster Resilience, States subject to Fragility, Conflict & Violence, and Urban Sustainability.

1.2.1 Economic, human and infrastructural resources

The EOP budget of the approved programmes increased from roughly 400 million euro in 2007 to 900 million euro in 2014. Since 2014, the EOP budget has increased

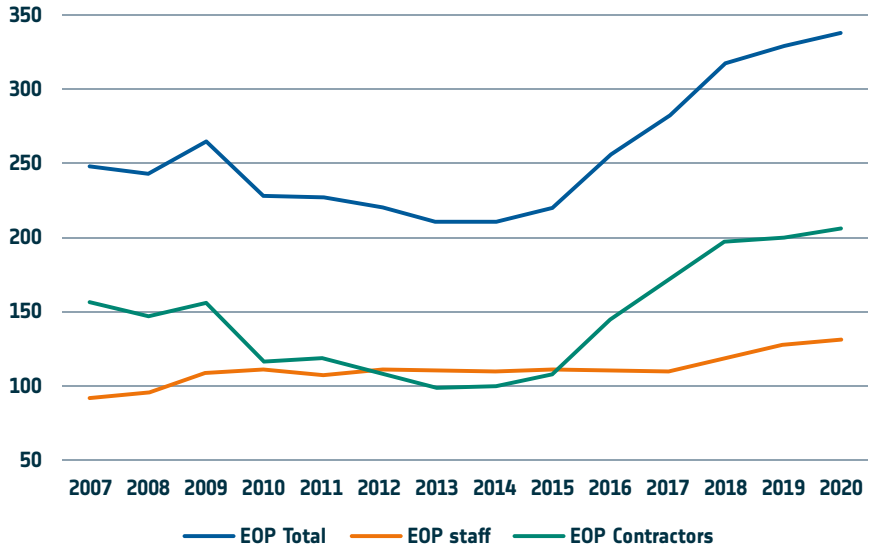
sharply to 1.544 billion euro in 2017, reaching the peak of 2.541 billion euro in 2019, which makes EOP the most important ESA programme in terms of economic relevance.

The share of ESRIN's EOP budget increased from roughly 100 million euro in 2007 to 200 million euro in 2013. Since 2013, ESRIN's EOP budget increased sharply, reaching a peak of 350-400 million euro in 2016, then fell to almost 300 million euro in 2017. The ESRIN's estimated EOP budget (sum of Approved Programmes and Future Programmes) should remain close to 350 million euro until 2020, then, after a dip to around 250 million euro in 2021, it should increase sharply reaching a peak of almost 500 million euro in 2024. Finally, it should decrease again, reaching 450 million euro in 2027.

Since 2007, the percentage of ESRIN staff engaged in the EOP grew from 49% to 55.4% in 2017 to more than 60% in 2020, but a correct assessment should take into account that ESRIN also hosts a significant number of EOP contractors. The overall picture is that from 2007 to 2017, the number of EOP employees at ESRIN (staff plus contractors) increased by 33 units (+13.2%) and from 2017 to 2020 by 57 units (+20.2%) , attesting a strong increase in EO staff.

Specifically, the EOP staff grew by 20 units (+10.4%) following a rapidly increasing trend until 2010, and then remained almost stationary to the level of 111 units until 2017. Finally, from 2018 it grew rapidly to reach 132 units in 2020. Furthermore, in the period 2007-2020 the number of contractors increased by 50 units (+32%).

Graph 5. EOP employees at ESRIN, only staff, only contractors in full time equivalent (2007–2020)

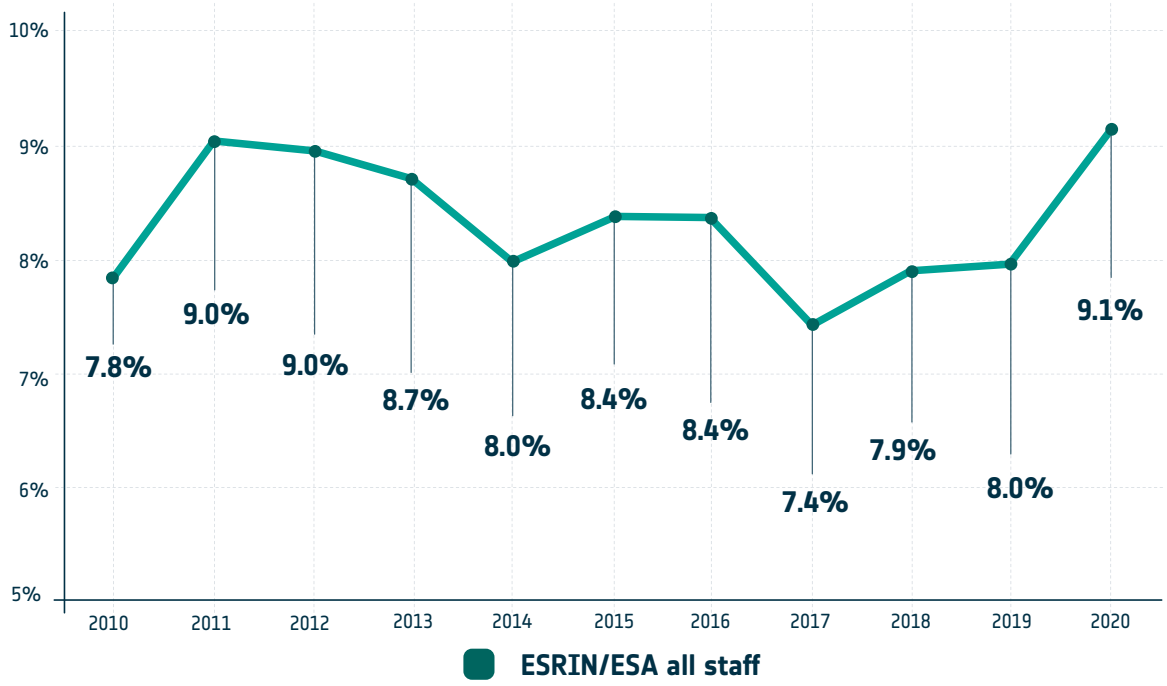


Source: our elaboration of HIF-EP data (2020)

Graph 6 a) illustrates how ESRIN staff (including permanent staff, young graduates in internships, internal research fellows, advanced recruitment) has decreased in proportion to the overall ESA staff from 9% in 2011 to 7.4% in 2017, and then increased to 9.1% in 2020. Looking closely at ESRIN staff, Graph 6 b) is showing the weight of EOP staff in ESRIN, which rose from 49% in 2007 to 60% in 2020, but the ratio representing the number of staff over the number

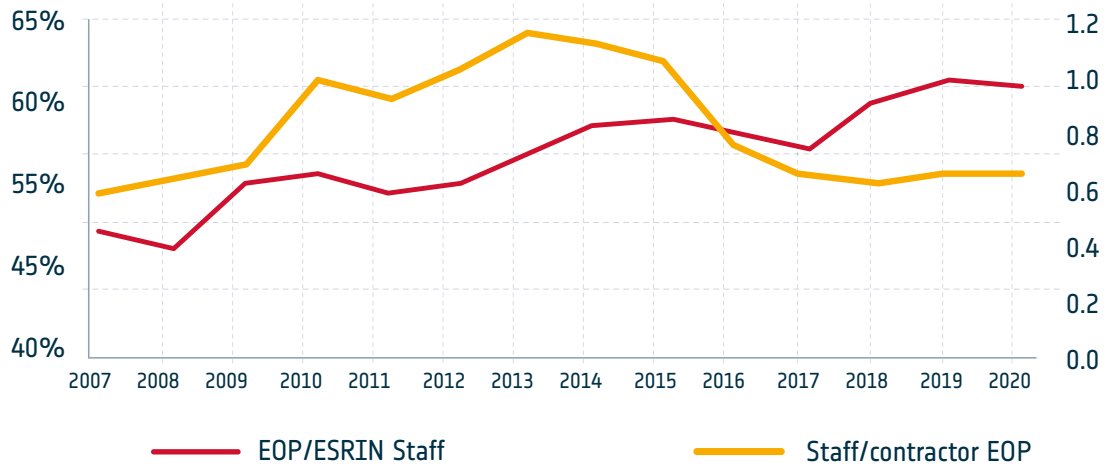
of contractors in EOP grew to 1.12 until 2013 before then decreasing to 0.64 in 2020 (similar level to 2008). This entails that the EOP offices located in ESRIN now have a higher weight in terms of ESA staff, but proportionally employ more contractors than in the past.

Graph 6 a) The relevance of ESRIN staff within ESA staff (2010–2020)



Source: our elaboration of HR-EOP data (2020)

Graph 6 b) The relevance of EOP staff within ESRIN (left scale) and the ratio of staff to contractors within the EOP (f.t.e.) (right scale) (2007–2020)



Source: our elaboration of HR-EOP data (2020)

1.2.2 A focus on Copernicus

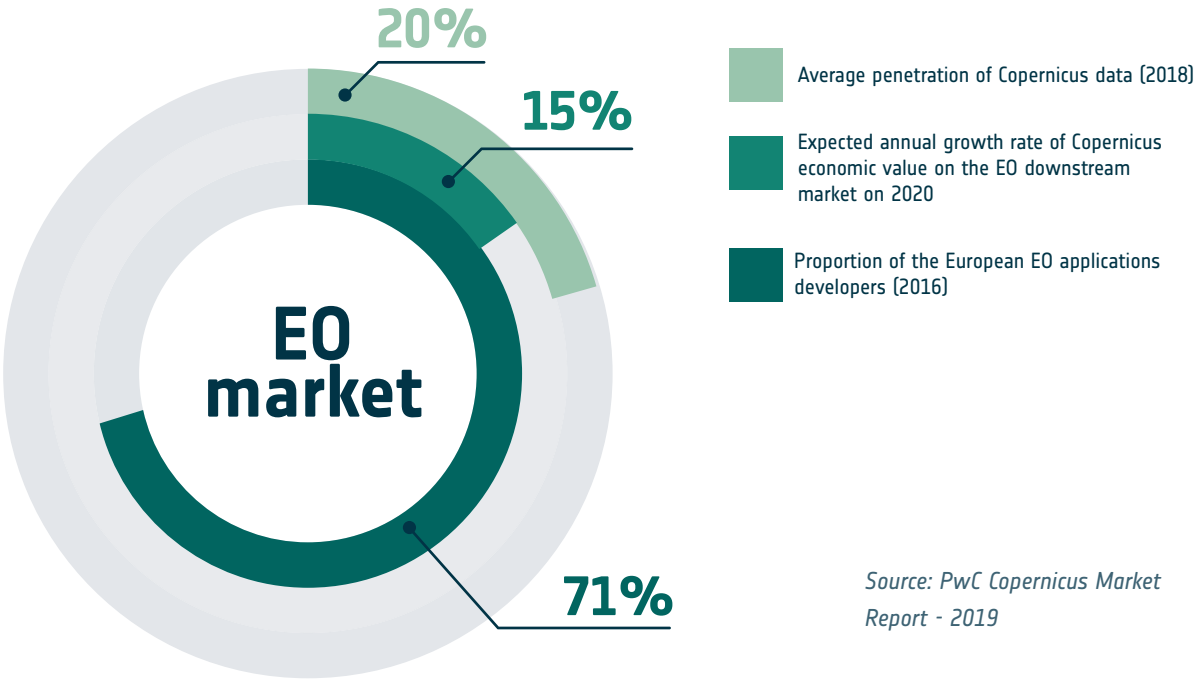
Copernicus is the most ambitious Earth Observation programme as it marks the transition from scientific to operational Earth Observation for the environment and civil security. Copernicus is a model for the future evolution of the EU-ESA relationship as ESA's R&D and space infrastructure expertise can support the fullfilment of EU policy requirements, while, at the same time, allowing the EU to integrate space applications into relevant sectorial policies and allocate the necessary funding.

Copernicus is a crucial programme for ESRIN and for Italy. In fact, almost 98% of the related procurement contracts originated thanks to the ESA's Italian establishment.

Furthermore, Copernicus generates business opportunities across the whole spectrum of the value-added chain (upstream and downstream), and provides platforms and infrastructure for information exchange and informed decision-making. Finally, space activities create benefits that are not always quantifiable with financial indicators, but are tangible in providing better global information about the Earth's state, the threats to its environment and people, which can enhance citizens' safety and quality of life (Aschbacher, 2017).

Since the beginning of its operational phase, Copernicus data have shown consistent diffusion across the EO market, as illustrated in Graph 7, and are now used by the majority of the EO application developers in the EU. The widespread diffusion of Copernicus data will increase its economic value of the programme at an annual rate of more than 15%.

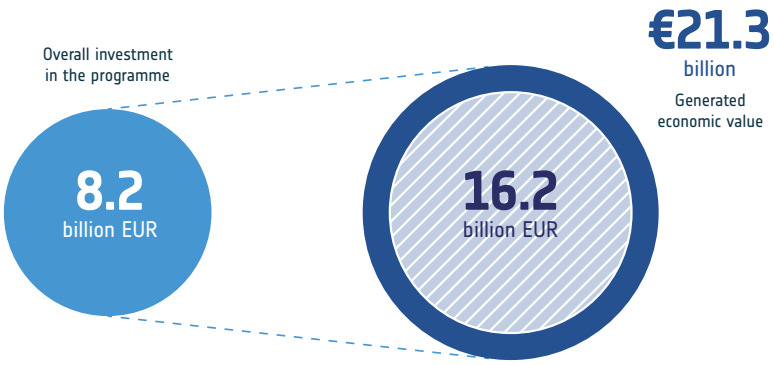
Graph 7. Copernicus data widespread diffusion in the EO Market



Source: PwC Copernicus Market Report - 2019

As illustrated in Graph 8, from an overall investment of 8.2 billion euro between 2008 and 2020, the overall value generated by the programme in Europe is estimated at 16.2- 21.3 billion euro.

Graph 8. Copernicus overall investment and economic value generated (2008–2020)



Source: PwC Copernicus Market Report - 2019

As of 2021, the EU and ESA jointly committed 6.8 billion euro to Copernicus for the period 2021-2027. Spending into the Copernicus programme generates a cascade effect with a Gross Value Added (GVA) producing benefits for both the space sector activities, with a percentage valued up to 60% and for the non space sector industry approximately 40%. The GDP multiplier ratio for the Copernicus programme in the upstream industry has been estimated at 1.4, meaning that "for €1 spent in public funds in Copernicus upstream activities, the GVA in the economy is €1.4 (*without including the impact from exploitation*)". Whereas, for the downstream industry, the expected benefits in 2018 were between 125 and 150 million euro, with a growth of 15% in 2020.

Table 5 focuses on the industrial procurement of the main Copernicus programmes, and lists the major Prime Contractors (sorted in descending order based on the value of the contracts), the overall value of the contracts signed with ESA from 2017 to March 2021. It is worth noting the economic relevance of the contracts signed by Thales Alenia Space Italy and Leonardo in procurement activities related to CSC-4 and EOEP programmes.

Table 5. Copernicus programme: main contractors and contracts value (2017–2021)

Copernicus programme	Major Prime Contractors
CSC-4	TAS (IT)
	OHB ITALIA S.P.A.
	LEONARDO Spa
	SITAEL
EOEP	LEONARDO Spa
	SERCO SPA
	TAS (IT)
	RHEA SYSTEM S.P.A.
	OHB ITALIA S.P.A.
	GTT ITALY
	ARESYS
	CNR
	ADS (IT)
	EXPRIVIA S.P.A.
OTHERS	LEONARDO Spa
	TYVAK INTERNATIONAL SRL
	TAS (IT)
Contract Value (€)	**200,923,526**

Source: our elaboration of EROS data for commitments placed with Industry, which are registered with IT nationality in Esa-Star

1.2.3 An in-depth analysis of Vega

Vega is the first launch system development programme where ESA has full technical and managerial responsibility. In 2000, the management of the Vega Small Launcher Development Programme was established in ESRIN. It is supported by an Integrated Project Team (IPT) including, besides ESA staff, staff from ASI and CNES and by several contractors. The Vega IPT has consistently improved ESA competences and knowledge in ESRIN in the areas of system engineering, solid propulsion, guidance navigation and control, safety and, in general, launch system development and exploitation engineering.

Vega's industrial organization is a forerunner of the future organization for European launchers development. It is based on having a Prime Contractor for each project: ELV (Italy) for the Launch Vehicle, Avio (Italy) which delegates to Europropulsion (Italy and France) for the P80, and Vitrociset (Italy) for the Ground Segment. Italy's involvement in Vega's development and exploitation programmes is exemplified by the consistent national long-term investments in almost all programmes related to the launchers. It has fostered the participation of several Italian industries and universities in various design and implementation activities.

During Space19+, i.e. the Council meeting at ministerial level on November 2019, Italy subscribed about 250 M€ for Vega programmes. Table 6 illustrates the overall investment for each Vega programme from 2015 to 2021, the Italian contribution and the Italian return coefficient (RC).

