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Att.: ESA EO Strategy 2040
Paris, 11 June 2015
(Original: English)

EUROPEAN SPACE AGENCY

EARTH OBSERVATION PROGRAMME BOARD

ESA EO Strategy 2040

Summary

Delegations will find attached the ESA EO Strategy for the period 2015-2040.

Following the EO Strategy & Earth Explorer Implementation Workshop on 19 November 2014, and following the comments received at and after the 161st PB-EO meeting on 19 February 2015, a first consolidated revision of the Strategy was tabled as document ESA/PB-EO(2015)19 in the 162nd PB-EO meeting on 19 May 2015, for endorsement by ESA Member States.

In that meeting, Members stated welcomed the document, nevertheless providing numerous comments for clarification. This allowed the Chairman to conclude that "the Board had expressed its support on the general thrust and content of the paper, but that wording needed to be improved. A clean version of the document would thus be tabled for information in the coming PB-EO meeting".

The present second revision is the result of the here-above process. The ESA EO Strategy 2040 will form the basis upon which future programmatic proposals will be prepared, inter alia in the C/M-16 context.

Required Action

Delegations are invited to take note of the present Strategy paper.

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ESA Earth Observation Strategy 2040

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EXECUTIVE SUMMARY

The vision of ESA is to enable the maximum benefit of Earth observation for science, society and economic growth in Europe, served by European industry.

ESA will implement this vision through its Earth observation programmes, working in close cooperation with Member States, the EU, EUMETSAT and European industry within the widest international framework.

Since the decision to build the first ERS satellite the EO programme has seen a period of constant growth and great success, particularly during the last ten years. The current document revisits the ESA Earth observation strategy in the light of significant changes in the global perspective on environmental and economic linkages; European developments in the European Union, EUMETSAT and elsewhere; ESA Membership; changes in industrial competence in Europe and worldwide; a revolution in information technology and data gathering; science which is ever more responsive to the need for excellence, innovation and relevance; and global competences in Earth observation. The successful development of the Copernicus programme designed originally mainly for environmental and security applications has been the most significant change in European EO data delivery. It offers for the first time an open data source with an unprecedented repeat acquisition rate and guaranteed data continuity for at least 14 to 24 years, and probably much longer.

Given past successes an evolution is proposed which adapts to new societal, political, technological and economic challenges today and in decades to come. This approach embodies several new aspects:

- It consolidates the mechanisms needed to respond to a wide range of societal and institutional challenges deriving from major European players: these include the EU, responsible for creating sustainable Earth observation services, supporting EU policies; EUMETSAT with its missions for operational meteorology and increasingly oceanography; Member States' national programmes; and commercial and service industries, including some outside the conventional space sector, investing in Earth observation.
- The scientific rationale of the Earth observation programme will be driven by societal needs in combination with scientific excellence and innovation.
- It responds to the ICT revolution that offers new opportunities in data management, communications, citizen science and data integration to serve wider and more diverse user communities.
- It recognises that economic factors are of increasing importance in decision-making, such that public programmes face a greater challenge to demonstrate both economic and strategic benefits to society
- The rising number of new and smaller Member States in ESA requires a new orientation to provide a new and attractive portfolio of actions.
- Rapid changes in the market in the space sector and in the information and service sectors, offering opportunities for export, innovation and competitiveness of European industry.

A programmatic approach is taken which is based on past success but which responds to the challenges posed by the 21st Century. It covers the period 2015-2040, with an interim review to take stock of progress in 2025.

1 A Vision for the Future

The vision of ESA is to enable the maximum benefit of Earth observation data for science, society and economic growth in Europe, served by European industry.

ESA will implement this vision through its Earth observation programmes, working in close cooperation with Member States, the EU, EUMETSAT and European industry within the widest international framework.

The ESA EO Strategy 2040 will help society to -

- **Observe:** develop and provide the observations to better understand the complexity of our planet and monitor its health
- **Understand:** enable improved predictions of the physical interaction of society with the Earth system
- **Decide:** inform decision makers and citizens on scenarios and consequences of political and economic decisions regarding our home planet

In implementing its strategy, ESA will act as an enabler, facilitator or leader in line with the ESA Convention and building on the strengths and experience of the Agency. Member States expect that ESA will continue to lead in innovation, technology development and risk reduction for the benefit of future EO missions in Europe.

The present document focuses on ESA's ambitions, its role and specific function in the activities to come in Earth Observation. It is nevertheless designed to be fully compatible with the strategies, ambitions and future activities of the other EO stakeholders in Europe, namely its Member States, the EU, EUMETSAT, industry, and the wider user communities. All these stakeholders are to be served by the present strategy.

The ESA EO Strategy 2040 will be implemented via a series of optional ESA programmes addressing the three main pillars served by this strategy, namely science and innovation, meteorology and Copernicus. Individual activities will be defined in partnership with Member States, with the European Union and with EUMETSAT. Underpinning all these is the technical and programmatic implementation of a Core programme, currently known as the Earth Observation Envelope Programme (EOEP), which will continue to provide the basic technology developments, to implement Earth Explorers missions and to develop the infrastructure necessary for exploitation of all classes of missions

These actions will be supplemented by individual elements, implemented today through the Earth Watch programmatic framework, representing more tailored opportunities for Member States, industry or other funding partners to invest in areas of specific interest to them. This strategy represents continuity, but also adapts to key challenges of the next decades.

ESA will reinforce its role as pioneer of technical development of Earth observation technologies, skills and communities to provide the best knowledge about the state of planet Earth, to the benefit of all EO actors in Europe. The research and development undertaken in the Agency will provide the core competence to underpin the development of missions satisfying the requirements of EUMETSAT and the EU and providing long-term sustainable observations of the Earth system. ESA will continue to work in direct partnership with the European science community in the progress of excellent and innovative translational science[1] missions. Security of access to data and continuing development of the different classes of user communities are further key components of the overall approach.

The successful development of the Copernicus programme has been the most significant change in Europe by allowing global data coverage every 5 to 6 days. This data access is open and free and guaranteed for at least 14 to 24 years.

The last ESA Earth observation strategy was written some twenty years ago and since then the overall EO programme has seen a period of constant growth and great success, particularly during the last ten years. Due to this unprecedented success the new strategy proposes a steady evolution to adapt to new societal, political, technological and economic challenges today and in decades to come. There are new features in this document to further develop Earth observation in response to new boundary conditions that represent new opportunities for Europe.

