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ESA/PB-EO(2019)44
Paris, 9 September 2019
Att.: Preliminary Definition of the Joint RTD-EOP Earth System Science Initiative
(Original: English)

EUROPEAN SPACE AGENCY

EARTH OBSERVATION PROGRAMME BOARD

JOINT EC DG-RTD/ESA EARTH SYSTEM SCIENCE INITIATIVE

Summary

The attached document, jointly prepared by the European Commission's Directorate General for Research and Innovation (RTD) and ESA's Directorate of Earth Observation Programmes (EOP), responds to the will and intention of both institutions to advance towards a reinforced and structured cooperation in the domain of Earth system science for the benefit of society, and in particular, to establish a joint programmatic initiative based on an effective alignment of selected scientific activities under future EC's Horizon Europe and ESA's FutureEO programmes.

In particular, the attachment provides a summary of the advances and the state of play in the definition of such an initiative. The description provided is based on both the on-going bilateral discussions between RTD and EOP as well as on the feedback and recommendation gathered during an extensive consultation process with different stakeholders including different RTD services, other DGs (e.g., DG-GROW), the scientific community and international and European partner organisations.

Required Action

Delegations are invited to take note of this document.

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Information Note

Preliminary Definition of the
Joint RTD-EOP Earth System Science Initiative

Jointly prepared by
EC's Directorate General for Research and Innovation (RTD) and
ESA’s Directorate of Earth Observation Programmes (EOP)

PURPOSE OF THIS DOCUMENT AND DISCLAIMER

This document, jointly prepared by the European Commission's Directorate General for Research and Innovation (RTD) and ESA’s Directorate of Earth Observation Programmes (EOP), responds to the will and intention of both institutions to advance towards a reinforced and structured cooperation in the domain of Earth system science for the benefit of society, and in particular, to establish a joint programmatic initiative based on an effective alignment of selected scientific activities under future EC’s Horizon Europe and ESA’s FutureEO programmes.

The document is supporting the preparatory work at the European Commission in DG RTD and in ESA in EOP to define a joint scientific programme in the domain of Earth Observation. It is by no mean a document that is committing or binding for ESA or the European Commission. In fact, the level of definition, even though rather advanced, is subjected to further developments and modifications depending on the approval and final content of both Horizon Europe and FutureEO programmes.

The following sections of the document provide a summary of the advances and the state of play in the definition of such an initiative. The description provided in terms of preliminary objectives, content and potential modalities of cooperation are based on both the on-going bilateral discussions between RTD and EOP as well as on the feedback and recommendation gathered during an extensive consultation process with different stakeholders including ESA’s Earth Observation Programme Board, different RTD services, DG-GROW, the scientific community and international and European partner organisations.

Special attention has been given to ensure that this new scientific initiative may complement and mutually valorise other relevant national, European national and international activities, including operational initiatives and programmes; e.g., Copernicus programme, its services, and the relevant activities in the future space research programme of Horizon Europe.

1. BACKGROUND

The European Commission's Directorate General for Research and Innovation (RTD) and ESA's Directorate of Earth Observation Programmes (EOP) have a well-established cooperation which has been forged over many years. This cooperation is intended to promote the use of Earth observation in the broad sense (i.e., satellite-based remote sensing, ground based measurements, citizen observations) for the benefit of research and innovation activities addressing different domains of common interest. It has been specially fruitful in areas such as Polar research, the alignment of strategies under the Group on Earth Observation (GEO), including, for instance, co-funding the Global Earth Observation System of System (GEOSS) portal enhancement, or the coordination of the RTD and EOP contributions to EuroGEOSS (the European component of GEOSS).

To build further on this work and responding to the strong interest of both parties to develop a closer cooperation, a joint RTD-EOP Working Group (WG) was set-up in 2017 to analyse the benefits and limits of the modalities of cooperation in place, to develop a strategic joint plan of activities for the period 2018-2020 and to provide recommendations to establish a solid long-term and well-structured programme alignment beyond 2020.

The joint WG concluded that EOP and RTD collaborative activities have demonstrated a high level of complementarity and synergy, with EOP actions and communities focusing on the EO component of science and RTD activities and stakeholders addressing a wider scientific scope and context, where EO may be a significant contributor. Such a complementarity offers a unique opportunity for Europe, its scientists, and citizens to benefit from a well-structured coordination of RTD and ESA activities to jointly advance Earth system science as a key driver towards a more sustainable and climate neutral society.

Key lessons learned drawn by the joint WG included:

- A key aspect for a successful cooperation is the existence of a common strategic agenda, which both institutions may adopt and pursuit in a coordinated manner, thus maximizing the impact and synergies of both programmes, while complementing existing ones (e.g., Copernicus programme and the space research programme of the EU).