Table 6. Italy's participation and returns in Vega development according to IPC 2021 (2015–2021)

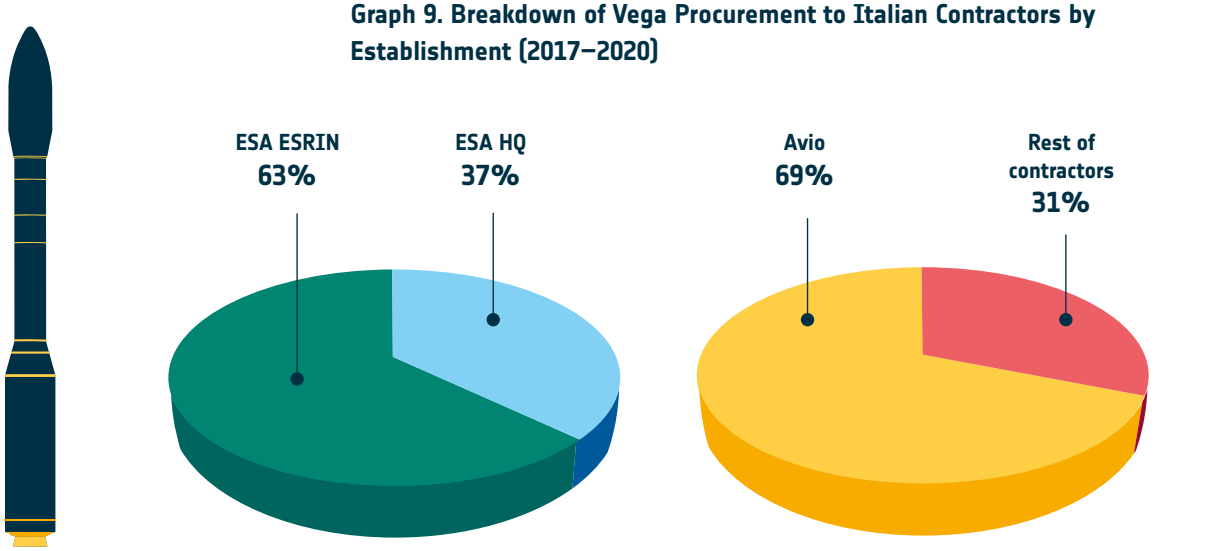
	Overall investment (K€)		Italian investment (K€)			
Vega Programmes	UW	W	UW	W	Italian investment (%)	Italian RC
LEAP (2013-14) - VEGA Classical & MCO	49,838	44,786	29,387	26,938	59.0%	1
LEAP (2015-16) - VEGA Classical & MCO	57,711	50,057	31,951	26,356	55.4%	1
LEAP (2015-16) - VEGA Supplementary	19,067	4,748	8,563	2,139	44.9%	1
LEAP (2017-19) VEGA Classical & MCO	74,397	58,059	47,411	34,653	63.7%	1
LEAP (2020-22) - VEGA/VEGA C Transition Accompaniment	33,509	32,552	19,127	19,099	57.1%	1
Reusable In-Orbit Demonstrator For Europe	198,418	196,300	138,948	138,373	70.0%	0.95
Ariane and Vega Development (VEGA Element)	344,093	319,776	185,981	173,796	54.0%	1.03
Ariane and VEGA Development (P120C Element)	573,757	468,976	236,611	179,802	41.2%	0.89
Ariane and VEGA Development (Launchers Evolution Element)	4,088	3,962	229	184	5.6%	0.53
VEGA Consolidation and Evolution Preparation Programme	72,971	70,848	41,738	40,887	57.2%	0.97
VEGA Research & Technology Accompaniment Programme	6,525	1,632	2,544	636	39.0%	1
VEGA Slice 5	44,933	43,604	41,195	40,032	91.7%	1
VEGA Competitiveness Improvements Element	159,110	158,447	112,874	112,829	70.9%	1.39
Commercial Space Transportation Services and Support Programme - Element 1	27,597	27,563	10	2	0.0%	1
Commercial Space Transportation Services and Support Programme - Element 2	42	10	4	1	9.5%	1

Source: our elaboration of ESA/IPC (2021)13 data

A significant heterogeneity emerges across the programmes for almost any variable considered. The most relevant programmes in terms of overall investment are the P120C Element Programme with 573.8 million euro of investment and the Vega element with 344 million euro. In most Vega developments, Italy contributed to more than 50% of the total investment. Significant exceptions are the Launchers Evolution Element, to which Italy contributed for no more than 5.6%. At the other end of the scale, the Vega Slice 5, to which the Italian contribution is attested at 91.7% of the total investment.

Italy is the major sponsor and developer of the Vega programmes 2020-23, with a share of 58%.

Graph 9. Breakdown of Vega Procurement to Italian Contractors by Establishment (2017–2020)



Source: our elaboration of EROS data for commitments placed with Industry, which are registered with IT nationality in Esa-Star

In the past Vega programmes, the Italian companies were awarded around 360 M€, contracted solely by ESRIN and ESA HQ, as showed in the pie chart on the left. The HQ's procurement is concentrated in the consolidated "Programme for Ariane and Vega Development", and in particular, for the P120C element.

The Italian supply side of the Vega Programme is very concentrated in the hand of a single contractor, Avio, which is the main Prime Contractor for the Vega programme.

2. The direct, indirect and induced economic impact of ESA ESRIN on Italy

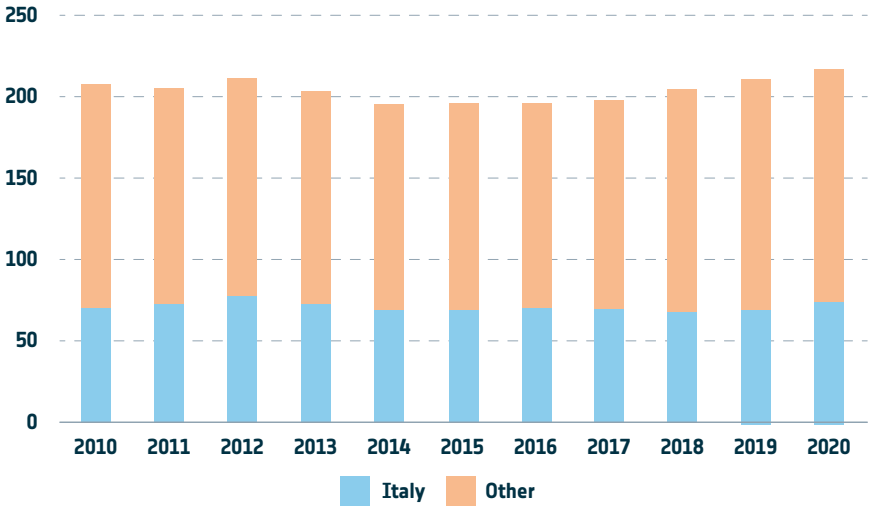
2.1 ESA ESRIN's direct impact in terms of employment and tourism

Employment and salaries

ESRIN's workforce of 858 people in 2020 (in full time equivalent) is composed of 218 ESA employees, 616 contractors and 24 internal research fellows and young internship graduates. The percentage of women is about 41% (see Chapter 1 for more details). Graph 10 shows the trend of ESRIN's staff between Italians and foreigners up to 2020, showing that the share of the Italian staff in ESRIN has remained stable over time around 33%. The salary cost of ESRIN's ESA staff increased in the last decade, reaching a peak of more than 39 million euro in 2020. Of this, slightly more than 13 million euro was earned by Italian employees. On average every ESA staff member earns an annual salary of around 92,000 euro.

Compared to the average wage in Italy, this value might seem high but ESRIN ESA staff are mostly high skilled and, compared to other ESA establishments, ESRIN's location demands a high cost of living for international staff. This is due to the absence of services such as international schools, the need to buy a car, inflated house prices and rents. This average wage amount has obvious benefits for the local economy since it translates into money being spent on goods and services from the nearby locality.

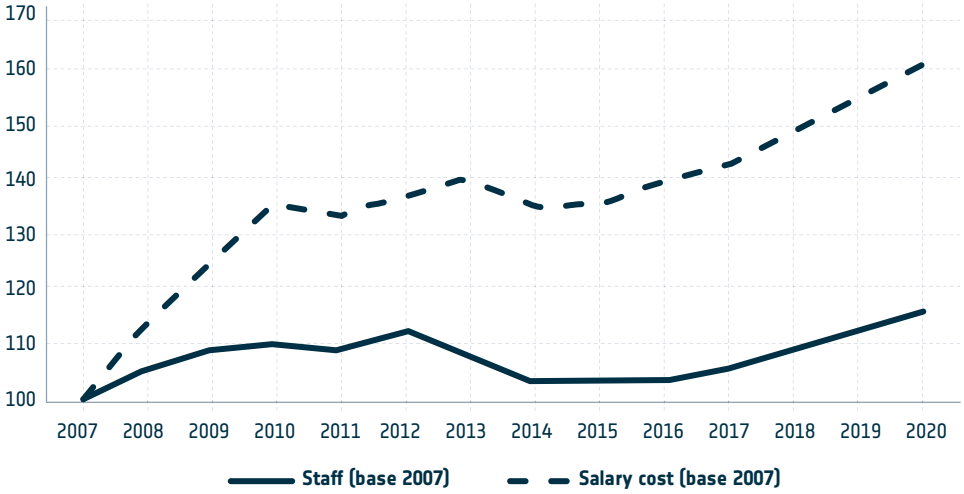
Graph 10. Trend of the Italian share of ESRIN Staff (f.t.e.) (2010–2020)



Source: source: our elaboration of HIF-EP data (2020)

Graph 11 shows the index numbers series for ESRIN staff and the salary cost (with fixed base=2007); as can be seen, while staff growth remains fairly constant until 2013 at an average annual growth rate of around 1.3%, from 2014 to 2017, the rate seems to have suffered a setback, remaining on average close to 0%. However, from 2018 it resumes its positive growth trend, recording a sharp increase of 3.3% on average. Moving to the salary cost, the significant growth registered until 2014, at an average of 5.8%, stops from 2014 until 2017 which is justified by the absence of new staff employed. With the expansion in the number of staff in 2018, the salary cost also started to grow, as can be reasonably expected, however at an average of 3.7%.

Graph 11. Index number series for Number and Salary cost of ESRIN Staff (base=2007)



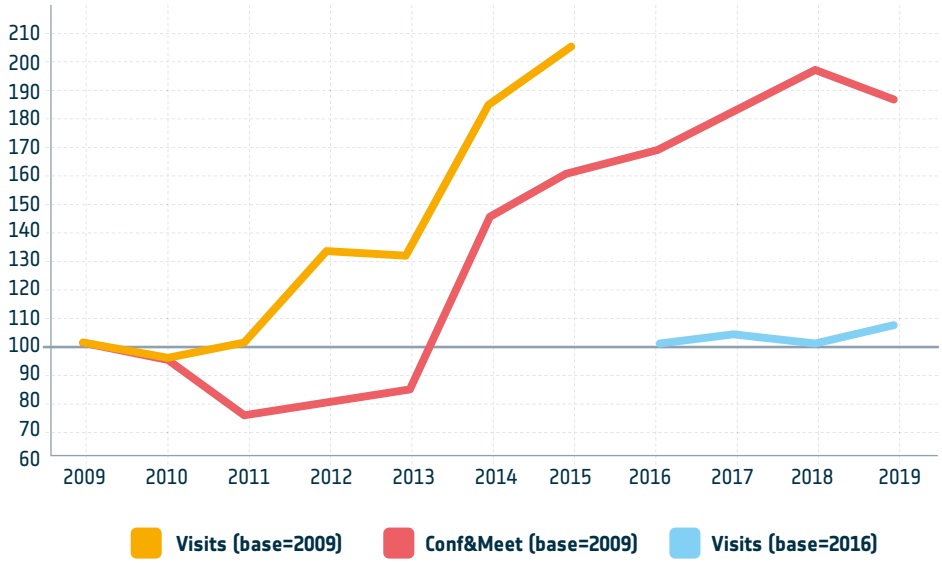
Source: our elaboration of HIF-EP data (2020)

Visitors and impact on the local economy

ESRIN hosts numerous scientific conferences, meetings with industry and events during the year that attract thousands of visitors. Some of them spend one or more days in the neighbourhood, generating a consistent demand for touristic activities, local goods and services.

Even if business tourism is clearly outside the core business of ESRIN, it is still worth noting this positive pecuniary side effect of the establishment's location for Italy. As illustrated in Graph 12, the number of visits to ESRIN grew exponentially from 2009 to 2016 at an average annual rate of 12.7%[10]. In 2020, the number of visits reached 50,000, a significant achievement considering the pandemic crisis and the related restrictions. The desire to continue to involve an ever increasing number of visitors must, however, be supported by the creation of adequately designed spaces; in this sense the recent acquisition of the land adjacent to ESRIN could represent a concrete opportunity of growth. Similarly, the number of conferences and meetings also grew from 2009 to 2020 at an average annual rate of 6.4%. Such figures confirm ESRIN's primary position among ESA establishments in terms of number of visits.

Graph 12. Index number series for Number of visits and Number of Conferences & Meetings



Source: our elaboration of HIF-EP data (2019)

In qualitative terms, ESRIN attracts a heterogeneous visiting public: decision makers, VIPs, ESA personnel working in other ESA establishments, businessmen participating in industrial meetings, researchers and scientists, students, etc. However, each group has a different budget to cover the expenses related to the journey and to the accommodation.

The assessment of ESRIN's impact on local tourism deserves an accurate analysis, which is beyond the scope of this report. In the following box we estimate its order of magnitude by referring to publicly available data and some (approximate) assumptions.

[10] *It is worthy specifying that from 2016 the "business partners" category is no longer included in the visits computation, meaning that the growth from 2016 is, in proportion, even higher than the one resulting in the graph*

BOX1. An estimate of ESRIN's annual impact on local tourism in 2019

The assessment is based on ESRIN facility management data, and it refers to an overall annual number of 49,000 visits on site.

Family, friends and local business/research

A consistent number of visits involve ESRIN employees' family members and friends, but also business and research related activities with the neighbouring institutions (ASI, INAF, INFN, ENEA, the Universities of Rome, the Tor Vergata Polyclinic, the Tiburtino High tech district, Avio...).

According to the available statistics 2,500 personal visits (5.1% of the total) and 9,000 local visits (18.4% of the total) were recorded, and we assign a budget of 15 euro for each visitor (10 euro for one meal at the ESRIN canteen plus 5 euro for the train/bus ticket), obtaining a total expenditure of 172,500 euro in the local economy.

Educational visits

In 2019, almost 2,500 educational visits (5.1% of the total) were registered on site, including those related to the Open Days and Researchers nights.

According to the available data for 2019, almost 25% of those visits involved local residents, 25% involved students living in the Lazio Region, and the remaining part was accounted for by Italian students from other Regions. We estimate a daily expenditure (including travelling expenses) of 20 euro for local residents, 50 euro for students living in the Lazio Region, and of 132 euro for the Italian students outside the Lazio Region (including dinner, accommodation and travel). We therefore obtain an overall expenditure of 126,250 euro in the local economy.

Business and research visitors

The remaining 71.4% of the visits registered during the year are for business or for research purposes. This category was distinguished into three groups of visitors according to their provenance, 45% from Italy, 40% from UE, and 15% from extra-UE. As every visitor can stay one or more days in ESRIN, the number of visits exceeds the number of visitors. Moreover, reasonably we assume a higher chance that visitors coming from UE and extra-UE will spend at least two or three nights. Table B1 briefly summarizes our estimates, where an overall expenditure of 4,952,500 euro in the local economy emerges.

Table B1. Estimate of Visitors and Missions expenditure

Type of Visits	Visits	Visitors	TA(€)	TLT(€)	TnLT(€)	Impact Italy(€)
Family members	2,500	2,500	25,000	12,500		37,500
Educational	2,500	1,875	51,250	75,000		126,250
Local B&R	9,000	9,000	90,000	45,000		135,000
B&R from Italy	15,750	15,750	984,375	511,875	1,771,875	3,268,125
B&R from EU	14,000	8,000	860,000	260,000	2,500,000	1,120,000
B&R from Extra-EU	5,250	2,625	387,188	177,188	1,706,250	564,375
Total	49,000	39,750	2,397,813	1,081,563	5,978,125	5,251,250
Type of Missions	**number**	**nights**	**TA(€)**	**TLT (€)**	**TnLT(€)**	**Impact Italy(€)**
Inbound	4,000	7,000	480,000	400,000	2,000,000	880,000
Outbound Italy	2,500	4,375	300,000	250,000	750,000	1,300,000
Outbound extra-Italy	3,500	6,125	402,500	350,000	1,400,000	1,750,000
Total	10,000	17,500	1,182,500	1,000,000	4,150,000	3,930,000
Total Impact						**9,181,250**

Source: our estimate (2019)

***TA** | Total Allowance | **TLT** | Total Local Transport | **TnLT** | Total non Local Transport. In orange, the expenses that impact on the Italian economy*

ESA missions

Finally, ESRIN is the destination but also the place where numerous ESA missions towards Italy and the rest of the world are scheduled. Therefore, even for the estimation concerning the missions, distinguishing between the current ESA inbound missions of approximately 4,000 and the ESA outbound missions of roughly 6,000 becomes crucial.

For each mission the number of nights spent in the local region may vary; reasonably 50% of people involved in the missions will spend at least one night, 25% two nights, and another 25% three nights. At this point, we estimate a business allowance for travel and daily expenditure differently according to the type of mission (in ESRIN, from ESRIN to Italy, from ESRIN to the rest of the world), taking into account that the total non local transport (TnLT) for inbound missions (2,000,000 euro) cannot be included, whereas for Outbound extra-Italy missions only half of TnLT can be allocated in favour of Italian companies, accounting for a final value of 1,400,000 euro.

Therefore, we obtain a total annual impact of 3,930,000 euro in the local economy.

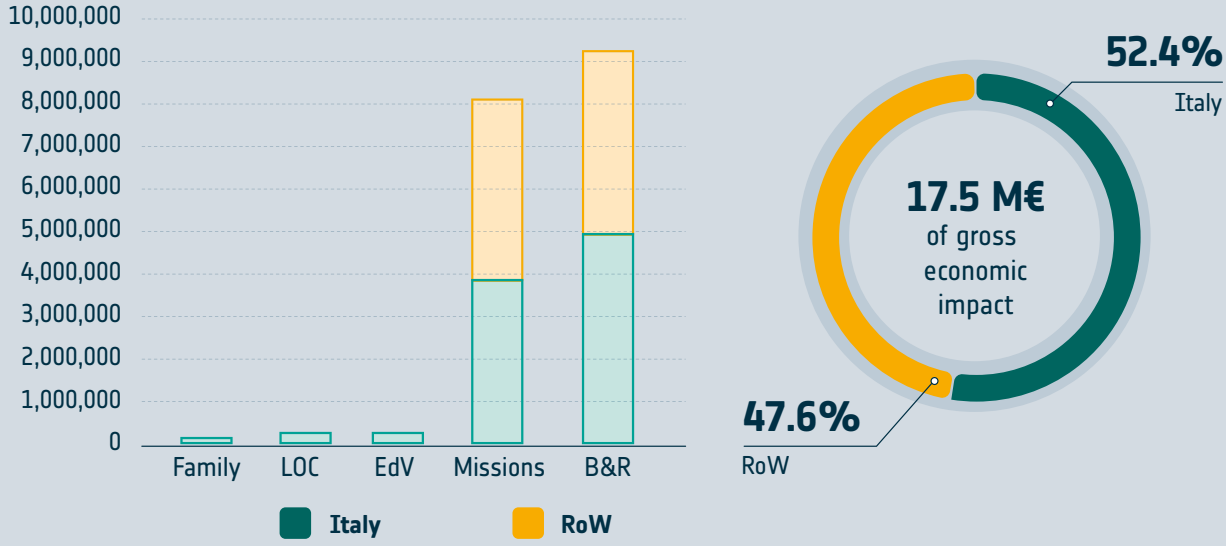
It shall be noted that in the forthcoming years the number of missions will progressively decrease, following the recommendations of the ESA Agenda 2025.