The concepts developed in this document include:

- It consolidates the mechanisms needed to respond to a wide range of societal and institutional challenges deriving from major European players, in a coherent and efficient manner. These include the EU, responsible for creating sustainable Earth observation services, to serve EU policies; EUMETSAT with its missions for operational meteorology and increasingly oceanography; Member States' national programmes; and commercial and service industries, including industrial players from outside the space sector, investing in Earth observation.
- The scientific rationale of the Earth observation programme will be driven by societal needs in combination with scientific excellence and innovation.
- It responds to the ICT revolution that offers new opportunities in data management, communications, citizen science and data integration to serve wider and more diverse user communities with innovative and responsive services.
- It recognises that economic factors are of increasing importance in decision-making, such that public programmes face a greater challenge to demonstrate both economic and strategic benefits to society
- The overall suite of programmes will respond to challenges in climate, environment, security, food, water and energy, where user communities are now much more sophisticated and mature.
- The rising number of new and smaller Member States in ESA requires a new orientation to provide a new and attractive portfolio of actions.
- Rapid changes in the market in the space sector and in the information and

[1] Translational science is the channel of communication between the user of EO data and users in the world of economic and societal applications.

service sectors, offering opportunities for export, innovation and competitiveness for European industry.

All these challenges require that ESA refines its role as the system architect for Earth observation in Europe, leading innovation while supporting the ever-growing Earth observation interests and programmes of European partners.

2 A CHANGING WORLD

2.1 The heritage of the Living Planet Programme

The last strategy for Earth observation in ESA has its roots in two documents created in 1995 and 1998 respectively (ESA/PB-EO(95)7, rev.2 and (98)13, rev.2) that gave rise to the concept of the Living Planet Programme. Up to this point, ESA's EO activities had proceeded through a sequence of individual missions (ERS, Envisat, Meteosat) with no guarantee of continuity and with any necessary ancillary activities supported through subsidiary programmes such as the EO Preparatory Programme and Earthnet. This gave no guarantee of sustainability or coherence. The development of the concepts of 1995 and 1998 represented a step change in the approach to Earth observation, an approach that continues to the present day. The current strategy builds on these very strong foundations in an evolutionary process, taking into account the changed circumstances of the last twenty years.

The advent of the EO Envelope Programme (EOEP) and the Earthwatch mechanism gave an approach that has served not only ESA and its Member States but also the remainder of the European Earth observation community well. It has seen the development of the series of world-class Earth Explorer missions, a major enhancement of ESA's partnership with Eumetsat and the advent of the series of Sentinel missions through the Copernicus programme led by the EU, a ground-breaking advance in the implementation of sustainable environmental missions. The Sentinel series also constitutes an important science resource, providing the long-term data sets needed by science and a sustained series of baseline observations against which novel measurements can be introduced at marginal cost, as already proposed for some Earth Explorer missions. ESA has been able, through EOEP, to consolidate the necessary technical developments for all these missions, to develop an integrated ground segment for delivery of data to all European users and to mount a significant and successful effort to engage the broader institutional and commercial user communities of Earth observation data.

The current document sets out a way forward that is evolutionary, based on the success of the Living Planet programme and its mechanisms that have served Europe well, but one which responds to the new challenges facing Europe. It recognizes the very significant evolution of the boundary conditions of the programme over that period, and proposes changes that will help target user communities more precisely.

2.2 A changing society

Society as a whole has an overwhelming appetite for increased access to resources. The world population will reach 9 Bn by 2050 and is expected to increase to 11 Bn by the end of the century. Together with an expanding global middle class, this would lead in the coming two decades to an increase demand for food, freshwater and energy of some 35%, 40% and 50%

respectively[2]. These are examples of the challenges facing society today. A successful response will depend on improved information about our home planet, placing those with access to the best information tools at an advantage.

But improved information on our planet also represents an opportunity for growth while responding to environmental pressures. For example, a McKinsey report[3] shows that some $3.7 trillion annual subsidies on water, energy and agriculture could be recovered if carbon were priced at $30 per tonne in an open market. These are issues that therefore are not only of environmental interest but also of major economic importance.

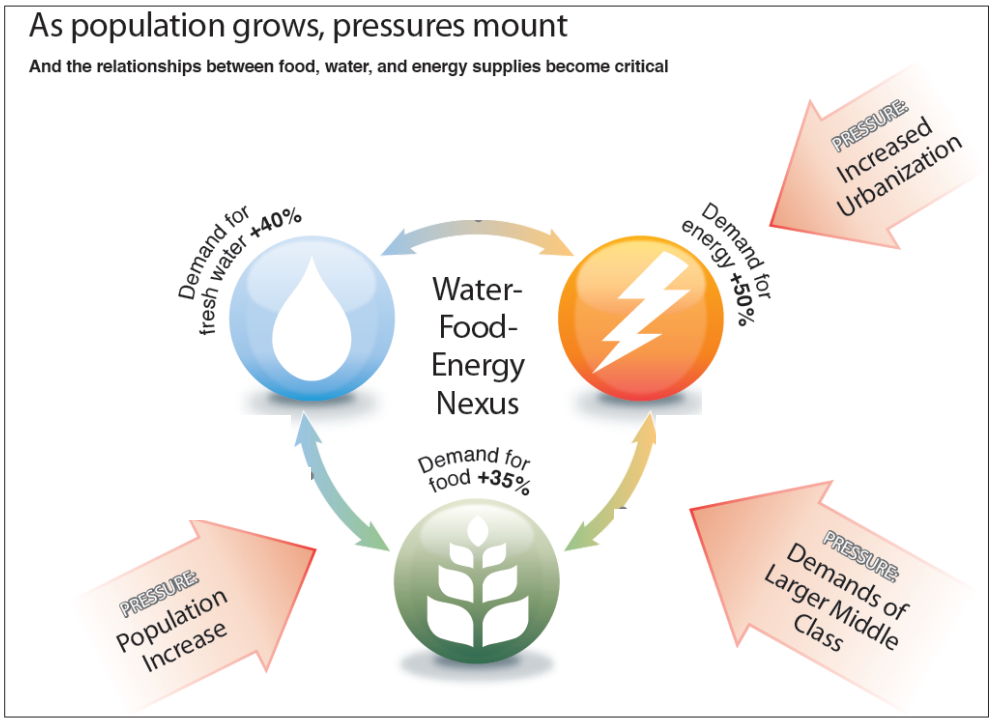

Fig. 1: Nexus of food-water-energy under pressure from increasing population, adapted from "National Security and Accelerating Risks of Climate Change", USA (2014).

Another recent report[4] prepared for the UN Climate Summit in September 2014 has highlighted the three most important factors in economy and climate as cities and urban growth, land cover, and energy. Energy issues can be addressed indirectly, and information on the first two is directly accessible from satellite platforms, with rapidly increasing capacity.

As a consequence, improved geospatial information, especially from satellites, will be of increasing importance in the coming years. The ability to provide the increased resources necessary for humanity will require support from these data.

[2] US National Intelligence Council, 2012: Global Trends 2030, Alternative Worlds.
[3] *McKinsey Global Institute, Sustainability and Resource Productivity Practice 2011.*
[4] *Global Commission on Energy and Environment, Sept 2014: www.newclimateeconomy.report*

2.3 A changing industry

European industry has developed with the arrival of new players and new technological capabilities, showing considerable strength in commercial EO activities. Small missions have become of great interest, and feasible, to a wide range of countries. The information technology infrastructure for Earth observation has changed in line with the more general and radical changes in information systems. The advent of global industrial players in geospatial data applications, the concepts of cloud computing and Big Data, broadband data diffusion, the ubiquity of mobile phones, tablets and other hand-held computing devices for acquiring and processing data have created an IT framework within which space infrastructure is increasingly embedded, and which needs to be reflected in the design of future data systems.

New industrial players are entering the satellite data market that is increasingly driven by information and service companies and not by the traditional aerospace industry. This is likely to give rise to a new paradigm for European industry. Although this will derive its impetus from the ICT sector rather than from the space sector, ESA nevertheless needs to take it into account in its developments in the coming years. This will require a partnership with European entities and governments for the incubation of new paradigms in the European IT field. The integration of such data into other forms of geospatially referenced, social and economic data for the provision of commercial services will become of primary importance. In addition, as environmental data become of greater economic importance it is possible that observations other than high–resolution land imagery – for example atmospheric composition measurements – may become viable through commercial sources. ESA will need to ensure that European industry is fully equipped to deal with any such developments both in the space segment and in the information sector. ESA plays a crucial role as catalyst for Member States in technology and service developments. The “Integrated Applications” of the new century are those which integrate the new ICT world, such as smart phone apps, cloud storage and broad band wireless, with space data and infrastructures so that the user sees only the result of a service without needing to recognise the underlying technology. Bringing space-based data alongside these capacities leads to an integration of space into everyday life and to increased opportunities and competitiveness for Europe as a society.

We have also seen the emergence of a much wider range of actors in the space environment. China in particular has become a major player, but other countries worldwide continue to develop national capabilities, particularly in Earth observation. Greater emphasis on international cooperation and the emergence of new organisations such as the Group on Earth Observations shows how international co-operation among agencies and with major institutional users has progressed. As a consequence major data archives, from within Europe and from the rest of the world, are now an important resource for the service industry. ESA will work to develop the capacity of European industry to deliver innovative and cost-effective services taking full advantage of these developments, working with other players both outside - chiefly in Copernicus services - and inside ESA to deliver integrated applications in society.. Coupling the technical innovation of EOP with new financial mechanisms is also an attractive prospect for European industry.

Euroconsult[5] has reported that over the period 2003–2012 some 164 Earth observation (EO) satellites were launched by civil government and commercial entities from 32 countries. This generated a total of $19.1 billion for the satellite manufacturing industry. The number is

4. Satellite-based EO market prospects to 2023, Euroconsult report (2014)

expected to expand to 360 satellites from 2013 to 2022, translating into $35.8 billion in manufacturing revenues over the period. New government and commercial entrants are also anticipated, with 42 countries expected to have launched at least a first-generation EO satellite by 2022. This creates a significant export market for European industry in terms of the manufacture of satellites (including small satellites), instruments and components, which ESA will support by developing with industry the necessary technologies. This will in turn create further opportunities of partnership between industry and ESA, for instance with the development of hosted payload opportunities on commercial EO satellites.

ESA therefore has a twofold responsibility towards industry: developing the technologies – hence retiring risks - and approaches to new mission configurations which will enable European industry to remain a strong player in satellite engineering, and supporting the integration of Earth observation data into the wider economic and social context for the development of appropriate markets and information services. In addition it will work with European partners, notably the EU, to establish the necessary regulatory and legal framework to further the development of commercial services based on Earth observation data.

2.4 A global approach to sustainability

Driven by the awareness of a need for better management of resources for the planet Earth, there has been a significant strengthening in the overall political framework which underpins global sustainability. Since the introduction of the Rio Conventions in 1992 much greater emphasis has been placed on the need for international cooperation in the pursuit of global goals for humanity. The Johannesburg World Summit on Sustainable Development (2002), the Millennium Development Goals, now transformed and given greater emphasis as the Sustainable Development Goals (SDG) of the UN, the Rio+20 Summit of 2012, the Third UN World Conference on Disaster Risk Reduction of 2015 and the gradual increase in awareness of the need for political action over climate change, especially since the publication of the Fifth Assessment Report (AR5) of IPCC in 2013, are all examples of the increasingly global approach being taken to environmental sustainability. Today, satellite Earth observation data are also in a position to contribute more significantly to these initiatives, with a much wider range of measurements sustained in the long term. There is also greater awareness of the role that satellite data can play.

In European terms, the requirements deriving from the above needs will be met through innovative Earth Explorer missions addressing novel measurements, or through integration of the needs into European user requirements for sustained environmental or meteorological missions. In the latter case the role of ESA is to translate, in conjunction with the EU and EUMETSAT, these user needs into mission and system definitions.

The increased importance assigned to Earth observation data by these global initiatives will be reflected in the ESA EO Programme, taking into account the wealth of international partnerships and cooperation mechanisms now available for coordinating the resources of space agencies worldwide. ESA will continue to play a leading role in these initiatives.

2.5 Enhanced European capability in Earth observation

A major success, arguably *the* major success, of the last decade for Earth observation in Europe has been the advent of the Copernicus Programme of the European Union and the development by ESA of the suite of Sentinel missions in support of it. Copernicus is the realization of a long held ambition to ensure continuity of observations for environmental and

climate monitoring from space, and is a much-envied model of co-operation aspired to by other nations.

In addition, the EUMETSAT programme has developed from a single geostationary programme to a complex system of both polar orbiting and geostationary missions covering a wide range of meteorological needs, supporting numerical weather prediction and climate research and services. These both represent long-term commitments to the provision of operational observations from space. ESA continues to provide technical innovation, mission design and implementation serving the needs of European citizens through these programmes.

These developments are of major consequence for ESA. Through these programmes Europe is uniquely placed to provide sustainable observations in support of environment, climate and meteorology. Europe is at the leading edge of provision of satellite Earth observation data worldwide through their implementation, with development undertaken by ESA.

2.6 The growth of translational science and innovation

Earth science has never been a discipline that could be regarded in isolation from the benefits which a greater understanding of the Earth system can offer to humanity. But there is today a specific recognition in the ESA EO Science Strategy (ESA/PB-EO(2014)38) of the need to consider the capability of satellite missions and the associated research to deliver a better understanding of the Earth system of demonstrable value to society. Sometimes referred to as translational science, this is a cornerstone of the scientific thinking of ESA. Missions supported through the future Core programme will need not only to fulfil the continuing criteria of scientific innovation and excellence, but also demonstrate the societal impact of improved understanding.