An overall picture of ESRIN impact on the Travel & Tourism sector

Graph B1 illustrates our estimate of ESRIN's annual impact on local tourism and on the travel industry. It compares the national contribution to the RoW (rest of the world) contribution.

Due to the underlying assumptions, almost one-third of visits (family and friends, business and research relations with local institutions) provide a quasi-null economic impact on the travel and tourism sector. Also, it seems that educational visits do not generate relevant economic impacts overall. ESA missions instead generate a consistent economic impact in terms of travelling and local tourism. The most important economic impact depends on visits for business and research purposes but excluding those from local institutions. Overall, we estimate a gross economic impact in 2019 of slightly more than 17.5 million euro, that generates a net direct impact on domestic travel-related and touristic activities of almost 9.18 million euro (5.66 million euro in the local economy). The other 8.3 million euro go to the rest of the world for travel expenses.

Graph B1. ESRIN's annual estimated economic impact on tourism (€) by group of visits for Italy and the Rest of the World (RoW)



LOC *| Local Institutions |* ***EdV*** *| Educational visits |* ***B&R*** *| Business & Research visits* *Source: our estimate (2019)*

An alternative measurement of ESRIN's economic impact on local tourism

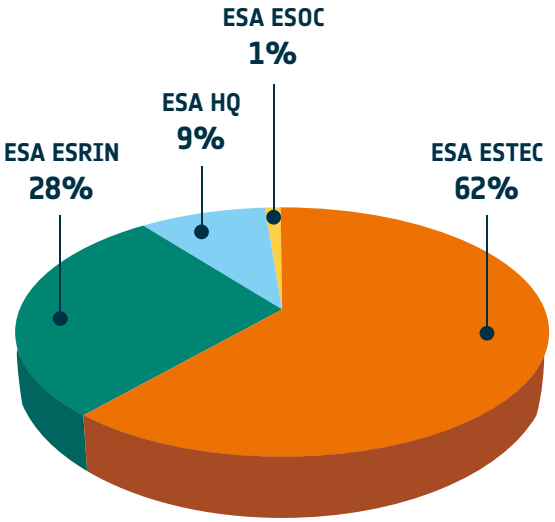
In order to test the magnitude of ESRIN's annual estimated impact on the local economy, we analyse the value added to Rome's tourist economy. In 2019, this amounted to almost 6.7 billion euro according to the National Institute for Statistics (ISTAT). By considering that Frascati makes up 0.51% of the population of the province of Rome, if spending on tourism were distributed uniformly across both populations, then Frascati should contribute almost 32 million euro to the overall value. However, a recent survey suggests that ESRIN, ENEA, INFN and ERICSSON generate almost 70% of the local touristic demand. By equally weighting the four institutions, ESRIN should generate almost 5.6 million euro of local tourism spending.

It's worth noting how the annual value of almost 5.6 million euro, which we estimated in the previous section, is similar to the value computed based on ISTAT data. Therefore, we consider our estimate reliable to the order of magnitude.

2.2 ESA ESRIN's procurement

During the last four years, ESA signed numerous contracts with Italian businesses, generating consistent benefits in terms of industrial commitments worth more than €2.5 billion. The share of procurement contracts awarded to Italian contractors is summarized by the pie chart below (Graph 13). Not surprisingly, ESTEC is the major contracting source. In fact, while ESTEC spans its activities across a varied range of programmes, ESRIN focuses its core functions around Earth Observation, Launchers, Security and IT. Therefore, the procurement of these two establishments cannot be compared, as they are representatives of different programmes and structurally different in terms of capital intensity (such as the construction of satellites in ESTEC).

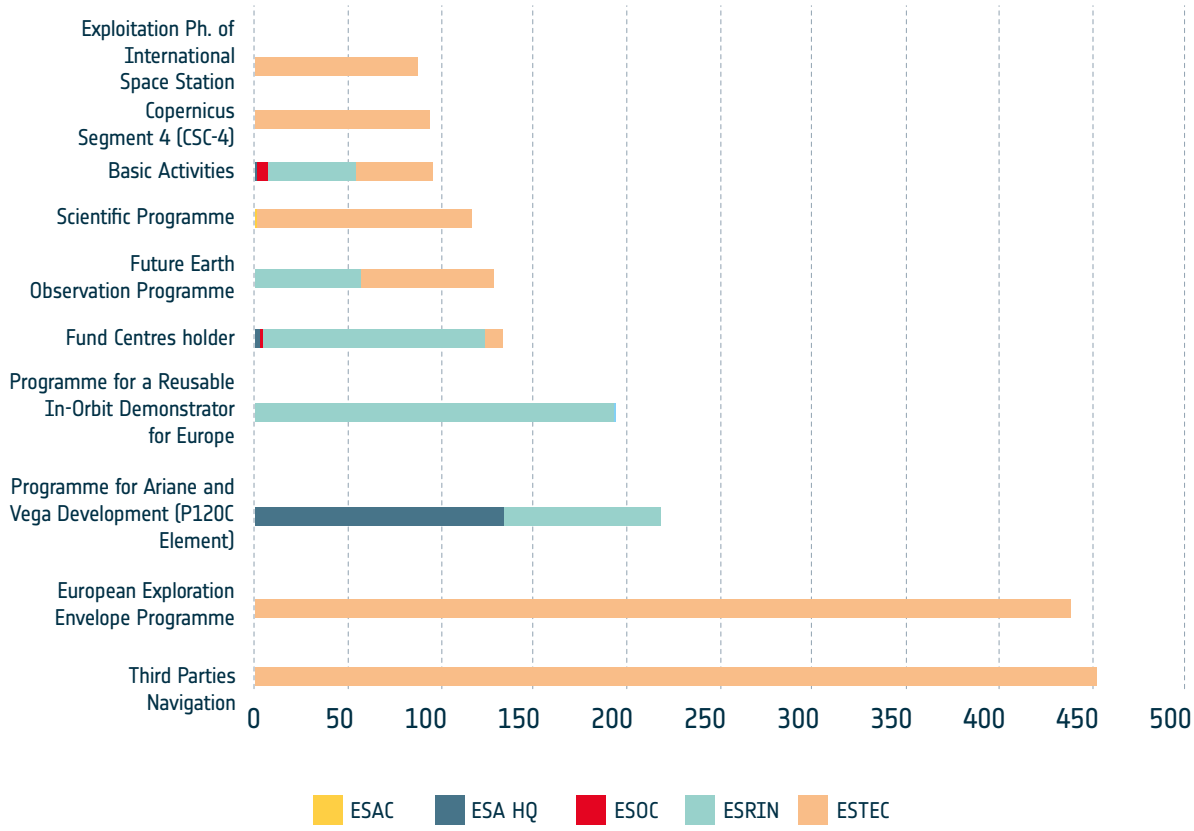
Graph 13. ESA's Procurement with Italian Companies per Establishment (in %) (2017–2020)



Source: our elaboration of EROS data for commitments placed with Industry, which are registered with IT nationality in Esa-Star

Graph 14 gives an overview of the ESA's procurement toward Italian Contractors according to the ESA's main programmes. In this regard, ESRIN's procurement is shared across five programmes, and a sizable amount relates to corporate functions.

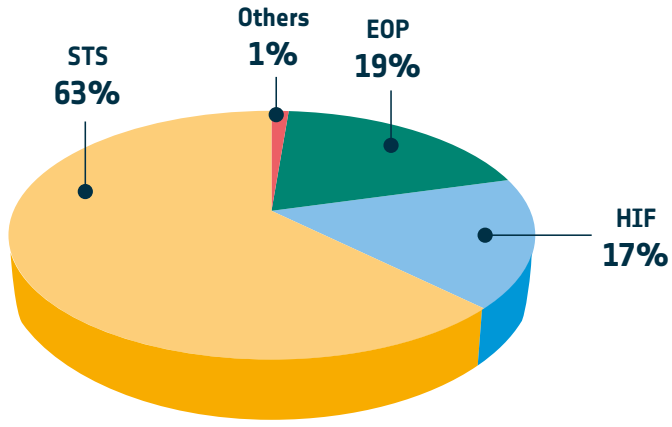
Graph 14. ESA's Procurement with Italian contractors by programme and by ESA contracting establishment (2017-2020) (M€)



Source: our elaboration of EROS data for commitments placed with Industry, which are registered with IT nationality in Esa-Star

Although ESRIN represents the ESA's centre for Earth Observation, Italian companies were mainly contracted by the Directorate of Space Transportation (STS). This is not surprising, given the general higher capital intensity of Space Transportation programmes compared to other space activities, as well as the traditional major contribution of Italy in the Vega Development and Exploitation programmes. In fact, as illustrated Graph 16 in the breakdown of the STS programmes in which Italian businesses are involved, these are directly or indirectly related to the Vega launchers.

Graph 15. ESRIN's Procurement by Initiating Service (2017–2020)

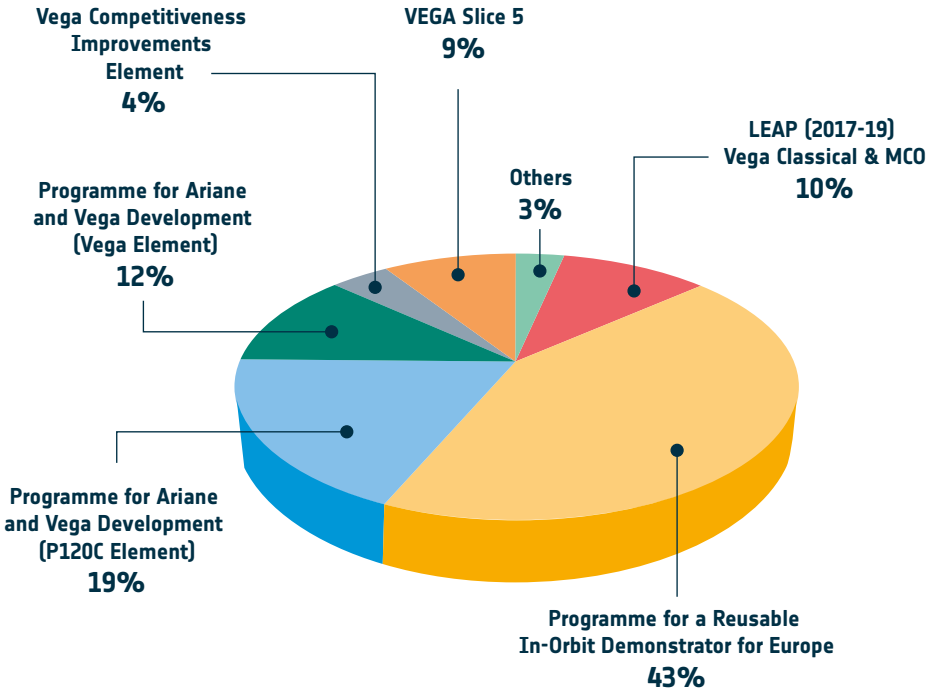


Source: our elaboration of EROS data for commitments placed with Industry, which are registered with IT nationality in Esa-Star

Finally, a sizable share of ESRIN procurement (17%) comprises contracts awarded for the functioning of the establishment such as Human Resources, Facility Management, Finance and Controlling, and Information Technology, which falls within the Directorate of Internal Services (HIF).

In order to understand the evolution of ESRIN's procurement toward the Italian industry, we use a large timeframe starting from 2013. Graph 17 reveals that this value was stable for the first two years, then rose considerably by about 45% to 49% in 2016-2017.

Graph 16. Percentage breakdown of ESRIN's STS contracts by Programme (2017–2020)



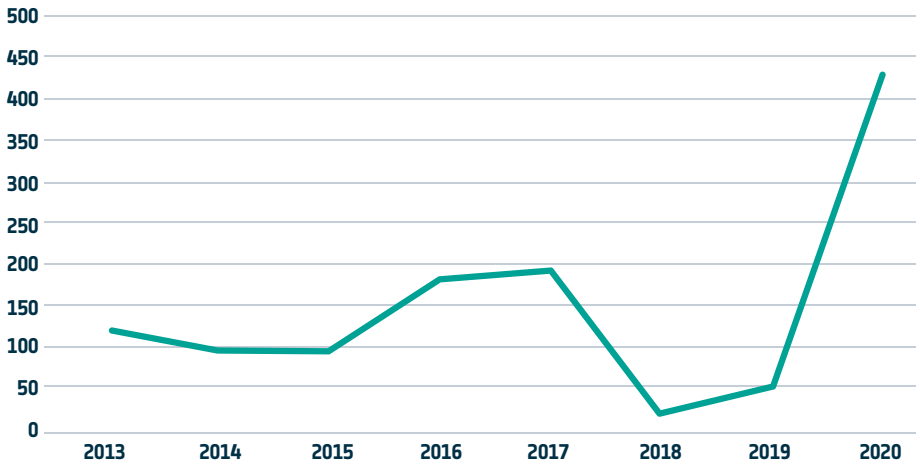
Source: our elaboration of EROS data for commitments placed with Industry, which are registered with IT nationality in Esa-Star

However, two main events stand out: the major fall in the expenditure to an all-time low in 2018 (a decline of about 90%), and the massive surge in 2020. The 2020 rise is particularly remarkable for two aspects:

(1) The outbreak of the Covid-19 pandemic and the resulting economic collapse of the Italian economy, whose GDP shrank by 8.9%[11], and also did not spare the Italian Aerospace industry[12].

(2) The value invoiced in 2020 represents about 60% of the total value issues in the previous years (2013-2019) and 38% considering the entire timeframe.

Graph 17. Evolution of ESRIN's procurement with Italian Contractors (M€)



Source: our elaboration of EROS data for commitments placed with Industry, which are registered with IT nationality in Esa-Star

[11] *Source: ISTAT (2021)*
[12] *Cluster Tecnologico Nazionale Aerospazio (2021), L'industria aeronautica italiana e il Covid tra resilienza e trasformazione.*

However, these two events shall be put in the Agency's perspective, in particular by focusing on the fact that in November 2019 in Seville, the ESA's Ministerial Council Space19+ reshaped the space programmes and consistently increased the assigned resources. Therefore, the fall in expenditure can be reconnected to the depletion of the last resources for the existing space programmes, while the boom in 2019 derived from the inception of the new budget which reserved substantial resources to Earth Observation's programmes such as Future EO, Copernicus and Incubed.

Therefore, the Space Economy generating from ESA is somehow resilient and relentless in the face of major and unforeseeable worldwide events, such as global pandemics. This represents a crucial sign for the Italian Space industry and for its business expectation in the current and future programmes.

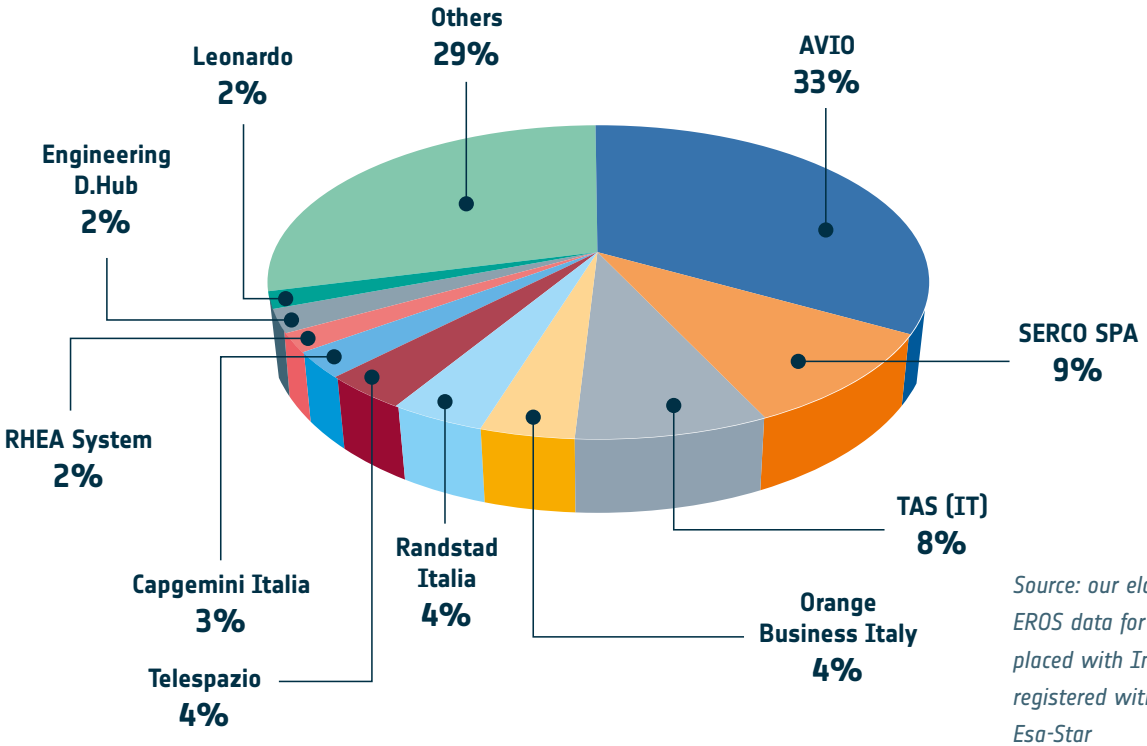
Furthermore, at the time of writing, the Italian Government is allocating through the National Recovery and Resilience Plan (NRRP) and other national budget resources for the period 2022-2026, 1287.5 M€ to ESA for the assistance to be provided to the Italian National Project concerning Earth Observation (IRIDE Constellation) and Space Transportation. Therefore, we expect not only a significant growth of the space economy in the years to come, but also a strengthening of the position of ESRIN in the Agency's context.