This is a common theme in science in the 21st Century. Programmes such as Future Earth of ICSU are posited directly upon the need for co-design of scientific research in a partnership between the science community and society more generally. This is also reflected in other major programmes such as the H2020 programme of the EC, where again societal benefits coupled with innovation figure largely in the criteria for selection of research projects.

This is entirely consistent with the approach taken by ESA both in its EO Science Strategy and in this document, and indeed previous Explorer missions have demonstrated their ability not only to deliver fundamental science of the highest order but also results which have immediate impact. The future strategy for ESA encompasses the increased requirements for science to be of immediate relevance to society, building on its past successes on this theme.

The increased emphasis placed on translational science in the EO Science Strategy is echoed in the specific thinking on science here, but also in the wider approach to the future EO programme and the relationship between science and society.

3 A UNIQUE ROLE FOR ESA

3.1 ESA at the Heart of European Earth Observation

Europe currently leads the world in the scope, coherence and content of Earth observation activities. These include not only those undertaken and funded directly through ESA, but also the operational programmes of EUMETSAT and of the EU (Copernicus), programmes of individual Member States and the increased capacity of European industry to undertake and deliver programmes funded by the public sector serving growing private sector and export markets. This has led to a broad European panorama of diverse activities covering the range of Earth observation.

As the European agency for space Research & Development (R&D) and innovation, ESA plays an essential role in the *definition*, *development*, *procurement*, and *evolution* of the European EO flagship infrastructures with the major institutional stakeholders, not only for Copernicus but also for meteorology. In addition, in the context of its own programmes ESA plays a key role towards its Member States to offer and coordinate the different solutions they may need in terms of space.

ESA acts as a space system architect of the overall European space assets, providing major European space partners with technical expertise and know-how in space to implement existing European space systems and drive their evolution. This role is offered by ESA to all stakeholders in Europe, providing an up-to-date mapping between the cumulative user demand and the cumulated offer in terms of Earth Observation capacity. This is an essential tool to design an efficient multi-disciplinary for the benefits of all European users.

The functions required for a system architect comprise a wide range of tasks across the different programme implementations, depending on individual governance. They range from the end-to-end mission development and exploitation life-cycle, to the translation of user requirements into mission and system requirements, system design integrating the space-ground-user value chain, industrial implementation of new requirements, the monitoring of performance and the provision of initial services as well as the animation of user communities for space data exploitation. All this in turn provides further opportunities by preparing the ground for investments in space by other actors.

Moreover, this integrated responsibility allows ESA to be reactive to Member States' or industry's requests associated to the development of small missions in a bi/multi-lateral cooperation for which ESA can act as broker, or play a substantial integrating role. The task of system architect will also enable ESA to fulfil a pivotal role as moderator of the system offer and demand in order to ensure a sound planning of space activities not only in Europe but also as part of a worldwide cooperation, for example through CEOS, CGMS and GEO.

3.2 The Agency of All Member States

Member States may have different rationales for investments in space, and more specifically in Earth observation, in particular for their investments via ESA. This requires that ESA be flexible in its offer to present a package attractive to all.

ESA must perform at least four roles on behalf of its Member States: (i) bring together human, technical and financial resources beyond the means of any single country, as required by the Convention, (ii) promote European capability, services and industry among

international partners, (iii) act as the national space agency for those countries that wish this, and (iv) providing the necessary technical development capability for the EU and EUMETSAT for meteorological and Copernicus programmes.

Earth Explorer-class missions will be implemented with a science- and innovation-led approach to selection. But ESA will also respond to a more varied suite of opportunities, through coordinating efforts of Member States and industry for small missions, international partnership hosted payload opportunities and so on. The programme will be more responsive, and flexible, in responding to the ambitions of Member States and in identifying opportunities for their satisfaction. The overall programmatic framework, set out below in Section 4, reflects the need for a more innovative response to new and more diverse mission implementation opportunities.

The current ESA EO 2040 Strategy also recognises that over the last twenty years there has been a significant increase in the implementation of missions by Member States, both in the numbers of missions flown and in the range of Member States which are capable of doing so. The ESA programme must reflect this and continue to underpin the development of relevant technologies for national missions. It also encompasses an overall European strategy for data management and operations which maximises user benefits while reflecting the diversity of investments made through national programmes.

Resonating with the wider interest in missions, ESA Member States also have a broader interest in data management, access and exploitation through the implementation of national and European services. These may also be conducted in coordination with, or funded through, other European programmes such as the EU Copernicus programme or the EUMETSAT Satellite Application Facilities.

For the entire range of activities listed above, the Executive will engage into a dialogue with Member States, to help realise national ambition and, in line with the ESA Convention.

ESA will further work with Member States to ensure that the investments made through the range of relevant programmes in data management and delivery remain cost-effective and serve their needs.

3.3 ESA as the Development Agency for EUMETSAT

The long-standing partnership for the development and provision of satellite missions in support of operational meteorology and climate approved by EUMETSAT Member States has been a cornerstone of the ESA EO programme since before the inception of the first Envelope programme. Europe will continue to implement part of a world-wide observing system with contributions to both polar orbiting and geostationary infrastructures. These will build on the heritage of Meteosat, MSG, MTG and MetOp and MetOp-SG. The current MTG and MetOp-SG programmes already foresee the provision of operational services until the late 2030’s and mid 2040’s, respectively, and it is expected that new developments will be required within the timeframe of this strategic view to extend and improve on the services provided by this generation of platforms.

It is hence foreseen that ESA, in partnership with EUMETSAT, will continue to offer development programmes to its Member States for next generation meteorological satellites systems and other missions required by EUMETSAT, initiating appropriate technology activities in time to support enhanced continuity of existing observations and timely development of new ones.

3.4 ESA as the Space agency of the European Union

The EU is responsible for development and implementation of many sectorial policies, including environment, climate, transport and civil security policies, and due to this the partnership with the EU is of primary importance to ESA. This co-operation in Earth observation, under the overall EU-ESA framework agreement on respective roles, has enabled the Copernicus programme and in particular the Sentinel series of missions which are a cornerstone of provision of environmental data for a wide range of users depending on accurate and timely information now and for the foreseeable future. Free and open access to Sentinel data will be a key factor in stimulating the European economy and improving decision-making in relation to life on our home planet. Sentinel data will also be critically important for scientific understanding of the earth system. Alongside ESA-owned missions, EUMETSAT and national missions in Europe, Copernicus is clearly a major pillar that will be served by the implementation of the ESA EO Strategy.