2.2.1 Italian Primes

ESRIN's procurement from Italian companies is very concentrated. Avio, the Prime Contractor for the Vega and sub-contractor for the Ariane programme secured almost 30% of these contracts, while the other top 10 Italian Primes split up most of the rest of the pie. It is worth noticing that the procurement awarded to these Prime contractors by ESRIN represents 71% of the total spending, while SMEs secured about 5% of these contracts.

Table 7 lists the top 10 Italian Prime ESA Contractors through ESRIN and briefly summarizes the main aspects of their activity. It can be noticed that many of them are non-space contractors, or linked to the internal functioning of the establishment.

Graph 18. ESRIN's Procurement by main contractors (2017–2020)



Source: our elaboration of EROS data for commitments placed with Industry, which are registered with IT nationality in Esa-Star

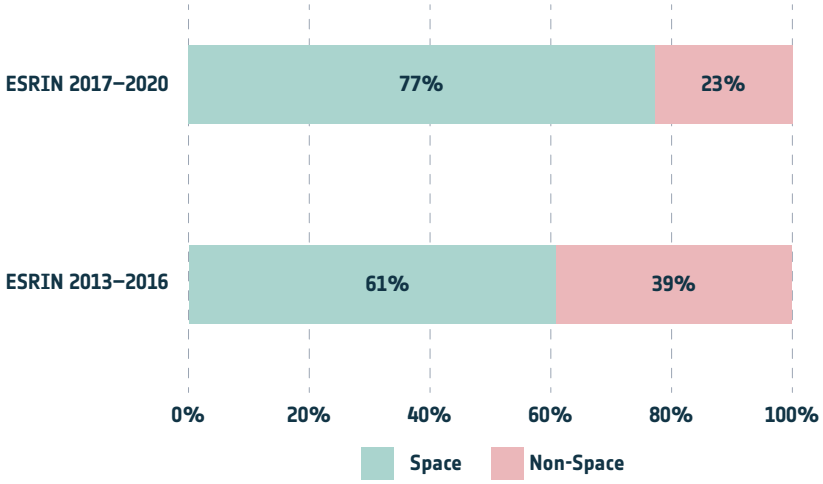
Table 7. ESRIN's Top 10 Italian Primes, their industrial sector, their percentage of the total procurement and the initiating services which contracted them (2017–2020)

Top 10 Italian Primes (ESRIN)	Industrial Sector	% Tot Proc ESRIN	Initiating Service
AVIO SPA	Space	33%	STS
SERCO SPA	Public Services, Space	9%	EOP, HIF
TAS (IT)	Space	8%	STS, EOP
ORANGE BUSINESS ITALY SPA	Telecommunication	4%	HIF
RANDSTAD ITALIA	HR	4%	HIF, EOP, DG, IPL
TELESPAZIO	Space	4%	EOP, STS
CAPGEMINI ITALIA SPA	IT	3%	HIF
RHEA SYSTEM S.P.A.	IT, Space	2%	EOP
ENGINEERING D.HUB	IT	2%	HIF
LEONARDO Spa	Space	2%	STS

Source: our elaboration of EROS data for commitments placed with Industry, which are registered with IT nationality in Esa-Star

Graph 19 illustrates the results of a comparative analysis of the total amount invoiced by the Italian contractors with ESRIN in two timeframes, 2013-2016 and 2017-2020. This diagram shows that the share of non-space related procurement is still significantly relevant in ESRIN, although it has shrunk considerably in the last three years by about 16%. Very likely this is one of the first outcomes of the resources allocated to space programmes by the 2019 Ministerial Council. In this regard, since only two years have passed, we can only expect the space related share to grow in the upcoming years.

Graph 19. ESRIN Procurement toward Italian Contractors weighted value for Space vs Non-Space Procurement (2013–2016 and 2017–2020)

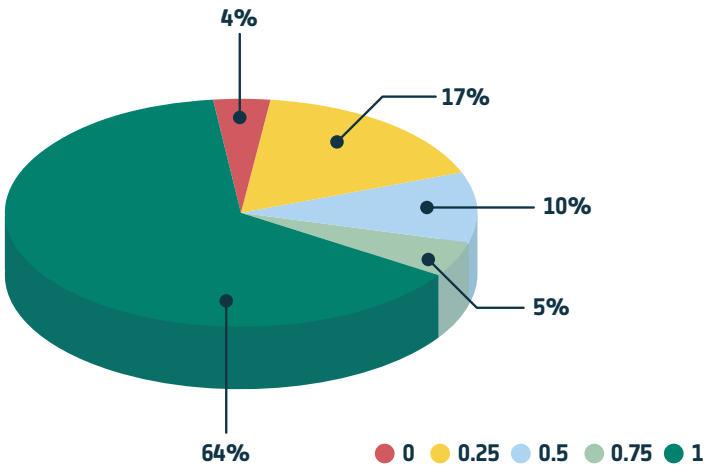


Source: our elaboration of EROS data for commitments placed with Industry, which are registered with IT nationality in Esa-Star

The 2017-2020 values are further broken down in the pie chart below according to the related "weighting factor[13]". The weight allows us to assign a scientific/ technological value to the different activities performed by the Agency and to reduce the value of non-space related contracts.

More than a third of the activities carried out in ESRIN have a technological weight lower than 1. It is worth noting also that the major share of ESA non-space procurement is mostly related to Information Technology, therefore it is scientifically relevant anyway.

Graph 20. ESRIN procurement (2017–2020): unweighted value by weighting factor (Total invoiced amount 690.4 M€)



Source: our elaboration of EROS data for commitments placed with Industry, which are registered with IT nationality in Esa-Star

[13] *Possible Weighting factors are distinct values: 0, 0.25, 0.50, 0.75 and 1*

- *WF=1: All activities around technology and development, depending on various aspects around 80 or more percent of the activities, as a rule of thumb.*
- *WF=0.75: Launch complex and launch range activities*
- *WF=0.50: Only two activities: Development and production of Mechanical Ground Segment Equipment (MGSE) and Centralised parts procurement*
- *WF=0.25: Launch purchase, manpower and many other activities*
- *WF=0: No technological values, typical facility management, guard services, gardening, catering and canteen services, etc.*

2.2.2 The major Italian Prime Contractors in EOP

As in most ESA programmes, several EO activities are contracted out to public institutions and private companies in order to maximize the returns of Member States' investments in ESA. The major Italian Prime Contractors are indicated in Table 8. Other entities, public and private institutions have a relevant presence in the EOEP, and a low presence in all other EOP sectors.

Table 8. ESA major Italian prime contractors in the period January 2017–March 2021 by principal EO programmes (M€)

Contractor	FEOP	CSC-4	MetOp-SG	MTG	TOTAL
TAS (IT)	●	●	●	●	
LEONARDO Spa	●	●	●	●	
OHB ITALIA S.P.A.	●	●	●	●	
SERCO SPA	●	●	●	●	
RHEA SYSTEM S.P.A.	●	●	●	●	
ADS (IT)	●	●	●	●	
ARESYS	●	●	●	●	
GTT ITALY	●	●	●	●	
CNR	●	●	●	●	
EXPRIVIA SPA	●	●	●		
TERRADUE SRL	●	●	●		
SITAEL	●	●			
TELESPAZIO	●	●			
TOTAL	**108.0**	**94.1**	**26.2**	**15.0**	**243.3**

***FEOP** | Future Earth Observation Programme | **CSC-4** | Copernicus Segment 4 (CSC-4) | **MetOp-SG** | MetOp Second Generation Programme 2013-2022 | **MTG** | MTG Space Segment Development Programme*

Source: our elaboration of EROS data for commitments placed with Industry, which are registered with IT nationality in Esa-Star

2.3 The direct, indirect and the induced benefits of ESA ESRIN to Italy

Finally, Graph 21 illustrates how the Italian contribution to ESA during 2017-2020 (2,106 M€) and ESA's industrial commitments with the Italian Prime Contractors (2,120 M€) have almost the same overall value and the same composition. This shows how ESRIN adds economic value to the overall Italian investment.

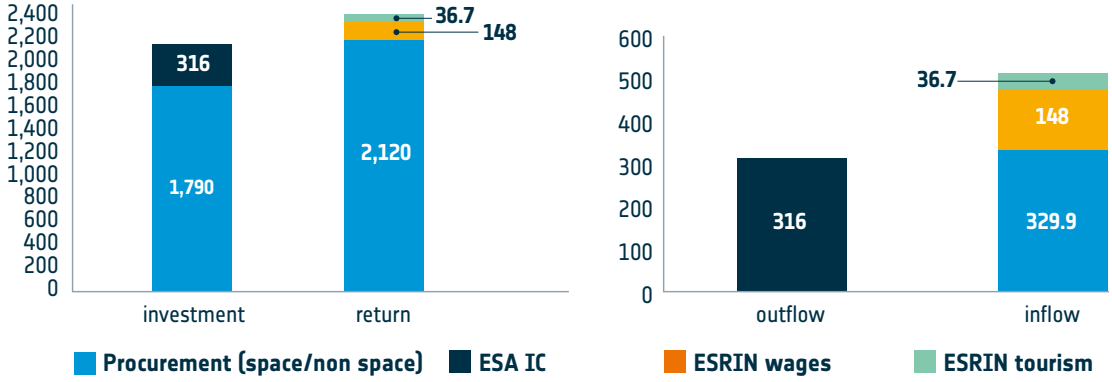
Specifically, ESA procurement is worth almost 14 million euro more than the Italian contribution to ESA including the Agency's internal costs, i.e. 0.67% more. By considering that roughly 15% of the Italian contribution covers ESA's internal costs[14], we estimate an outflow of almost 316 million euro. This corresponds to a net inflow of greater value. Indeed, ESA's industrial commitments with Italian companies are worth 330 million euro more than the estimated net Italian contribution to ESA (gross contribution minus estimated contribution to ESA's internal costs), most of them are signed through ESRIN. Furthermore, ESRIN staff allows Italy to benefit from an exogenous expenditure on domestic goods and services equal to ESRIN's staff wages of 148 million euro in the period 2017-2020, plus an additional 36.7 million euro spent on tourism and local transport services[15].

[14] *This percentage value was considered reliable in several reviews conducted at ESRIN and ASI.*
[15] *This value was obtained by reparametrizing the annual results illustrated in BOX1 to the cumulative number of visitors registered in the period 2017–2020, and by multiplying the number of ESA missions by four.*

Considering these figures, we estimate that in the period 2017-2020 compared to the overall Italian contribution to ESA, Italy obtained an estimated 9.4% return on each euro invested, apart from the benefits of proximity in non-space procurement (already included in the assessment).

Graph 21. Italian investment and returns from ESA (2017–2020): a focus on net flows (M€)

Source: our elaboration of ESA-p data and our Italian investment and returns from ESA (2017–20)



The Italian return is even more consistent in percentage terms if compared to other values. As an example, compared to the national contribution to ESA's internal costs (outflow), the Italian return (inflow) is more than 63%. We can note that 55% of the total Italian non space contracts in 2017-2020 are committed by ESRIN.

Furthermore, considering that ESRIN's procurement value with Italian companies in the period 2017-2020 is 690 M€ and adding ESRIN staff wages and the expenditure in tourism and local transport services, ESRIN's economic value to Italy in the period 2017-2020 is estimated at 875 M€.

In this section we present a simple model of calibration with the aim of providing an estimate of ESRIN's overall (direct, indirect and induced) economic benefits to Italy. This attempt mostly reflects a widely used approach that should provide relatively unbiased estimates with respect to the actual values, due to the narrow interval of years selected to estimate the most relevant parameters (the last four years of economic activity).

An overview of Italian investments and returns in ESA is provided in Table 9. The process has been separated into several steps.

BOX 2. DIRECT, INDIRECT AND INDUCED EFFECTS

1) Direct effects: the exogenous expenditure in the space economy generates an additional production within the space economy itself, and in all those non-space sectors that produce intermediate products and services used as inputs in the production process.

2) Indirect effects: the exogenous expenditure in the space economy also activates indirectly other non-space economic sectors, following a chain of actions and reactions that propagates the initial stimulus in all the economic sectors of activity.

3) Induced effects: the direct and indirect chains activated by the exogenous expenditure in the space economy remunerate households with labour income, generating an additional expenditure in final consumption goods, that activates an induced chain of actions and reactions, providing an additional stimulus in all sectors of economic activity.

The total added value generated in the national economy by an exogenous expenditure in the space economy can be estimated by summing the direct, indirect and induced effects, measured in terms of added value.

Step 1. The Italian Government endows ASI with an amount of funds equal to (1 + a) euro (call this amount "A").

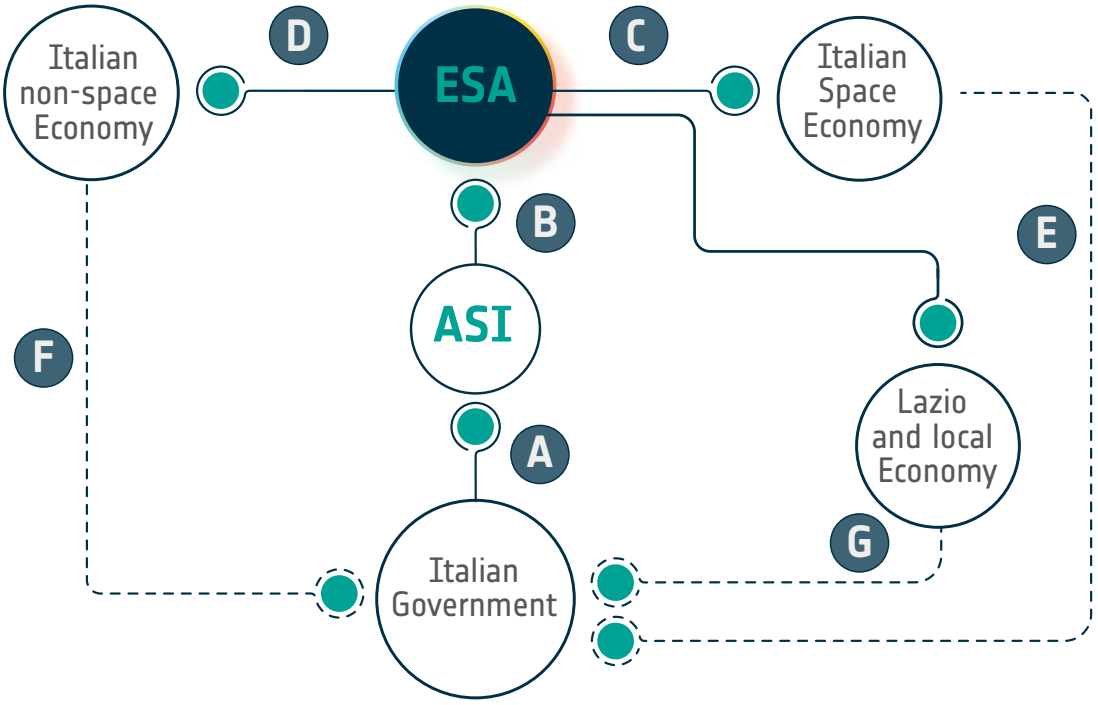
Step 2. ASI spends 1 euro in ESA (B).

Step 3. ESA collects 1 euro from ASI and spends part of its overall budget, which includes contributions from all Member States, to buy goods and services from both the Italian Space and non-space economic sector (C and D).

Benefits to Italy are at least threefold[16]:

- Italian contractors obtain on average contracts for a weighted value (E) greater than one with respect to the ideal share of the Italian investment in the optional programmes (Italian return coefficient > 1), and ESRIN guarantees proximity advantages to the Italian companies.
- Furthermore, the weighted value of contracts signed by the Italian contractors is complemented by an average 20/30% share of the unweighted value (F); due to proximity advantages several Italian non-space contractors obtain unweighted contracts for a consistent value;
- the local economy benefits from an exogenous demand of goods and services approximately equal to the amount of wages of ESRIN employees, and also from a consistent demand for local touristic services, as ESRIN attracts business and non-business visitors (G).

Table 9. A flow chart of Italian investiments and returns in ESA



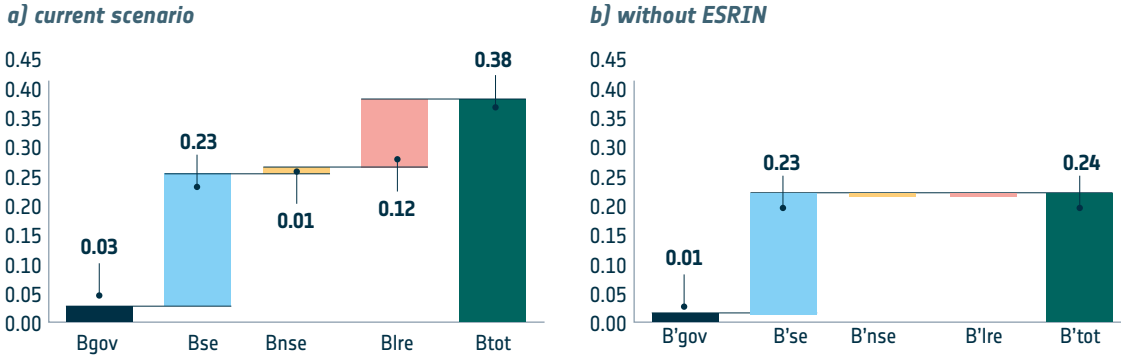
Source: our elaboration

[16] *Even if E, F and G have the same nature of the direct, indirect and induced benefits, they reflect the expected multivariate "impulses" in terms of exogenous expenditure, rather than the "response" in terms of direct, indirect and induced effects. The latter can be roughly estimated by multiplying the former using "fair" multipliers derived from other researches. Results might be biased, but at least the order of magnitude of the cumulative effect should be correct. An ad hoc estimate of a multiplier for the Italian space economy in 2020 might provide unbiased estimates, but this analysis goes far beyond the scope of this research, and presents several theoretical challenges that to the best of our knowledge are still unsolved*

The two figures in Graph 22 illustrate a heterogenous array of benefits, reflecting a multi stakeholder analysis rather than a macroeconomic perspective. Indeed, on the one hand the light blue, the yellow and the pink bars reflect the additional "Impulse", i.e. the additional exogenous expenditure generated by investing in ESA with respect to a direct contribution to the national space economy (it is worth noting how these values are not multiplied, as they reflect the initial additional stimulus to the national economy). On the other hand, the initial dark blue bar indicates how the Italian contribution to ESA produces additional revenues also for the public sector in terms of fiscal drag over a five-year horizon: it can therefore be considered as an investment rather than as a subsidy[17].

Graph 22a therefore illustrates the net benefits that one euro of the Italian contribution to ESA generates for a heterogeneous set of stakeholders (overall, almost 0.38 euro for each euro invested). Graph 22b illustrates the same benefits in a counterfactual scenario that does not account for ESRIN-related benefits (overall, almost 0.24 euros for each euro invested).

Graph 22. Benefits to the Italian economy for one euro invested in ESA by the Italian Government



Source: our elaboration on ESA-p data and IPC (2021)

***Bgov** | benefits for the Italian Government | **Bse** | benefits for the Italian Space economy | **Bnse** | benefits for the Italian non-space economy | **Blre** | benefits for the local and regional economy | **Btot** | Overall value to Italy. Labels with the apostrophe refer to the same in the counterfactual scenario without ESRIN.*

By considering a fiscal multiplier for the Italian economy close to three (which includes direct, indirect and induced benefits), the Italian contribution to ESA provides (net) positive returns (estimated yield over a five years horizon) for the Italian government itself[18]. Furthermore, it provides a positive return (exogenous additional stimulus) for a wide array of stakeholders: the Italian space industry (0.23 euros), the Italian non- space industry (0.01 euros), the local and regional economy (0.12 euros). Under the same assumptions, in a scenario that excludes ESRIN's value to Italy, an Italian contribution of one euro to ESA generates a return (estimated yield over a five years horizon) of almost 0.01 euros for the Italian public sector (government) and 0.23 euros of return (exogenous additional stimulus) for the Italian space industry.

If we extend our benefit analysis to the whole economy, i.e. if we consider the "response" (the sum of the direct, indirect and induced effects) rather than the "additional impulse" (the additional multivariate exogenous stimulus) we are

[17] *It is worth nothing how this value is obtained by multiplying the exogenous expenditure in the national economy by a spending multiplier. we have considered the level of taxation collected over the direct, indirect and induced effects of the exogenous expenditure in the space economy.*
[18] *We consider a cautions annual value of 0.04 euros for each euro spent. Without discounting uncertainty, this value is instead close to 0.20 euros for each euro invested.*

finally able to obtain a rough estimate of the added value generated by the Italian Government when investing in ESA for all economic sectors of activities and consumers. Specifically, by considering:

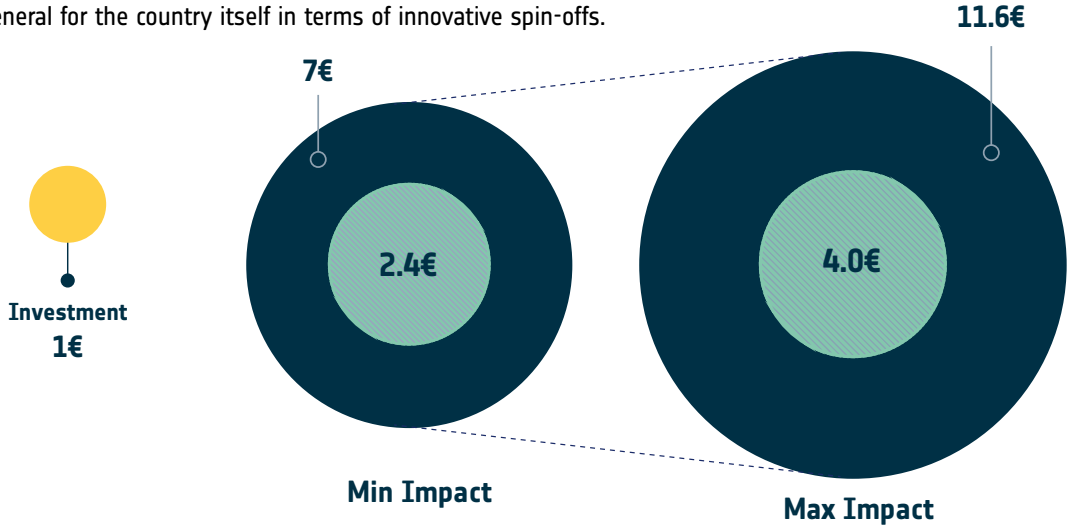
- a gross benefit of 1.38 euro (the euro invested plus the additional 0.38 euro of exogenous expenditure collected, i.e. the sum of the bars in Graph 22 a) over each euro invested by the Italian Government in ESA and
- a fiscal multiplier ranging from 1.8 (direct plus indirect benefits) to 3.0 (direct, indirect plus an average estimate of the induced benefits) euro

we can safely assume that Italy obtains an added value ranging from 2.4 to 4.0 over a five-year horizon for each euro of Italian contribution to ESA. Furthermore, if we consider the value of 2.9 as the ratio between the sales multiplier and the value added multiplier reported in a Technical Study for ESA[19] for the launchers sector in 2019, we obtain a sales multiplier for the Italian contribution to ESA in the whole economy ranging from 7.0 to 11.6 euro. Finally consider that, as shown in the third section, there is an added contribution given by the wide array of non-monetary societal benefits.

Over a five-year horizon, for each euro of Italian contribution to ESA we estimate an overall impact on the whole Italian economy ranging from 7.0 to 11.6 euros

In brief, this calibration model illustrates how investing in ESA guarantees considerable economic benefits to Italian industry and to the Italian government itself: a win-win game. Moreover, it allows Italy to maximize proximity advantages and guarantees additional economic benefits to the Italian public sector (in terms of estimated yields over a five-year period) and to the local and regional economy (in terms of an exogenous additional stimulus).

This confirms that by involving ESA partners in space activities of national interest, Italy raises the financial resilience of its investments by catalysing additional financial resources to cover costs, and gains the opportunity to participate in a wide range of other initiatives that might prove profitable for the Italian Space economy and more in general for the country itself in terms of innovative spin-offs.



[19] *PwC, 2019, "Socio-Economic Impact Assessment of Access to Space in Europe: Ariane 6 and Vega-C. Italy relevant extracts"*

3. The relational and scientific value of ESA ESRIN to Italy

In the previous section we have illustrated how ESRIN generates consistent additional benefits to Italy with respect to the national contribution to ESA. This highlighted that ESA provides a profitable way of investing in space for the Italian Government, which generates consistent benefits for the national space economy and for the regional and local economy in which ESRIN is located (the Lazio Region and the Municipality of Frascati).

It is now important to complete the assessment of ESRIN's value for Italy with more qualitative issues. This will illustrate better 'why' Italy should invest in ESA in terms of the scientific and relational spin-offs achieved, and the additional scientific value obtained by hosting ESRIN.

In the first sub-section below we show the growing trend in exploiting satellites' data for scientific studies and publications, with almost 10,000 publications released since 2012, and Italy positioned among the leading countries worldwide. In particular, we have presented the publications split by country and by scientific area. The main users of ESA EO data at the national level are mostly public institutions, and the consistent involvement of the Italian public sector as a user of EO data constitutes an Italian primacy worldwide. Therefore, it is reasonable to assume that the Italian Government is obtaining consistent benefits from the implementation of Copernicus, as the latter is a game changer in most Earth Observation activities due to the exponential growth of the data it produced. To this extent, it should be considered that Europe is the Continent with the largest Copernicus data user-community, as we will show in the next paragraphs, with Italy in third position in terms of registered users.

Italy obtains consistent benefits also in terms of research and educational activities related to the launcher sector, and the consistent involvement of local universities in the programme is not a mere coincidence. The Vega IPT generates innovative spin-offs to the Italian industry in terms of new technological achievements that can be used in other sectors of economic activity.

In the second sub-section below we provide a brief description of the wide array of public and private institutions that obtain benefits from the Italian contribution to ESA. Indeed, several Italian institutions benefit from the ESA free and open data policy in EO and are involved in the operations of the most important ESA and EU programmes. The same is true for the many Italian companies (both large enterprises and SMEs, including start-ups) involved in the programmes hosted in ESRIN and in several other ESA programmes in terms of industrial commitments.

Furthermore, the Italian participation in ESA is of the utmost importance at industrial level because it connects Italian space endeavours with those of the other ESA Member States, generating mutual benefits and fostering the competitiveness of the Italian industry in an international environment without losing the proximity advantages achieved by hosting an ESA establishment.

Finally, in the third sub-section we provide a brief overview of the actors that are involved at the local and regional level in space-related activities, and that are involved in the nexus of agreements signed by ESRIN with local partners. We show how ESRIN is deeply rooted in the local context, and how it is currently involved in creating the synergies to foster even more the scientific and technological research at the local level.

As can be intuitively concluded, ESRIN plays a leading role in the Italian efforts to consolidate the Italian position in the European space industry, confirming it as a major driver of change and of internationalization for the locality.

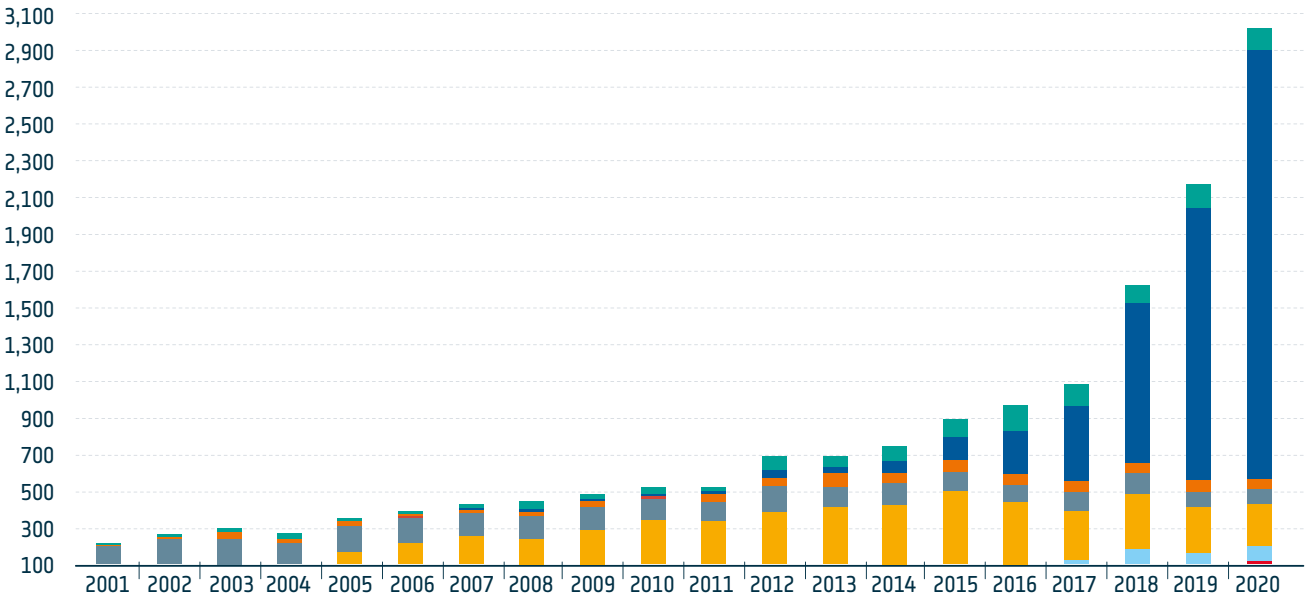
3.1 ESA ESRIN in its global context: scientific achievements in EO and launchers

In the last twenty years, the scientific production of articles, books and conferences dealing with machine learning techniques for the processing of satellite data and their application in many scientific sectors has grown exponentially. This rapid growth is due both to the increase in computational capabilities for the processing of this type of complex data, and to the availability of new analysis techniques, from machine learning to deep learning, and to the growing spread of satellite data from the many satellites launched by ESA, pushed by the open data policies promoted by the European Community.

Graph 23, through a search on the SCOPUS search engine, shows the distribution of satellite-derived scientific publications in the last twenty years, according to the type of satellite (about 10,000 products). It can be observed that the studies relating to sentinel data, starting from 2012, are increasingly numerous.

Analysing the same publications by country, it can be seen in Graph 24 that about 22% of publications were produced in the United States and China but 24% came from Germany, France and Italy, and more than 40% if we consider all EU states (UK excluded). In this ranking, Italy is in fifth place with almost 7% of publications.

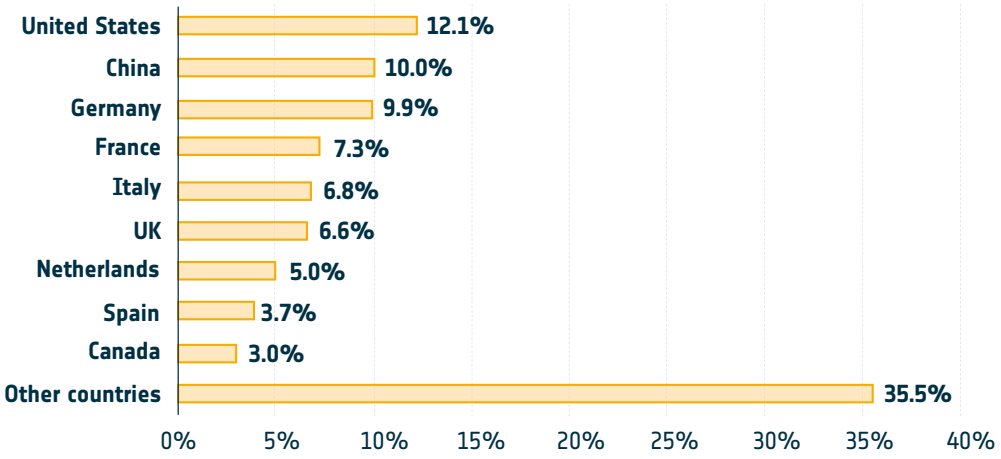
Graph 23. Satellite-derived scientific publications (articles, book chapters, notes, ...) by satellite (2001–2020)



years	smos	sentinels	goce	ers	envisat	cryosat	swarm
Total 2001-2020	1,190	5,612	816	1,463	4,810	531	793

Source: our elaboration of SCOPUS database

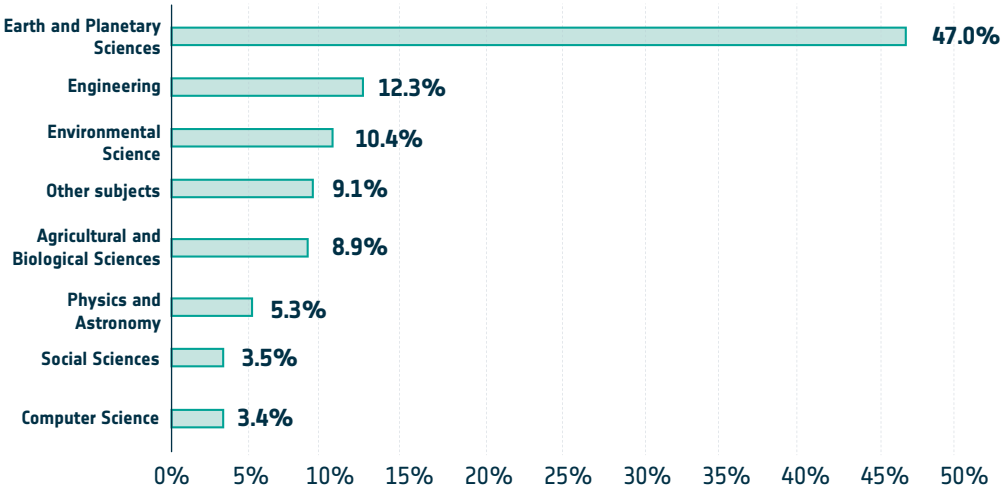
Graph 24. Distribution of authors of satellite-derived scientific publications by countries (2001-2020)



Source: our elaboration of SCOPUS database

Graph 25 shows the distribution of satellite-derived scientific publications by scientific area. The Earth and Planetary Sciences area is considered in almost half of the publications. This scientific area is characterized by strong interdisciplinarity and involves experts in astronomy, geology, chemistry, physics, and/or biology. About 10% of the products concern Environmental science which is also an interdisciplinary academic field that integrates physical, biological and information sciences with the study of the environment, and the solution of environmental problems. About 9% of the products concern Agricultural and Biological Sciences, a scientific area that finds many applications in the use of satellite data. Finally, the Social Sciences area represents 3.5% of products, a field that is currently still underdeveloped and will tend to find more and more interest and value in the use of satellite data.