It is not necessary to repeat here the long established rationale for this partnership: it is clear that it will remain at the centre of ESA's strategy for the provision of sustainable observations from space for decades to come. ESA will continue the implementation of the Sentinel mission as defined, and will work with the EU to identify further requirements for the extension of the capabilities of the Copernicus space component both in time and in scope.

ESA will also seek coherence between the Earth observation programmes of the Agency and those of other sectorial policies of the European Commission, notably its Research and Innovation Directorate General. There is great complementarity between the ambitions of these programmes and ESA will work with the European Commission to ensure that their programmes have coherent objectives and implementation mechanisms of ESA are aligned to relevant EU programmes.

Over the period covered by this Strategy new needs for Earth observation may emerge from European policies. ESA will continue to assist the EU and European Commission in developing and implementing space-based solutions to address emerging societal and political priorities of the EU.

3.5 The Agency working with industry

3.5.1 Maintaining a world-class industry

The development and maintenance of European capacity in space, and more specifically in Earth observation, is a fundamental task for the EO programme. It is also critical for the agency itself, as without such an industry the rationale for ESA disappears. The EO programme must continue to provide a driving force for innovation and competitiveness of European industry across the board in relation to geospatial data; in the space segment, in the relevant data management competences and in the service sector. The progress of Earth observation in Europe continues to be inextricably linked with the capacity of European industry to deliver world-class technology, missions and services.

3.5.2 Space segment

As we have already seen, there has been a rapid increase in the numbers of Earth observation satellites launched worldwide. This has resulted in a strong market, both within Europe and for export, for European satellite and systems manufacturing industry. European industry is currently the world leader in the export of Earth observation satellites to third party countries, taking advantage of investments in technology through ESA. ESA will continue to support and reinforce this opportunity for Europe by the development of world-class technological capacity in European industry, addressing emerging techniques and markets. Industry is keen to be challenged by ambitious new developments: this approach will be underpinned by the integrated technology approach described in Section 4.3.1. Industry further expects ESA to provide a programmatic vision and framework which also includes and serves the market requirements. ESA will welcome partnerships with industry to achieve this end and will support the capacity of European industry to serve not only ESA programmes but national ambitions and commercial opportunities arising in Europe and elsewhere.. Concretely, ESA will inter alia seek with industry how to translate innovative scientific instruments developed as prototypes through ESA programs into competitive industrial solutions. Another key aspect will be the paradigm change brought by the advent of the massive constellation of low-cost EO satellites, for which a successful European industry-led solution will require further R&D support.

Special support will be provided to new industrial actors, especially with reference to SMEs and industry of new ESA Member States, which should participate in the development of the space segment according to their innovation skills. An evolution in project management approaches is part of the effort that will be deployed to cater for the different industrial competences, roles and backgrounds, particularly for the development of small satellites, which – through constellations and formations – can contribute dramatically to extending EO capabilities in terms, for instance, of improved spatial and temporal sampling of observations over the globe. ESA will support industry in appropriate responses to the needs of the full range of user communities, including the private sector, where intervention is justified

3.5.3 Ground segment and information systems

Ensuring full access to Earth observation data will continue to drive the ground segment. Fast, free and easy access to data from the full range of European and international missions is the cornerstone for success of the European service industry and for the success of the Earth observation programme more generally.

ESA will marshal the capacities of the European ground segment and data management industry to ensure a more cost-effective implementation for ESA programmes. In return, ESA will use its programmes to support industry to gain a leading edge and to generate commercially attractive offers to external customers.

The corresponding challenges reach beyond the immediate data handling tasks and encompass the broader IT environment. Wide data integration and the emerging technologies needed for managing Big Data concepts and crowd-sourced data, while addressing individual citizen interests, are becoming ever more important. The emergence of these more eclectic and complex information management challenges is a prominent feature of the IT world. The space sector is an important customer for data handling innovation in its own right, but also serves as a fertile test environment for European IT industry to exercise and demonstrate its capacity to develop new products and services. Synergies will be sought between IT

dissemination solutions and provision of services.

The constant evolution of data interface and cooperation standards will require a matching evolution of the architecture of space data management infrastructures in Europe. The formal definition and assurance of data quality, and the rights of data users in science and applications, will need to be maintained in this transition. A new Ground Segment Evolution Strategy pursued with European and international partners is being developed that will provide a reference in which engineering and new IT service technologies are merged to maximise the use and benefit of Earth observation data and engage entirely new user communities.

3.5.4 Service industry

Europe is already a strong player in the delivery of space based information services, and this capability will be of increasing importance in the future. With the increased interest in the use of environmental information in both policy and economic sectors, further development of the service industry in Europe will be a driver for expanding the overall exploitation of EO data. As we have already seen, this in turn creates new markets for both space and ground segment industrial activity. The service elements in the EO programme have been critical in developing and demonstrating the capacity to deliver solutions based on satellite data to a wide range of existing and potential customers. The ESA EO programme will continue to work with the European service industry to satisfy these needs in both public policy and commercial sectors and will continue to consult with the industry and the major institutional stakeholders in programme implementation.

Coherently with the document ESA/C-M(2014)5 “Draft Resolution on ESA evolution”, Chapter IV “ESA Relations with Industry”, ESA will be committed to support the growth of the EO services sector in a mature market place, with the appropriate engagement of the downstream sector in the definition of future EO missions and programmes.

ESA has an important role in the development of the capacity of the European service industry by supporting appropriate R&D for new services and applications. Through its partnership with policy agencies at the national and European level it can also help generate applications in new areas of increasing relevance, for example in the developing world, leading to opportunities for the European service industry. The implementation of reliable space-based and ground-based infrastructures which secure access to key data streams over the long term, together with guaranteed free of charge access to the data, provides the basis for the development of sustainable services by industry and allows their customers to have confidence in their long-term availability.

The service industry and its development remains the main driver for the extension of the overall suite of requirements, and hence of customers, of the space industry. It is the shop window of space.

3.6 International co-operation

As the organization that developed Europe’s meteorological, Earth science and environmental observing systems over more than four decades, ESA brings unique scientific and technical capabilities to global cooperative actions addressing critical societal challenges of the 21st century. A broad international partnership is instrumental in the delivery of the strategic

objectives of the programme, and co-operation with other agencies is vital in ensuring efficient and effective implementation.

International cooperation in the delivery of EO data continues to strengthen. With recent developments in many countries ESA faces a much wider array of potential partners and of potential customers for European technologies and services. The increasing use of thematic or virtual constellations, comprising carefully co-ordinated contributions from different space agencies, formation flying and physical constellations of systems from multiple agencies, satisfies the need for contemporaneous and coherent observations of different elements of the Earth system. ESA will also continue to pursue opportunities for substantive collaboration with other space agencies worldwide through such opportunities as hosted payloads and joint mission opportunities.