Graph 25. Distribution of satellite-derived scientific publications by subject area (2001–2020)



Source: our elaboration on SCOPUS database

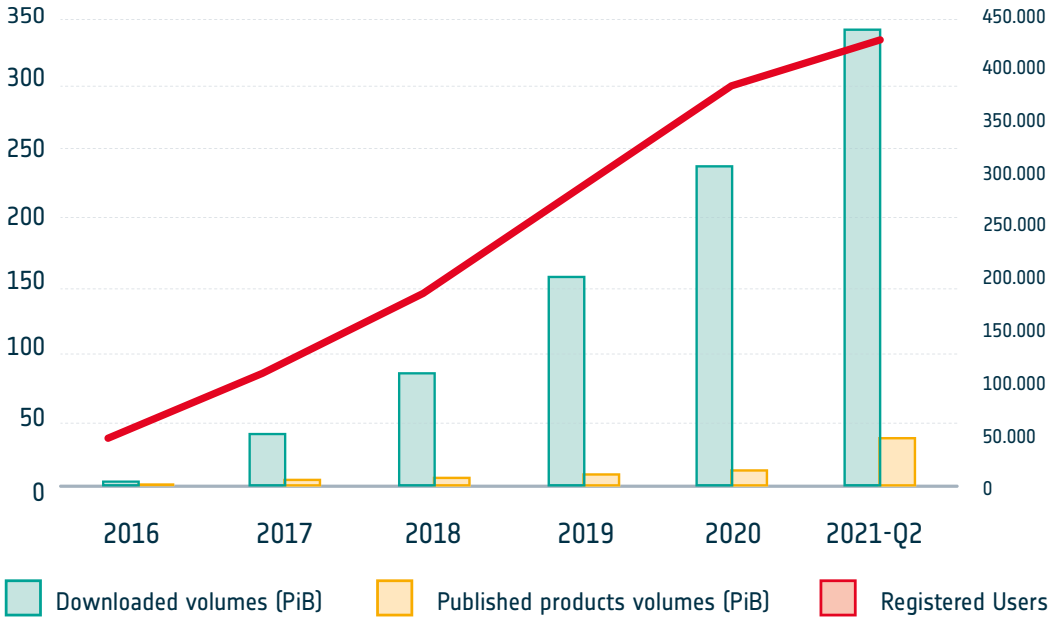
An overview of ESRIN's value for Italy must consider the relevant impact in terms of the scientific and technological achievements obtained by the Italian public and private research institutions due to their cooperation with ESA, at least in part due to ESRIN's proximity. As it is very difficult to disentangle the technological and scientific benefits that Italy might have achieved by participating in ESA independently from the existence of ESRIN from those obtained due to ESRIN's proximity, we restrict our focus to the ESA programmes hosted in ESRIN (EOP and Vega) and we try to identify those topics in which the data indicate a more consistent Italian presence or contribution.

3.1.1 A focus on Copernicus' applications and users

Copernicus provides a unified system through which vast amounts of data are fed into a range of information services designed to benefit the environment, satisfy humanitarian needs and support effective policy-making for a more sustainable future.

Graph 26 illustrates the exponential growth registered by Copernicus statistics starting from 2016, highlighting several important records, in particular the one of registered users, which reached more than 420,000 in the first half of 2021, compared to 52,000 in 2016, the Published Product volumes moved from 1.23 (PiB) to 37 (PiB) in the same period, but the most surprising result concerns the downloaded volumes, which registered an increase from 2.43 (PiB) in 2016 to 340 (PiB) in 2021, with an even higher expected growth till the end of this year.

Graph 26. Rise in Data Hub Registered Users (Amount, right scale), Published Products and User Download Volumes (PiB, left scale) (2016–2021-Q2)

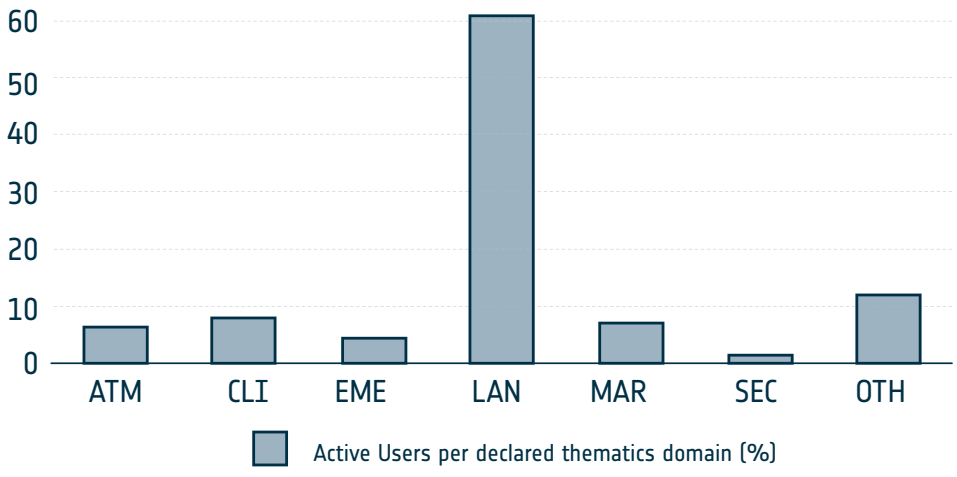


Source: our elaboration of SERCO data (2016, 2017, 2018, 2019, 2020)

PiB = Pebibytes, i.e. 1 Pebibite = 250 bytes, almost 1.13 Petabytes (PB)

Graph 27 provides an overview of Copernicus Open Access Hub users. Almost two-thirds of them are interested in Copernicus Land Management (CLMS) products, especially for research (49%) and education (42%) purposes.

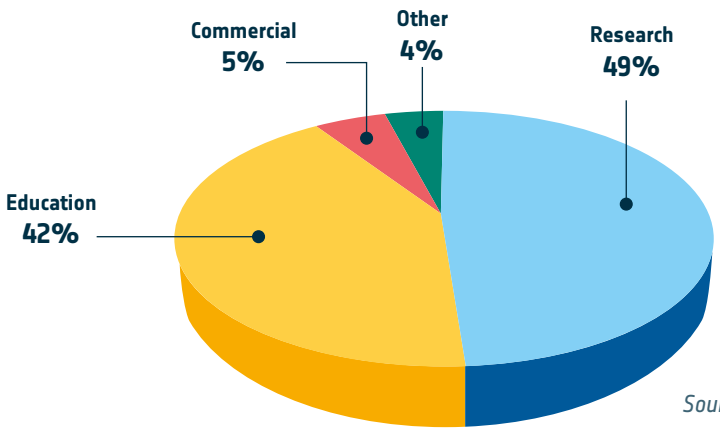
Graph 27. Copernicus Open Access Hub users by:
a) declared thematic domain in % (2020)



Source: SERCO Annual Report 2020

***ATM** | Atmosphere | **CLI** | Climate Change | **EME** | Emergency, | **LAN** | Land | **MAR** | Marine*
***SEC** | Security | **OTH** | Other*

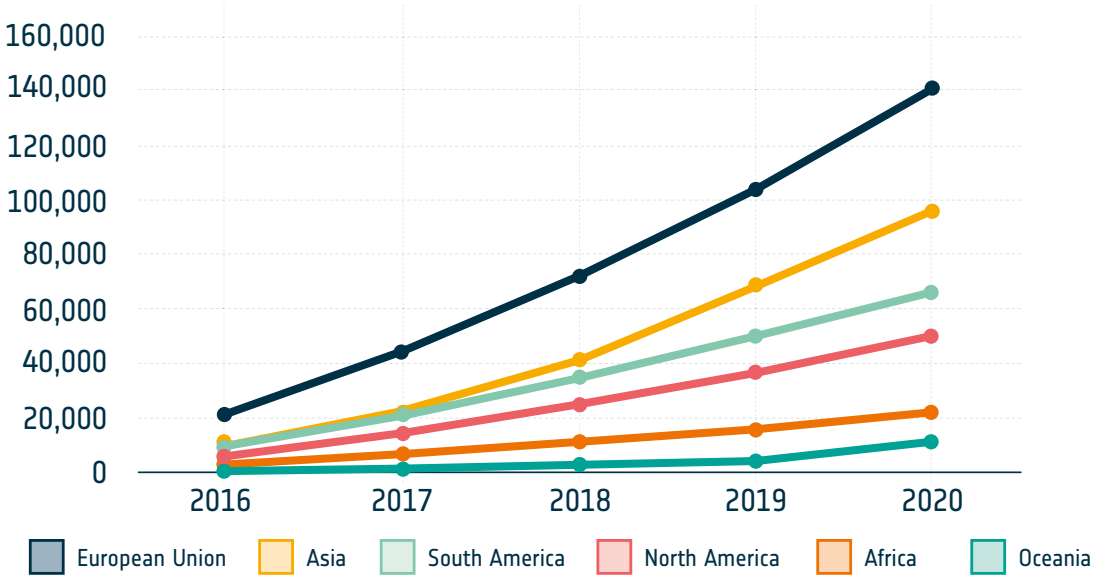
b) usage type (%, 2020)



Source: SERCO Annual Report 2020

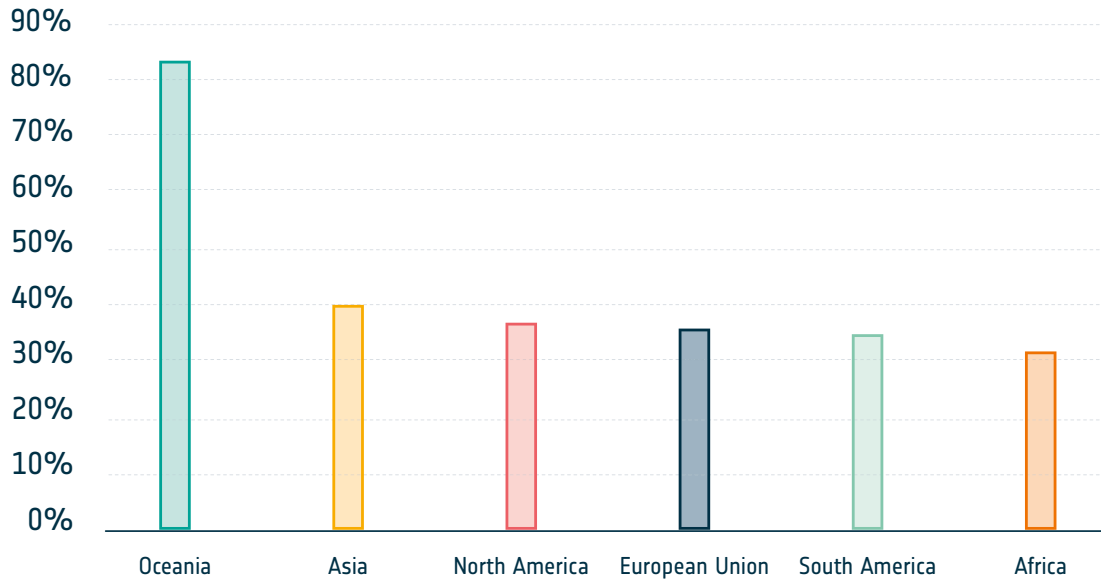
Graph 28 a) shows, in terms of geographical distribution, the registered users' frequency growth in the period between 2016 and 2020. As can be noticed, this frequency has recorded a significant and continuous increase in all the continents, and, at the same time, confirming a Copernicus users' geographical distribution mostly concentrated in Europe, for which we can see an exponential growth from 21,476 users in 2016 to 139,657 users in 2020 (+550%), with Italy ranking first in 2020 in terms of percentage increase in the number of registered users. Also the other continents replicated the important results, with Asia recording an increase from 10,948 in 2016 to 96,959 in 2020 (+785%) and South America moving from 10,021 users in 2016 to 66,526 in 2020 (+564%). Surprisingly, Oceania which seems to have the least marked growth trend, in 2020, registered the highest percentage increase accounting for + 84% compared to the previous year, followed by Asia, up by 40% and by the other Continents, with a growth exceeding 30% in each case, as showed in Graph 28 b). From the graphs what we see clearly emerging is that Europe remains the continent with the largest users' community; however what can also be noticed is a growing awareness about the importance of these data in the other Continents.

Graph 28 a) Registered users' frequency by Continent (2016–2020)



Source: SERCO Annual Report 2020

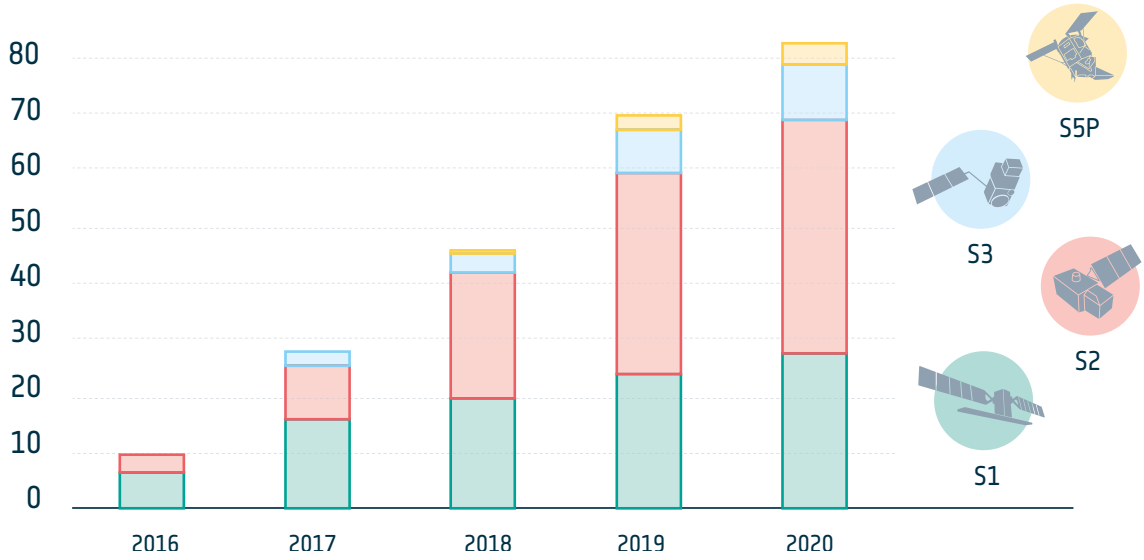
Graph 28 b) Registered users' growth rate (%) by continent in 2020 compared to 2019



Source: our elaboration of SERCO Annual Report 2020

Graph 29 illustrates how the volume of products downloaded since the start of the operations has grown both due to the increase in the Sentinel 1 (S1) and Sentinel 2 (S2) downloaded products and to the additional download of Sentinel 3 (S3) and Sentinel 5P (S5P) products, entered in operation respectively in 2016 and in 2017 . Meaning that the growth showed in the graphs below, although significant, should be calibrated by considering the introduction of new Satellite data deriving from additional missions developed progressively.

Graph 29. Volume (PiB) of products downloaded by year and mission (2016–2020)



Source: our elaboration of SERCO Annual Report (2016, 2017, 2018, 2019, 2020)

PiB = Pebibytes, i.e. 1 Pebibite = 250 bytes, almost 1.13 Petabytes (PB)

Finally, the Copernicus Sentinel Data Access System is providing free and open access to Copernicus Sentinel data products to various user typologies, by means of four dissemination points, known as hubs, each configured in order to suit the specific needs of the target community of users: the Open access, the Collaborative, the International and Copernicus Services. The Open access Hub is by far the most used Copernicus Hub, offering to all users free, full and open access to Copernicus Sentinel data based on a self-registration process. It is the first Hub where data products from a new mission are published. The Collaborative Hub is open to all Copernicus Participating States which signed the CollGS agreement with ESA or other agreements with the European Commission at the international level. Concerning the International Hub, it is addressing international partners' needs and the access is subject to a signature of an agreement with EU Commission or ESA. Finally, there is the Copernicus Services Hub targeting Copernicus Services and EU institutions. Since the beginning of the operations, Copernicus has served more than 350,000 registered users (+250% compared to 2016), with more than 250 petabytes of data downloaded (+594% compared to 2016), indicating not only the presence of a consolidated user base, but also an increasing widespread engagement in exploiting the potential of this data.

Table 10 provides an overview of Copernicus users in Italy. These figures cover the period December 2019 – November 2020, and apply only to use of the Copernicus Open Access Hub. They show how the total number of Italian registered users during the period was 15,394 (almost ten times more than in June 2017). However, the number of 'active users', i.e. users who made one or more downloads during the same period for either Sentinel 1 or Sentinel 2, is significantly lower (1,172 for S1, 2,577 for S2 and 759 for S3).

Table 10. Copernicus users (registered and active) and downloads (TiB) for Italy (2020)

		Number	Europe, rank for Number	World, rank for Number
Registered Users		15,394		
Active users	S1	1,172	2	5
	S2	2,577	3	5
	S3	759	1	3
Downloads	S1	162,240	5	8
	S2	397,530	5	8
	S3	491,264	4	7

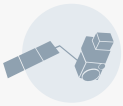
1 TiB=0.001 PiB

Source: our elaboration of SERCO Annual Report 2020

Europe still remains the Continent with the largest Copernicus data user-community as shown in the previous graphs. More in detail, Table 11 illustrates the top five EU countries for registrations and user downloads per Sentinel in 2020, with Italy confirming its third position in terms of registered users and recording the second highest percentage increase compared to 2019, just after Spain. It is worth noting how Italy was in the top 5 European countries for

S1, S2 and S3 downloads. Just for completeness, Sentinel 5-P is not included because the downloads are still on the PreOps Hub.

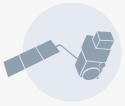
Table 11. Top 5 European Countries for registrations and user downloads by Sentinel in 2020

Registrations since start			Downloads					
			 Sentinel 1		 Sentinel 2		 Sentinel 3	
Country	N.	2019 Change	Country	TiB	Country	TiB	Country	TiB
GER	21,445	30%	FR	1,327,654	GER	4,712,212	GER	1,652,180
ESP	15,533	47%	GER	511,540	FR	3,896,197	POL	534,946
ITA	15,394	49%	UK	477,010	UK	574,075	NOR	529,372
UK	15,244	27%	NOR	511,540	NOR	539,102	ITA	491,264
FR	10,531	35%	ITA	162,240	ITA	397,530	UK	407,967

Source: our elaboration of SERCO Report 2020

To get a complete picture, Table 12 represents the total number of active users per Sentinel-1, Sentinel-2 and Sentinel-3 in 2020. Differently from registered users, active users can be considered those who completed at least one download. To better clarify, the number of active users does not correspond with the volume of data downloaded for each user; indeed a user can download various different products during the year, counting as a single user. At the global level, Italy is ranked in the top 10 for number of active users, covering the fifth position for both Sentinel 1 and Sentinel 2, and the third for Sentinel 3. However, Italy's positioning improves looking at the European level, where it is located in second position for Sentinel 1, in third position for Sentinel 2 and first for Sentinel 3.