The societal benefits of EO are potentially greatest and most immediate in developing countries, notably in Africa. This is an enormous challenge but is facilitated by broad international partnerships, within which individual Member States and specific Services of the European Commission are responsible for the implementation of development and external aid policies. Future ESA programmes should therefore continue to support EO capacity-building in developing countries, by improving access to European EO data, tools, demonstration projects and by training. Such actions in developing countries will support the objectives of ESA Member States in relation to their development aid programmes.

International co-ordination on data standards, measurement traceability and metadata, and integration of data portals to achieve, in effect, a world-wide-web of well-documented, easily accessible EO data will be an indispensable requisite for quantitative higher level products and information from regional to global scales.

ESA will continue to work with partners such as GEO to establish authoritative requirements in the key areas of societal benefit to be derived from EO. GCOS has been a model for such a partnership in the area of climate, and this continues to be a great strength of the work of space agencies. The broader perspective afforded by GEO can benefit from a similar alliance, and ESA will work with GEO to ensure that the long-term strategy for GEO consonant with such an approach.

3.7 Meeting integrated European requirements

As the knowledge broker for space in Europe, ESA must take account of a wide spectrum of user needs, encompassing those of Earth science disciplines, industry, European and Member States national policies, European bodies, public and private sector users, Earth observation expert communities and the needs of applications and service developers. This calls for convening a broad range of partner and stakeholder organizations, representing the interests of these different user communities.

User needs are defined by a number of different organisations. Foremost in this respect are EUMETSAT and the European Union, who are responsible for the user needs of the meteorological and Copernicus operational systems respectively. This cannot be undertaken in isolation and requires an iterative process whereby user requirements are considered alongside technical capabilities, but may also be inspired by new technologies. Once user requirements are established, ESA has a key role in translating them into mission and system designs fit for purpose.

ESA has in addition a primary role in gathering and addressing the needs of innovative EO research and development user communities within Europe. Science and innovation remain fundamental drivers of the ESA programme.

The challenge for ESA is to develop a systematic approach that offers a coherent and efficient implementation of the space segment through the full range of European partnerships and programmes.

4 A STRUCTURED PROGRAMME TO DELIVER

4.1 Introduction

Through its overall EO programme, ESA shall act as overall system architect to develop relevant space-based solutions for Europe that collectively respond in the most efficient manner to EU policy priorities, to science challenges, to meteorological observation needs as well as to European industrial ambitions and requirements of European citizens at large.

The ESA EO programme shall provide a framework that remains fully compatible with an implementation involving different governing mechanisms and different funding sources, including ESA Member States, the EU, EUMETSAT, commercial or mixed public-private funding streams. The integrated content of the different programme elements reflects the need to provide underpinning technology development, requirements management, mission development and implementation, ground segment development and operations and service delivery, all within a coherent planning environment.

4.2 Overall programme structure and delivery

Without describing programmatic detail – this remains the prerogative of individual programme proposals – it is possible to describe the general framework for future programme delivery, and the broad outline of the content of each. The future suite of activities will comprise:

- an optional Core programme, building on EOEP, funded by ESA Member States *(section 4.3)*
- a continuation of the partnership with EUMETSAT, through the next generation of geostationary and polar orbiting missions, potentially augmented by more specific missions addressing e.g. oceanographic or climate needs *(section 4.4)*
- an extension of partnership with the EU, building on the current Copernicus Space Component Programme, broadly along the lines of the CSC Long-Term Scenario (REF) *(section 4.5)*
- a flexible implementation of programme elements to be implemented under the Earth Watch Declaration mechanism, addressing more specific geographical, technical, sectorial or industrial interests of Member States or opportunities in international cooperation. *(section 4.6)*

A reinforced dialogue with Member States and Industry will inform the implementation of this ESA EO programme

These are all familiar programmatic concepts but the contents may contain significant changes from those to date.

It is critical that the combination of all these different elements are managed in an integrated approach that takes into account the affordability of the sum of all programmes. The timing of the different elements must be managed to ensure that Member States are not presented with simultaneous calls for funding of different and competing programmes originating in different governances. This calls for overall programme coherence and management.

These mechanisms have a direct heritage from the current EOEP, programmes developed in partnership with the EU and EUMETSAT and small programmes developed under the European Earth Watch Declaration. This is a reflection of the their success over the last twenty years. The basic elements of the overall programme will be presented as appropriate to subsequent funding decisions, with specific proposals being made at that time. However, the overall framework is flexible enough to allow a range of possible implementations to be addressed, as appropriate.

4.3 The ESA Core Programme

EOEP will form the "Core" for all EO activities in the Agency. Its importance as a resource for technical innovation will grow as the operational programs served with technology developments, preparation studies and application developments multiply. It will comprise the following elements set out and discussed in greater detail in subsequent sections:

- Preparatory activities relating to innovative technologies, preparation for all classes of missions and instruments with increased support to European industry to strengthen its effectiveness in dealing with the new challenges of EO, including in the commercial world.
- Implementation of "Earth Explorer" missions, including operations, communally funded by Member States through the EOEP programme. The size, scope and rationale for such missions will be governed by the emerging conditions set out in each Call.
- Data acquisition, management, archiving and access to users in a rapidly changing ITC landscape served by European service industry.
- User engagement, application and service development addressing the new societal challenges, with ESA pursuing R&D and enabling new players to work together.

These elements have origins in the current Envelope Programme but will be oriented towards priorities set out in this document and future programme proposals based on priorities from partners and user communities. The basic technologies and services developed through the Core programme will remain the foundation for all future missions, no matter where the eventual programmatic locus may lie for their funding. This continues the heritage of the EOEP which has been the source of the early development of Explorer, Sentinel and meteorological missions.

A future Core programme could have options of 3, 4 or 5 years or some combination, for example a "3+2" scenario as implemented by the Science programme. A link to the frequency of Ministerial Councils may ease funding decisions. The magnitude, numbers and frequency of missions funded through the Core programme must be consistent with the level and timing of new funding decisions. Details of successive programme proposals will continue to be subject to, and learn from, reviews of the Core programme.

4.3.1 Technology development

In the coming decades we can expect there to be missions of many classes originating in response to a variety of requirements from science, institutional users and services, the needs of Member States and industry. A single coherent programme of basic Earth observation technology development will continue to provide the support for all these, including instrument development to a level appropriate to the eventual mission , for example through international or hosted payload opportunities. This provides advantages of efficiency, sharing of intellectual and financial resources, breadth of expertise and coherence across the European gamut. It will be integrated closely with other technology development programmes in ESA, particularly in the Technology Requirements Programme (TRP), to ensure an appropriate sharing of risk and intellectual responsibility and to ensure the best use of the overall resources of Member States. Continuous development in technology is needed not only to ensure the most innovative missions, but also for efficient mission implementation, early risk retirement and overall risk management.