Table 12. Number of Active Users (AU) per Sentinel-1, -2 and -3 in 2020 Global level

 Sentinel 1			 Sentinel 2			 Sentinel 3		
Country	AU	% 2019 change	Country	AU	% 2019 change	Country	AU	% 2019 change
CHI	2,137	1	CHI	4,188	27	US	814	-11
AUS	1,610	164	BRA	3,316	15	CHI	774	24
IND	1,384	2	SPA	3,260	30	ITA	759	9
GER	1,219	-3	GER	3,226	7	GER	754	-2
ITA	1,172	6	ITA	2,577	28	SPA	677	10
US	982	1	US	2,396	64	IND	589	18
UK	793	-9	IND	2,233	18	UK	453	-11

Source: our elaboration of SERCO Report 2020

3.1.2 Technological achievements in the launchers sector

The Vega IPT has activated important connections with universities and research institutions. An Italian research institution involved in Vega IPT activities has been the Italian Consortium of Aerospace Research (CIRA). The other main collaborations have been illustrated in Table 13, this includes a now long standing collaboration with the University of Rome La Sapienza, which is still ongoing. Furthermore, the Vega IPT activated a collaboration with the Office National d'Etudes et de Recherches Aérospatiales (ONERA), with the Netherland Organization for Applied Scientific Research (TNO), with the Industrieanlagen-Betriebsgesellschaft mbH (IABG).

Table 13. Main collaborations of Vega Programme with universities and research centres

Country	
IT	University of Rome La Sapienza
IT	Italian Consortium of Aerospace Research (CIRA)
FR	Office National d'Etudes et de Recherches Aérospatial (ONERA))
NE	Netherland Organization for Applied Scientific Research (TNO)
DE	Industrieanlagen Betriebsgesellschaft mbH (IABG)

Source: Vega IPT (2017)

Table 14 illustrates the most innovative industrial spinoffs of the Vega Programme. The carbon material for throat insert is currently used in the construction of nuclear power plant, aircraft and road vehicles. Secondly, the adhesives for high-performance boarding are currently used in the automotive sector, while the pre-impregnated carbon fiber reinforced polymer (prepreg CFRP) is currently used in the production of tennis rackets, golf clubs and fishing rods.

Table 14. Main industrial spinoffs of the Vega Programme

Technology	Sector	Spin off
Carbon/Carbon materials for throat insert	Nuclear power plant	Reactor material for neutron moderator
	Aircraft	Discs for high performance brake systems
	Automotive	Discs for high performance brake systems
Adhesives for high performance bonding	Automotive	Secondary structures and interiors
Prepreg CFRP	Sports and goods	Tennis rackets, golf clubs, fishing rods.

Source: Vega IPT (2017)

3.2 ESA ESRIN and the Italian Space Economy

3.2.1 The public space centres in Italy

Italy has an excellent record in space research: it was the third country after the USSR and the USA to launch and operate a satellite (San Marco 1 in 1964), it is one of the ESA Founding Members and is currently the third major ESA contributor. As a consequence, Italy currently owns a consistent heritage made up of several institutes and infrastructures, most of them already active.

The **'Piero Fanti' Space Centre** is located in Fucino (Abruzzo). Established in 1963, it is actively involved in satellite operations, in the provision of telecommunications, television and multimedia services. Specifically, it hosts, beside the Control Centre of the COSMO-SkyMed Earth, one of the **Galileo Control Centres (GCC),** an infrastructure that manages satellite navigation and the quality of services supplied to the end users. Fucino, as a centre of excellence for more than 50 years, obtained in 2018 the full certification by the World Teleport Association, witnessing its compliance with the highest standards.

The **ASI Centre of Space Geodesy (CGS) "Giuseppe Colombo**" is located in Matera. It was inaugurated in 1983 as a joint effort between CNR, the Basilicata Region and NASA. Currently, it is one of the main research and technological transfer institutions in Southern Italy, but also the main ASI operation centre. In addition to Space Geodesy, CGS progressively expanded its fields of activity in remote sensing, "free space" quantum telecommunications and space debris tracking. CGS also accommodates one of the INRIM (National Institute of Metrological Research) network's nodes committed in time and frequency meteorology related experiments. Matera hosts the **ASI Space Centre for Earth Observation,** which has been active since 1994 in the field of acquisition, elaboration, archiving, and dissemination of EO data. Specifically, the centre is involved in the acquisition and processing of Cosmo SkyMed data for civil purposes, one of the most innovative programs in the Earth Observation field, and it is part of the Copernicus Core Ground Segment.

The **Italian Aerospace Research Centre (CIRA)**, with headquarters and operational structures in Capua (Campania), was created in 1984 for the purpose of performing research in the fields of space and aeronautics. Thirty years since its set up, CIRA now has the biggest research facilities in the field of aerospace in Italy, testing facilities that are unique in the world, and state-of-the-art laboratories that are all used by industries around the world.

The **'Luigi Broglio' ASI Space Centre** is located in Malindi (Kenya). It has been managed since the 60's by the University of Rome La Sapienza, through **the San Marco Project Research Centre (CRSPM)**. It has a fundamental role in Italian space history and, due to its equatorial location on the Indian Ocean coast, it is an ideal site for launch activities and ground-based satellite monitoring. The center is made up of two segments: the sea segment, with the ocean-based launch platform, and the land segment, with the data reception center, providing support operations for several scientific and technological programmes in collaboration with other international agencies (e.g. NASA, ESA, CNES and the Chinese Space Agency).

The Space Science Data Center a facility of the Italian Space Agency (ASI), established at the end of 2016 is a fundamental infrastructure located at ASI Hq in Rome which

collects and archives all the data from missions covering a wide range of fields, making them promptly available for the scientific community. The SSDC has also developed a **Multi Mission Interactive Archive (MMIA 2.0)** able to bring together the data processing information from the various missions by means of a single interface.

The **Sardinia Deep Space Antenna (SDSA)** is the ASI scientific unit located in Cagliari. It was established thanks to the ASI-INAF (National Institute of Astrophysics) and the ASI-NASA agreements. SDSA is operational within the NASA Deep Space Network providing support to multiple interplanetary missions and deep space exploration in collaboration with the Jet Propulsion Laboratory (JPL), and also to the development of radio-science activities. Moreover, SDSA will contribute to communication and navigation services for European interplanetary probes through the ESA's ESTRACK network.

The **new ECMWF Data Centre** was installed inside the Bologna Tecnopolo and became operational in September 2021. This new technology is able to enhance and overcome the current limits of weather forecasts with the ambitious goal to obtaining daily forecasts on a long-time frame, rather than biweekly. In the next few years, the Emilia-Romagna Data Valley is destined to become one of the most powerful supercomputing facilities in Europe, concentrating over 80% of the national supercomputing capacity (20% considering the European context). In fact, the European supercomputer Leonardo will be briefly installed on the same site. The facility will go further in deepening weather issues, also actively contributing to the ecological transition, the health sector, the digital and ecological transition, and so on.

Beside the national centres, Italy also hosts the European Commission **Joint Research Centre (JRC)** at Ispra (Varese), the third biggest European Commission site, also considered one of the European leading research campuses, which has been historically active in the development of environmental monitoring applications based on satellite data.

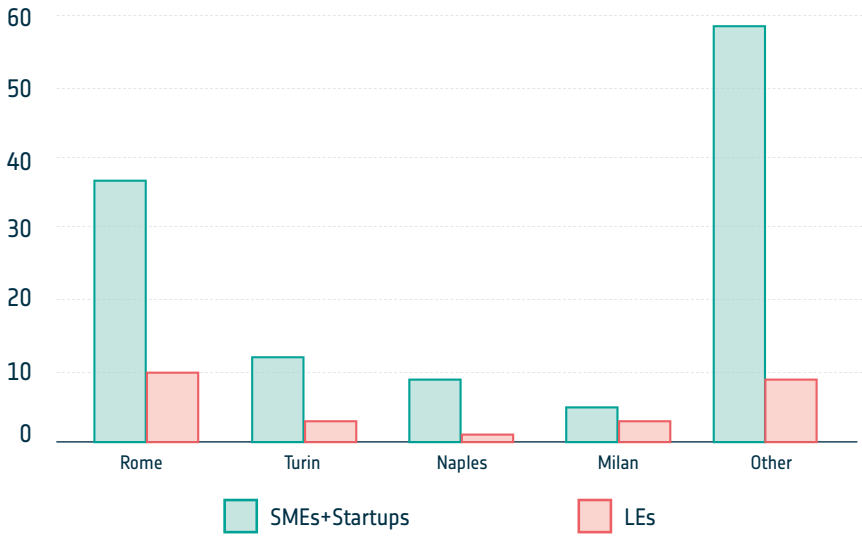
Finally, Italy hosts several activities related to the most important research institutions in Environmental Sciences (European Facility and Airborne Research, Euro-Argo, Eurofleets, Joint European Research Infrastructure Network for Coastal Observatories, Integrated Carbon Observation System, Lifewatch, the Long Term Ecological Research Network, Svalbard Integrated Arctic Earth Observing System) and coordinates three of them (European Research Infrastructure for the observation of Aerosol, Clouds and Trace gases, European Plate Observing System, European Multidisciplinary Seafloor and water column Observatory).

3.2.2 Italian Space Industry

In terms of scientific design, Italy is one of the few countries worldwide to have a complete space supply chain, made of several applications for civil and defence purposes, an important international presence both at technical and scientific level (i.e. in remote sensing), and a successful interaction among theoretical research, applied research and commercialization. Today, the Italian aerospace industry is ranked fourth in the European context and seventh worldwide generating around "*13 billion euro in revenues and employing 64,000 people (ASI-ICE 2020 Catalogue)*".

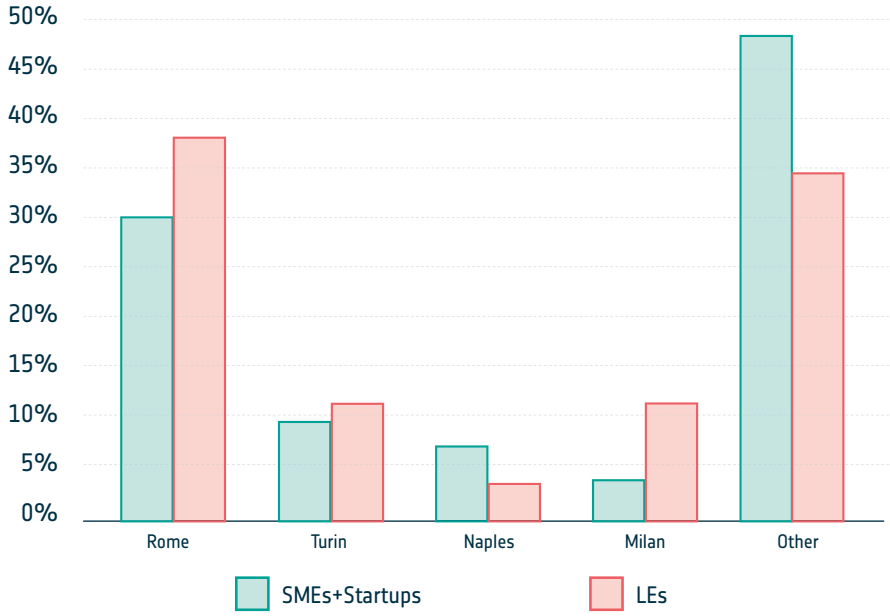
These surprising results are supported by large specialized companies and innovative SMEs involved in the National Space Economy, which have shown a rapidly increasing trend with 26 large enterprises (16 in 2016) and 122 SMEs (59 in 2016), including 11 start-ups in 2019 as listed in the Italian Space Industry Catalogue (ASI-ICE 2020), bearing witness to the leading role played by space activities in the Italian economy.

Graph 30 a) Frequency distribution of Italian Space Enterprises by Province (2019)



Source: our elaboration of Catalogue (ASI-ICE 2020) "Italian Space Industry: Products – Services – Applications – Technologies"

Graph 30 b) Percentage distribution of Italian Space Enterprises by Province (2019)

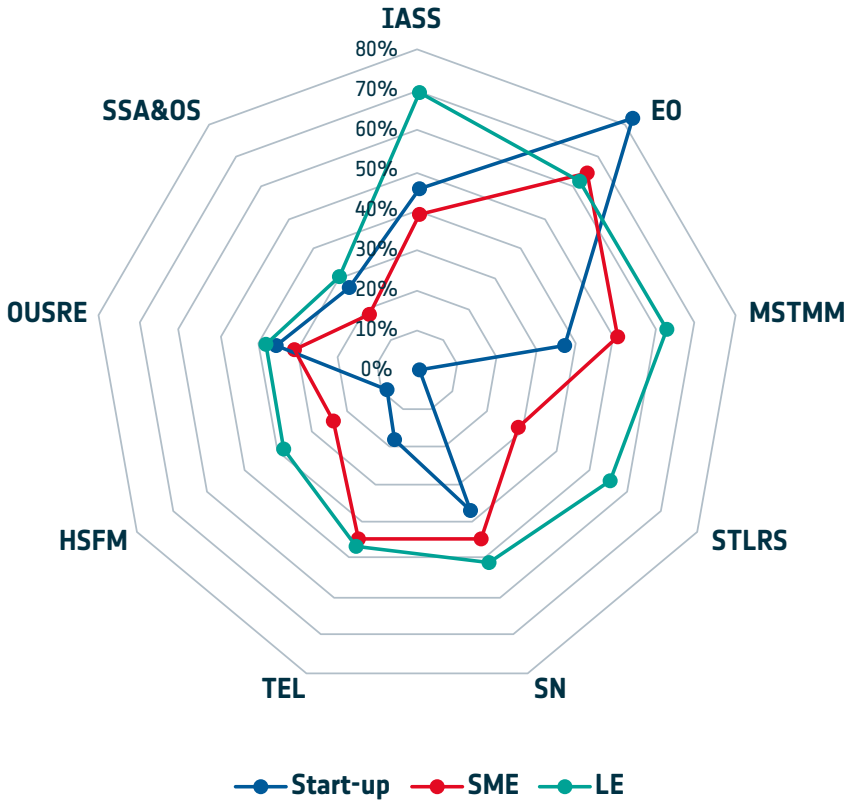


Source: our elaboration of Catalogue (ASI-ICE 2020) "Italian Space Industry: Products – Services – Applications – Technologies"

The Province of Rome hosts the headquarters of 32% of the Italian companies operating in the space sector (10 large enterprises and 37 SMEs and start-ups). Moreover, more than 50% of space companies are located in four provinces: Rome, Milan, Turin and Naples. Although there is no way of evaluating proximity advantages, there is evidence that the enterprises are concentrated near ASI headquarters, major centres and other Italian space centres. We interpret this as proof of proximity advantages, both for the Large Enterprises (LE), and for the Small and Medium Enterprises (SME) for which proximity is an enabling factor for internationalization in the space sector.

Concerning the application domains, Graph 31 illustrates the solid presence of large companies in all application domains with a strong focus on integrated applications security services, materials, structures, thermo-mechanical, mechanisms and Earth Observation. SMEs are confirming a strong stake, even compared to 2017, in the Earth Observation field, nevertheless a good specialisation can also be found with regard to Materials, structures, thermo-mechanical, mechanisms and Telecommunications. Furthermore, whereas the large enterprises in 2017 were on average involved in more application domains than the SMEs, the graph shows the progressive evolution, with the SMEs, to date, able to cover all the domains in which the presence of Large Enterprises has been detected, witnessing the SMEs rapid growing trend in the Italian aerospace industry. A novelty compared to the previous analysis is the inclusion of Start-ups, which cannot be neglected

Graph 31. Italian Space Economy: share of Start-up, SME and Large Enterprises by application domains (2020)



Source: our elaboration of Catalogue (ASI-ICE 2020) "Italian space Industry: Products - Services - Applications - Technologies"

***IASS** | Integrated applications security services and others | **EO** | Earth Observation | **MSTMM** | Materials, structures, thermo-mechanical, mechanisms and others | **STLRS** | Space transportation, launch and re-entry servicies | **SN** | Satellite navigation | **TEL** | Telecommunication | **HSFM** | Human space flight and microgravity | **OUSRE** | Observing the universe, science and robotic exploration | **SSA&OS** | Space situational awareness and in orbit servicing*

given their fundamental contribution to an even faster growth of the Space sector. As can be observed from the graph, start-ups are dominant in the Earth Observation field, reaching the highest percentage even compared to the presence of large Enterprises and SMEs. However, their participation is also significant in the Integrated applications security services, in materials, structures, thermo-mechanical, mechanisms, in satellite navigation and in observing the universe, science and robotic exploration domains.

3.3 ESA ESRIN and the regional context: towards a scientific and technological district

Far from being 'only' a scientific centre of national and international relevance, ESRIN is also deeply rooted in the local and regional context, where it has a leading role in terms of technological transfer and innovation.

In 2008, ESA signed with the Italian Government, represented by The Ministry of Education, Universities and Research (MIUR), a Memorandum of Understanding (MoU) for the reinforcement of the role of ESRIN. The two Parties shared the common understanding that the role of ESRIN had to be strengthened so as to be commensurate with the Italian investment in ESA.

The major achievement by ESRIN connected with the aforementioned MoU was in terms of site extension, with the recent acquisition of approximately 30,000 m^2 of land adjacent to ESRIN.

As a follow-up on the Memorandum of Understanding (MoU) signed in 2008, ESRIN has entered into several agreements with local institutions of national scientific and economic relevance, developing a consistent portfolio of relations in support of local development.

Firstly, ESRIN cooperates with several Italian National Research Institutes CNR, INFN and ENEA, in sharing networks and computing GRID infrastructure on several projects of scientific interest. Secondly, ESRIN has signed an agreement with the Lazio Region and MIUR (now MUR) to implement the MEGALAB Project for high-speed interconnectivity between several neighbouring research centres (ESA-ESRIN, CNR, ENEA, INFN), the University of Tor Vergata, the Tiburtino Space Technology District and the Lazio Region itself. Thirdly, ESA has signed an agreement with BIC Lazio to found an ESA BIC Incubator (EBI) to provide business start-up support as well as technical expertise to space-related economic initiatives, moreover FabSpace 2.0 a network for geodata-driven innovation has been established. Fourthly, as regards research, education and training, ESRIN has a framework agreement with Tor Vergata University and cooperates closely with other Italian universities on training and projects (Sapienza University of Rome, Politecnico of Milan, Venice University, etc.).