This approach emphasises the role of ESA in providing the underpinning technology development in support of missions that could be implemented through any of the above programmatic formulations; by ESA alone, with European partners, in national programmes or by industry either alone or in partnership with public sector funding. This will enhance efficiency, flexibility and coherence in the overall range of missions to be implemented in Europe whether in ESA programmes or via other mechanisms.

4.3.2 Implementation of Science and Innovation Missions

A key element in the future program of ESA EO programme will continue to be the implementation of world-class innovative missions for scientific research and understanding. They will be fully funded through the Core programme, with selection against the set of criteria developed in coherence with the EO Science strategy. They will continue the heritage of both first-rank science and technical innovation already firmly established through the Earth Explorer series.

As set out in the EO Science Strategy (ESA/PB-EO(2014)38) these missions will reflect the need for progress in both the scientific understanding of the Earth system and the societal issues that drive the need for that understanding. They will reflect the strengths and capacity for innovation of European industry. .

Explorer missions will remain demonstrators for new measurement techniques that may lead to sustained implementation of follow-on missions through other funding sources. In such cases a funding model which could support a sustained implementation will be developed early in the life cycle of such missions.

4.3.3 Management of European data access and related infrastructure

As set out in an earlier section, the technical environment for ESA’s infrastructure and data management activities has evolved and will continue to evolve rapidly in the coming years. The EO programme will take account of this in ensuring access to data from both ESA and other mission sources for science, public sector and commercial users within an overall European framework for data access.

The approach will be one of integrated data access, including the provision of necessary tools, opens source toolboxes and new approaches to exploitation platforms and confrontation of data and algorithms. The implementation will take full account of the revolution in cloud data

storage and access, network capacity and data models that have taken place over the last decade and more.

ESA will continue to be responsible for the operations of its missions in the most cost-effective scenario. The feedback acquired by ESA through its end-to-end responsibility for the management of satellite missions is vital for it to be able successfully to undertake its role as the R&D agency for future systems. This will include the maintenance of data quality from ESA instruments and the development and implementation of data services appropriate for more integrated models of information management, coupling satellite data with a wider variety of other data sources. The maintenance of a long term, guaranteed data archive linked to the LTDP, particularly for the purposes of environmental and climate security, maintained at minimal cost and using latest technologies, will be a priority for the future programme.

4.3.4 User interaction, applications demonstration and service development

The permanent interaction between ESA and the user community in its entirety is a fundamental condition for ESA to map the desired global and efficient EO offer in the future.

Only by this dialogue with the user community the most appropriate mission operating schemes, data management needs, calibration/validation needs, engagement mechanisms, etc. can be identified while also supporting the interaction between user communities and programmes such as Copernicus.

It also supports the ongoing capacity building of existing and new users of EO based services in Europe and in markets across the world, notably in developing countries.

The use of big data streams is in a revolutionary phase far beyond but including Earth observation data. Many new application areas are developing and many “big players” from e.g IT, agriculture industry and insurances are starting to invest and search for partners. New big data methods like crowd sourcing combined with new internet based in situ sensors can be combined with satellite data to enable new services. To use this potential more investment in R&D is necessary in this field to bring necessary skills from different disciplines together. ESA will offer Thematic Exploitation Platforms for themes like geohazards, forestry, agriculture and food security.

The ESA EO programme has led the way in Europe by fostering ground-breaking advances in EO scientific methods, opening new fields of application, and developing fit-for-purpose services, through relevant elements of the EOEP, through the GMES Service Element for Copernicus, and through the Climate Change Initiative (CCI). These have proved to be not only wise investments in terms of delivering world-leading science and cost effective services in their own right, but also critical agents in promoting the use of space data and demonstrating the need for greater investment in the space segment. They have served to develop new user communities, to demonstrate the potential of space data applications and to build critical partnerships with major private and policy users of EO data in the EU, in UN agencies and in major commercial sectors such as non-renewable resource exploration.

In addition, multilateral development banks such as the World Bank are critically important partners in supporting a wide variety of geospatial services in the developing world. ESA will progress its successful partnership with them to ensure that satellite based earth observation plays a full role in delivering these programmes through the European service industry.

This approach will be enhanced in future by advocacy towards new user communities, and through greater partnership with those national and international agencies able and needing to

assess the full economic value of satellite data in the development and implementation of public policy. Environmental data will be of increasing importance in the underpinning of government decisions of economic consequence; ESA will support the development of new services to ensure that full value is derived from satellite EO data in this process, and to strengthen the competitive position of European downstream industry on the global service market. This will also require further effort to be invested to develop the necessary capacity in the user sector to ensure take up of EO services.

4.4 Programmes in cooperation with EUMETSAT

A major success of the ESA programme has been the establishment of a long-term partnership with EUMETSAT to develop long term, sustained observational systems for meteorology. This partnership serves today as role model for the cooperation with EU.

The initial objectives in support of meteorology have evolved and expanded, for example through the development of high precision altimetry missions with European heritage. ESA and EUMETSAT also cooperate in the implementation of the space segment of the Copernicus programme, under EU leadership.

ESA will build on these excellent foundations. Current plans for the development of MTG and MetOp-SG will continue to form the basis of cooperation and programme implementation throughout the period of the lifetime of this document. In addition, the next generation of both polar orbiting and geostationary systems will need to begin their development within the Core programme, and their implementation in follow-on programmes beyond MTG and MetOp-SG. Dedicated ESA Meteosat Fourth Generation (to continue from MTG) and MetOp Third Generation (to continue from MetOp-SG) programmes will require approval in approximately the 2029 and 2035 timeframes, respectively – with preparatory activities to be conducted in the previous five years within the Envelope programme.

The initial, pre-phase A technology to be developed for these missions, together with their Phase A/B1, will be supported through the Core programme.

It should not be excluded that additional responsibilities may be covered by a joint initiative of ESA and EUMETSAT, for example in support of dedicated climate missions, should the political and financial evolution demand this in the coming years.

4.5 Programmes in cooperation with the European Union

Current plans will allow the implementation of a full suite of Sentinel missions, but work will begin on the next generation through, initially, developments within the Core programme and in due course a dedicated Copernicus Second Generation Space Component programme.