More recently, the District Roma MoU, the ASI-ESA Statement of Intent and the ESA_LAB@UNITOV MoC create synergies to favour scientific and technological research at the local level.

There is also an active local network including ESRIN, ENEA, INFN, the Monte Porzio Observatory, ASI and Banca of Italy which, leveraging on the establishment of ESRIN, promotes and realizes various projects and initiatives that aim to further enhance the ESA's role locally.

The ESA-CNR agreement and the ESRIN GRID Infrastructure – 2004

In 2004, ESRIN and CNR signed an agreement to interconnect their respective GRID dedicated infrastructures and data in a wide-area network and to grant shared access to identified research users. They also agreed to joint demonstration applications and to joint GRID technology developments. The ESRIN-CNR agreement fostered the development of a wider GRID infrastructure using high-connectivity bandwidth in the geographical area of Rome, to enlarge the utilisation of GRID to a wider scientific user community and to foster new applications of common interest to promote the use of GRID technology in their area of scientific influence. Furthermore, the agreement reinforced ESA/ESRIN and CNR co-operation in the field of outreach activities such as joint conferences, symposiums, exhibitions, and open days.

ESA had two GRID hardware infrastructures already, one located in ESTEC and one in ESRIN, and had developed several initiatives in the field (SpaceGrid, Concurrent Design Facility, Astrovirtel, GRID-aware End-to-end system Analysis and Service Environment…). It had also participated in several external activities (Astrophysical Virtual Observatory, DataGrid and DataTAG). One of the latter, the project DataGrid was funded by the EC and led by CERN with the participation of ESRIN. It aimed to develop a large-scale multidiscipline (mainly dedicated to High Energy Physics but also Earth Observation and bioengineering) GRID infrastructure and the necessary 'middleware'.

Following ESRIN's participation in DataGrid, the first large European Commission funded GRID project, the EOP Directorate at ESRIN developed a dedicated Earth Science GRID infrastructure under the name Earth Observation GRID-Processing-on- Demand, which is still active. This generic GRID-based environment (G-POD) ensures that specific EO data handling and processing applications can be seamlessly plugged into the system.

The ESRIN-Lazio Region Agreement for MEGALAB – 2004/2005

MEGALAB is a project launched with the Lazio Region and supported by the Frascati Living Lab. It is focused on GRID computing and provides high speed connection (HSC>10Gbps) across major local scientific institutions (ESRIN, INFN, CNR, Tor Vergata University) in order to promote cooperation between industrial and research centres and to develop innovative services for various sectors including e-government, aerospace, urban living, environment, e-health, education, tourism, culture, multimedia and audiovisual. Tecnopolo Tiburtino has been identified as one of the main points of reference in the network.

The ESA-BIC Lazio Agreement – 2009

The ESA – BIC Lazio collaboration agreement, first signed in 2009, was renewed in 2016 and finally extended until the end of 2023. This newest scheme, considering the Lazio Region's willingness to continue to incentivize the strengthening of a local ecosystem favoring the birth of new innovative companies, was approved and entered into force when it was signed on the 4th of August 2020 until the 31st of December 2023.

The Italian ESA Business Incubation Centre was founded in 2005, officially launched in 2009 and it is currently managed by Lazio Innova, whose role has been confirmed under the new Agreement for the period 2021-2023. ESA BIC Lazio is located at the business incubator ITech in Rome, situated near the European Space Research Institute (ESRIN) in Frascati, offering business start-up support. It also supplies technical expertise, particularly in the areas of systems and software infrastructures for data handling, and integrated Earth Observation, satellite navigation and communication applications. It further provides the 'incubates' with a chance to take advantage of the expertise located in ESRIN in the field of EO, launchers, IT and Telecommunications.

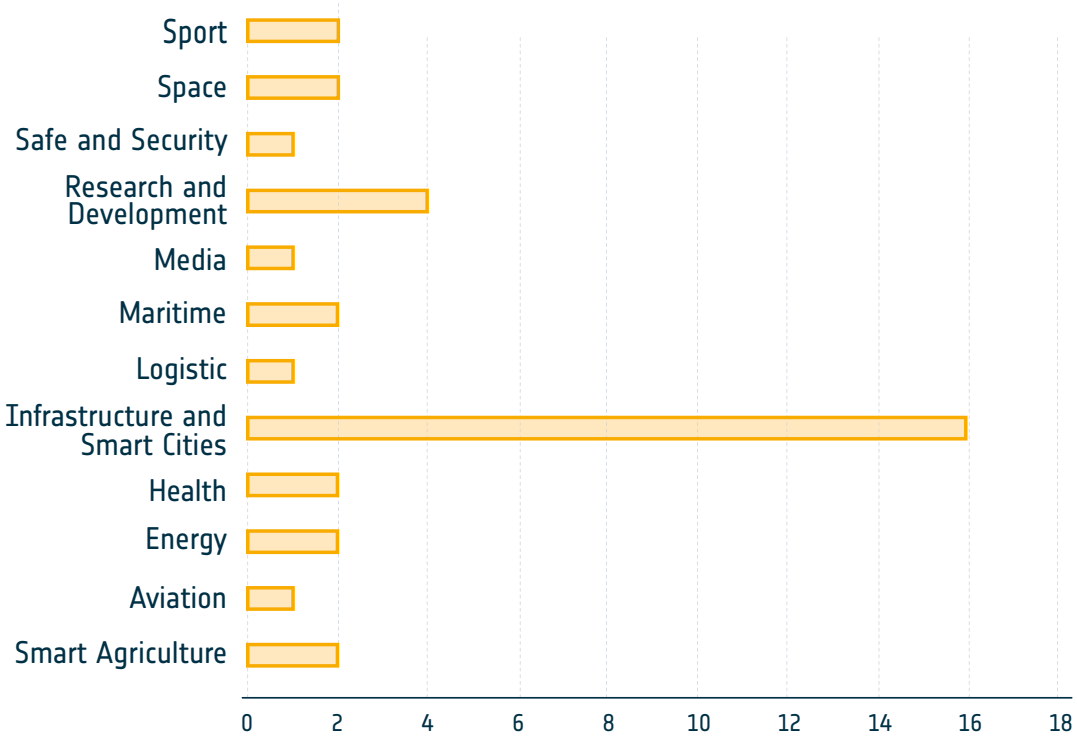
It is worth underlining that ESA BIC Lazio is one of the first ESA incubators to have been activated in Europe in 2006, and at the moment, Lazio is the only Italian region to have started and developed an incubation centre on space technologies.

Currently, ESA BIC Lazio has supported 40 startups so far, creating 120 Direct FTE jobs. The selected start-ups projects are incubated for 2 years at the Spazio Attivo Roma Tecnopolo, and they receive technical support from ESA and from ASI experts and entrepreneurial support from Lazio Innova tutors. The business ideas must be based on space-related technology, data, expertise and/or application and target the non-space market (downstream), or propose new innovations of potential interest to the space industry (upstream).

To date, ESA BIC Lazio has graduated 26 alumnus companies and it is managing 10 incubates, operating in several economic sectors and exploiting different technologies, as represented in Graph 32.

According to a recent survey, involving at the present only a subset of the supported startups, the generated revenue is 180 K€. With the latest update of the Agreement, covering the 2021-2023 period, Lazio Innova will support another 20 space related start-ups over the period of 4 years under the ESA BIC scheme.

Graph 32. Number of ESA BIC Lazio spin offs by sector



Source: our elaboration of ESA BIC Lazio data (2021)

Following the experience of ESA BIC in Lazio, ASI has expressed its interest in setting up a new ESA BIC to cover areas and regions not included by ESA BIC Lazio. This new ESA BIC in Italy will be set up as a network of federated nodes in order to cover a wider territory and will be aligned with the Italian Space Strategy so contributing to realising the growth potential of the Italian space industry.

A common incubation programme following the ESA BIC Common Approach will be offered at all locations, providing an attractive value proposition for start-ups with a space related business idea. Each node of ESA BIC Italy will support on average five start-ups per year per activated node, for an overall contract duration of five years. The contract was signed in January 2021.

ESA-Other Universities Agreement

ESRIN also works in close cooperation with other Italian universities on trainings and projects (Sapienza University, Polytechnic of Milan, Venice University, etc.). More generally, ESRIN itself is a centre of EO education with training courses, summer schools and international educational activities.

The growing exponential interest in the space sector and the close collaboration with Universities has led to the rapid spread of University Masters addressing space issues in the Italian territory, briefly reported below.

The II level Master "Space Exploration and Development Systems (SEEDS)" offered by Politecnico di Torino support students in acquiring specific skills and competences to develop space systems and missions in all the phases, from the early design stage up to the launch and operation stage.

The II level Master "Space Missions: Science, Design and Applications" by the University of Bologna is designed to offer, through an interdisciplinary approach which bring together scientific, technological and applicative areas, a broader and exhaustive vision of the space missions.

The II level Master "Space Optical Design and Remote Sensing" by the University of Cagliari covers the specific area related to optical devices and apparatuses projects, from the development until the prototyping phase.

The II level Master "Aerospace Medicine" offered by the University of Naples Federico II concerns a fundamental branch in the space industry, which is aimed to verify the flight personnel's eligibility in accordance with the new European standardized rules, as well as to develop specific competences for the application of the flight safety principles.

The Sapienza University of Rome has three different courses:

- **The II level Master "Satellites and Orbiting Platforms"** aiming to support the space market with professionals equipped with technical and managerial skills for the new missions and the related services.
- **The II level Master "Space Transportation Systems: Launchers and Re-entry vehicles (STS)"** is a training course for highly qualified personnel capable of holding managerial roles and / or carrying out research and technological development tasks.
- **The I level Master "Capacity Building in Astronautics"**, in collaboration with the University of Kenya, embraces a multidisciplinary approach covering the design, planning and management phases of the space missions.

The University of Rome Tor Vergata training offer includes:

- **The II level Master "Space Science and Technologies"** aiming to provide specific and advanced skills in the space exploration field.
- **The II level Master "Engineering and International Space Law in Communication, Navigation and Satellite Sensing Systems"** providing advanced technical skills and solid knowledge concerning the international and national legislation for better understanding and managing of the business opportunities related to the satellite world and the potential issues that may arise.

The II level Master "Mathematical and Physical Methods for Space Sciences (MPM Space Sciences)" offered by the University of Torino take advantage of advanced mathematics and physics knowledge to develop high-level skills for working in space industries.

Fab Space 2.0 – 2016

FabSpace 2.0 is a network for geodata-driven innovation that aims at making universities open-innovation centres for their regions. This network is designed to improve the contribution of these universities to the socio-economic and environmental performance of society. To achieve this goal, the FabSpace 2.0 project focuses on data-driven innovation, with a particular focus on Earth Observation data.

In the six European regions covered by the consortium, partner universities work together with co-located ESA Business Incubation Centres (ESA BICs) to turn space-connected business ideas into commercial companies, and provide technical expertise and business-development support.

Joint Consultative Committee (JCC) – 2016

The Joint Consultative Committee (JCC) was appointed, with art. 21 of Law 157, 4 August 2016, to monitor the Agreement between the Italian Government and ESA, signed in July 2012 and regarding the ESA's facilities located in Italy. JCC will promote and facilitate any potential opportunity relevant to ESA, formulating appropriate actions and recommendations, as well as coordinating all the necessary activities to achieve the expected goals.

LazioPulse – 2016

The Rapid transition of Research towards the Science 2.0 paradigm shows the on-going systematic changes in research and scientific activities. These are driven by rapid advances in ICT and Digital Technologies, combined with a growing demand to do Science for Society (actionable research) and in Society (co-design of knowledge). In this context, Lazio Pulse proposes the development of a regional Public Private Partnership of stakeholders interested in sharing data, know-how and infrastructures.

In detail, the Lazio Pulse project enhances existing resources and creates new ones, through eScience data (e.g. ESA's Earth Observations (EO), ENEA environmental data, INGV seismological data, Open Data from various government departments, etc. ...), high-level products (e.g. information on climatology, disaster management, smart cities, traffic control, predictive analysis, etc ...), e-infrastructures (e.g. the cloud and the ESA thematic exploration platforms, the INFN grid, etc ...), together with the business incubator service and the skills available from Research Centers in the area. All of these elements will allow the development of new services based on eScience, capable of attracting financial resources and ensuring economic sustainability for businesses through a continuous process of innovation.

This initiative was born within the European framework of open innovation, in which ESA is actively developing a European Network of "Earth Labs" that create innovations linked to Earth Observation (EO) and stimulate the birth of new companies focused on this specific service offering.

This ecosystem will be supported by the already existing infrastructures of the Research Centres mainly based in the Frascati area, which can share a large amount of data through open software and gain from the existing ESA BICs infrastructures (Business Incubation Centres).

The Edoardo Amaldi Foundation – 2017

The "Edoardo Amaldi" Foundation (FEA) set up by ASI in 2017 aims to promote scientific research by looking at the space sector as a crucial tool in supporting

the Country's economic development and enhancing innovation, thus empowering competitiveness, productivity and employment. The Foundation is closely connected with ESRIN activities, especially for the InCubed program, designed to give concrete support to start-ups, SMEs and large companies in developing innovative products or services, as previous mentioned in Chapter 2.

District Roma – 2019

In 2019 ESA signed the Memorandum of understanding (Protocollo di Intesa) involving the following parties: the Lazio Region, the University of Rome Tor Vergata, the National Institute of Nuclear Physics, the National Agency for New Technologies, the Energy and Sustainable Economic Development, the National Research Council, the National Institute of Astrophysics, the Italian Space Agency (ASI), the European Space Agency ESA-ESRIN, the National Institute of Statistics, the Municipality of Rome VI, the Municipality of Rome VII, the Municipality of Marino, the Municipality of Frascati, the Municipality of Grottaferrata. The Parties undertake to develop and implement a common action strategy *"opening up to the socio-economic context through the enhancement and transfer of knowledg*e", creating a network able to support research and the local development, and to foster innovation for the community. Leveraging on the synergies among the valuable research institutions located in the territory, the Memorandum intends to favour scientific and technological research at the local level, with the future aim to play a pivotal role as incubator and transferor of new methodologies and technologies with important implications for scientific, technological, economic growth, in the social and cultural area of the territory.

Additionally, it aims at promoting scientific knowledge dissemination based on cultural, social and educational activities, aiming to reach a wider audience

ASI-ESA Statement of Intent – 2019

In 2019, ESA signed a Statement of Intent with ASI to establish a "joint research fellowship scheme" aiming to maximize the exploitation of Earth Observation (EO) data, by fostering both the Earth Systems' knowledge and the EO-based applications, enhancing, in particular, the uptake of innovative technologies. The scheme design provides a 2-year post-doctoral fellowship granted by ASI to Italian scientists and on the other side ESA is committed to hosting the "Visiting Scientists" directly in the Φ-Lab site located in ESRIN, in order to provide access to EO data but also make available specific technical and computing competences and expertise for capacity building.

ESA-Frascati Agreement – 2019

The "Digital Twin Urban Pilot" (DTUP) project announced in 2019 between ESA and the city of Frascati is one of the ESA precursors for the larger Destination Earth initiative of the EU, which aims to develop a comprehensive high-precision and constantly updating model of the Earth that incorporates and forecasts the influence of human activities. The pilot project entails creating a 4D digital replica of the municipality to be used as an urban platform for visualizing and monitoring human activities. It thus provides the starting point for an integrated intelligent system that integrates data from satellites, sensors on the ground and drone campaigns to measure, derive and predict environmental indicators aimed at monitoring the environment from the perspective of smart cities and assisting policymakers in assessing the impact of and selecting the most appropriate interventions.

The use of machine learning and artificial intelligence techniques for integrating data and building predictive models further demonstrates the project's strong scientific content.

ESA-Tor Vergata Agreements – 2012-2021

In 2021 the Memorandum of Collaboration (MoC), between ESA and the University of Rome Tor Vergata was signed, to jointly support the creation of the ESA_Lab@UNITOV. The lab creates an institutional link between academia and the ESA ecosystem using a cooperative based approach, leveraging on the virtuous exchange of competence and scientific expertise between the parties.

In particular, the participants will collaborate to promote topics of research relevant for both parties, to disseminate knowledge and to create pedagogical materials for the Tor Vergata University students, organizing seminars, conferences or events connecting academia and space related topics, stimulating other industry or academic parties in actively contributing for the development of the space industry, with the aim to support European identity and cohesion to foster the growth of the space sector.

DestinE and Weather Prediction (ESA, EUMETSAT and the ECMWF's data centre in Bologna) – 2021

Moreover, as part of the DestinE programme, the Agency will work alongside the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) and the European Centre for Medium-Range Weather Forecasts (ECMWF) with its new data centre in Bologna, opened in September 2021.

In particular, these organizations will jointly cooperate on the launch of two digital twins: the Digital Twin on Weather-Induced and Geophysical Extremes, which will provide capabilities and services for the assessment and prediction of environmental extremes; Digital Twin on Climate Change Adaptation which targets the generation of analytical insights and testing of predictive scenarios in support of climate adaptation and mitigation policies at decadal timescales, at regional and national levels. The Commission (DG/CNECT) is providing 55 M€ funding for ESA for the first 2.5 years of the DestinE initiative.

Agreement between Italian Government and ESA (NRRP) – 2021-2022

On June 17, 2022, an Agreement was signed between the European Space Agency and the Department for Digital Transformation of the Presidency of the Council aimed at implementing the development program of the "IRIDE" satellite constellation, which will become the most important constellation of satellites in low orbit for Earth Observation in Europe, and of which ESA will be the implementing body. With an investment of around 1 billion euros allocated under the PNRR, the new constellation will be built in Italy and completed within five years. It will also be used in support of the Civil Protection and other Administrations to implement measures against hydrogeological instability, for the protection of coasts and to fight fires, monitoring of critical infrastructures, air quality, meteorological conditions; it can also provide analytical data for the development of commercial applications by startups, small and medium-sized enterprises and industries in the sector. As part of the same Agreement, a Space Transportation Project Component was signed with the Italian Government, this last aimed at developing key technologies for cryogenic stages and new green launch vehicles through an approach based on flight demonstration at cryogenic engine, stage, and system level.

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