ESA funding of the prototype developments for Copernicus first generation is now phasing out. Studies will start in 2017, within the next programme period (EOEP-5), for the Second Generation of Sentinel missions. This may give an opportunity for study of the further development of the Copernicus Space Segment into new areas. The development of the relevant prototypes with substantial ESA funding will start around 2020, which is also the year when decisions concerning the next Medium-term Financial Framework (MFF) of the EU will take place. This MFF period will cover the relevant elements of Copernicus Second Generation. This will entail further enhancement of the Copernicus partnership with the EU. Implementation of the space component is also undertaken in partnership with EUMETSAT

as above, but ESA will retain overall responsibility for the system architecture of the space component of Copernicus. The missions will, as already implemented today, respond to user needs based on EU policies and formulated by the European Commission, who will continue to lead the overall Copernicus programme. All these activities will be governed by the Copernicus Space Component Long Term Scenario as currently agreed.

As for EUMETSAT missions, the development of technologies and the early phases of missions for future implementation through Copernicus will be undertaken through the ESA Earth observation Core programme and coordinated with the European Commission.

4.6 A flexible response to new mission and service opportunities

The above two examples show how ESA has developed long-term partnerships - forty years and more - resulting in commitments for the development of very long time series of Earth observing satellites. But those so far defined do not span all the services that are already seen as important. Further services may be implemented through an extension of on-going partnerships - through an enhanced Copernicus programme, for example - or through partnerships with new entities like the Development Banks. Examples of applications sectors which might be addressed by specific targeted missions include:

- *Arctic services*
- *Food security*
- *Enhanced civil security*
- *Service missions in support of REDD policies*
- *etc…*

In addition, greater flexibility and responsiveness to the needs of Member States shall be accommodated in the future programmatic structure, improving the offer of ESA to Member States or other partners. Examples of potential interests are i:

- Small missions, down to the level of microsats/nanosats
- Opportunities with international partners
- Specific technological developments related to national or bilateral missions
- Programs aimed at serving specific communities of interest, either via the space segment or through development of specific services,
- Specific data management initiatives relating to cloud computing, Big Data or other such technologies
- Opportunities for development of technologies of interest to European industry in the export market
- Extended mission operations under specific arrangements
- Engagement with communities of interest of particular interest to groups of MS, either for geographical, programmatic or political reasons
- Programmes developed in partnership with industry or user-funded organisations, allowing also the development of public-private partnerships, that will be defined on a case-by-case basis by agreement between relevant Member States and the involved third parties

In particular, a small programme such as this could be used to encourage the development of very small satellites – 50kg for example, including debris avoidance – which could challenge industry to extend their capacity to new horizons. Small, ultra-low-cost satellites such as these are likely to be important in the delivery of cost-effective services in future, and a specific

initiative such as this could help European industry to develop their offer. It will also be a constructive challenge to ESA management processes. ESA will also investigate possible partnerships co-funded by governments and the European service industry to improve market take-up.

While some of the above activities could be implemented in the EOEP/Core programme context, others will be developed based on the current Earthwatch Declaration that offers a flexible and responsive framework. Proposals for Earthwatch initiatives need not be exclusive, or indeed even in competition since particular interests will likely appeal to different combinations of Member States and/or other partners such as industry. Such activities should only start once the programme is clearly defined and a sufficient level of funding has been achieved to allow successful completion of the defined objectives. It is important that the mechanisms for these options are able to respond in a timely fashion to opportunities as they arise.

4.7 Overall funding structure and compatibility among programmes

As already mentioned above, it is critically important to establish an overall coherent funding framework which takes into account the abilities of Member States to support multiple programme lines. This will ensure that Core, EUMETSAT and Copernicus programme funding calls are not in competition with each other at the same funding rounds.

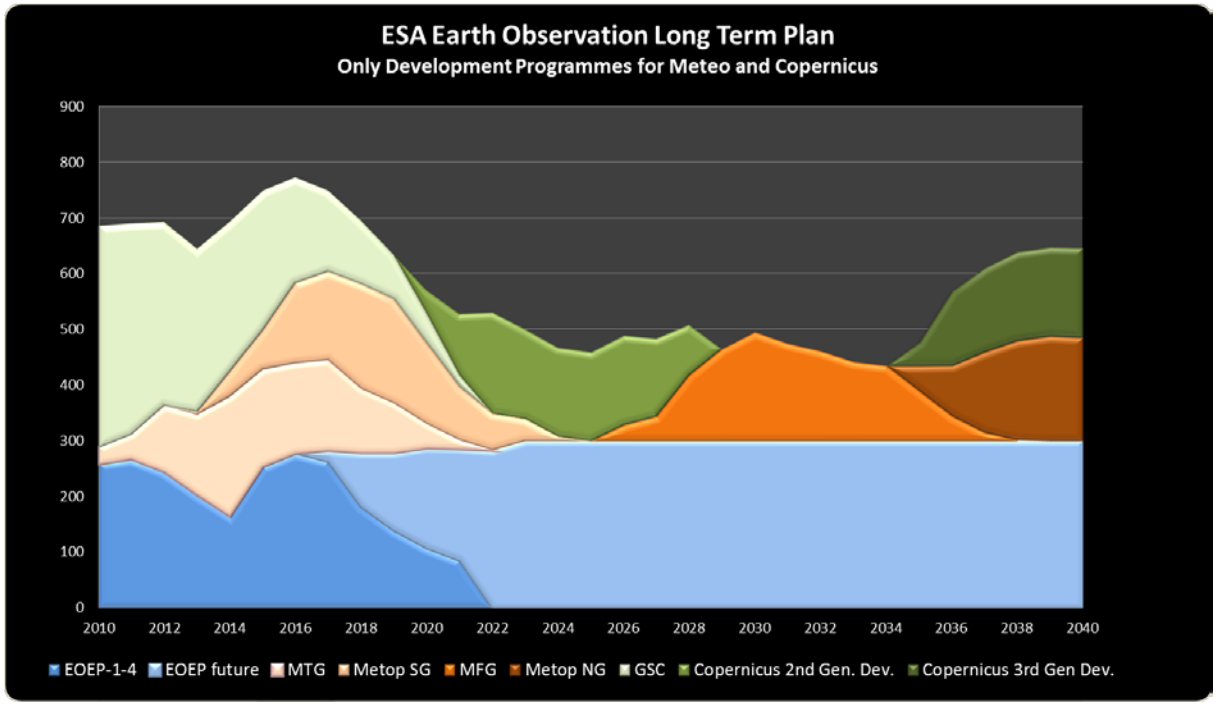

Fig 2. Schematic of ESA funding lines for the EO programme over the period 1980-2040.

Figure 2 above illustrates the future planned investments that are currently foreseen. The phasing out of the parallel funding cycles for MTG and Metop SG around 2020 and the serial funding need for the next generation of meteorological missions will make room for a strong core programme and the development of the prototypes of second generation Sentinel satellites.