- Another key element for success is to establish collaborative actions focusing on priority areas for both institutions supported by and based on a critical mass of current or planned activities on both sides, where the coming EO capacity could provide a significant contribution in terms of novel observations, innovative data products and scientific breakthroughs that may transit to the digital economy or impact the future evolution of operational information services (e.g., Copernicus services).

- RTD and EOP have different programmatic mechanisms, which operate in different timeframes and differing levels of flexibility, as well as the different procurement/grant frameworks and processes. These differences make current cooperation options rather non -trivial, limiting the potential to further advance in the programmatic coordination of activities and definition of synchronized joint actions. It was therefore decided to explore more structured approaches that may facilitate this process and provides both EOP and RTD with a suitable framework to mutually capitalize on the complementary expertise and synergistic capabilities of both institutions and programmes.

It was finally recognized by the joint WG that the great potential offered by a strong long-term alliance between RTD and EOP provides mutual benefits that goes well beyond the different activities jointly undertaken so far. It offers a real and unique opportunity to realize the common ambition to positioning Europe as a world leader in the domain of Earth system science for the benefit of society.

The coming decade will offer an unique occasion to realise that vision. The unprecedented synergistic potential offered by the coming EO capacity from space[1] will open new and unprecedented ways to observe, characterise and understand our planet, its processes and its interactions with human activities as never before. That exceptional holistic capacity needs to be unlocked, amplified with enhanced in-situ networks, citizen observations and existing geo-information data and services (e.g., Copernicus services)[2] and transformed into a deeper understanding of our planet as a tool to define alternative routes for society to transit towards a sustainable future.

Responding to these opportunities, it was strongly recommended by the joint WG to advance towards the definition of a common and ambitious Earth system science programme to be jointly implemented through dedicated elements of Horizon 2020 and the future EC's Horizon Europe and ESA's FutureEO programmes.

This recommendation have been adopted by EOP and RTD in a meeting held at Director level in ESA Italian premises (ESRIN) the 25th May 2018.

As a response, an Information Note describing the main elements of a Joint RTD-EOP Earth System Science Initiative in terms of objectives, content and preliminary modalities of collaboration was drafted by the joint WG and submitted to RTD and EOP Directors for approval in February 2019. The document has been them presented in different fora and discussed with different stakeholder groups. In particular the initiative was presented at the ESA Earth Observation Programme Board in February 2019 and at the EC H2020 - Space Programme Committee in March 2019.

In addition, a dedicated seminar jointly organised by ESA and RTD, took place in Brussels the 29th March 2019 to present and discuss the initiative with representatives of different services in DG-RTD, other DGs (e.g., DG-GROW), members of the scientific community (e.g., invited scientists, major international scientific groups such as the World Climate Research Programme,

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[1] *Including concurrent observations provided by the Copernicus Sentinels, ESA's Earth Explorers, the coming meteorological missions operated by EUMETSAT, novel EO satellites planned by national space programmes and commercial operators in Europe and additional complementary missions from international CEOS partners and new space actors worldwide;*

[2] *The Copernicus environmental services provide comprehensive decadal re-analysis and forecast of a wide set of Earth system variables, as well as derived thematic indicators, such as for the monitoring of the climate or the progress towards sustainable development goals.*

WCRP) and different European and international partners organisations (e.g., EEA, EUMETSAT, GCOS). Key messages from the seminar are integrated across the different Sections of the document (e.g., the need to ensure scientists may get full benefit from the coming EO capacity including satellites, in-situ and citizen observations, the importance of the Copernicus services for science, the key role of science as a public service, the need for EO and Earth sciences as a tool towards sustainability, the need to address the science gaps to better understand our planetary boundaries, the importance of new technologies such as Big data or AI for science, the need to reinforce the common scientific agenda with new topics, such as biodiversity, ocean health, acidification, upwelling areas, or science need associated to the global stocktake exercise of the Paris agreement and heath).

A dedicated Town-Hall meeting was also organised on 9th April at the General Assembly of the European Geoscience Union (EGU 2019) to present the initiative to the scientific community and discuss its preliminary scientific agenda.

Finally, the initiative was presented at the Living Planet Symposium, in March, where a dedicated Agora session was organised with the participation of the EC's Deputy Director General for Research and Innovation, Patrick Child and ESA's Director of Earth Observation Programmes, Josef Aschbacher. This action was supported by two parallel press-releases by ESA and EC respectively announcing the intention of both institutions to advance the level of the cooperation. Also, a joint RTD-ESA Agora session on Polar science was organise to discuss the potential modalities of cooperation and priorities for a coordinated ESA and RTD activity in 2020.

<u>This document provides a consolidated description of the main elements of the initiative based on the feedback and recommendation gathered during the above consultation process. It provides a summary of the advances and the state of play in the definition of such an initiative.</u>

2. RATIONALE

In the next decades population growth is expected to amplify current pressures on critical resources such as fresh water[3] or food[4], intensify the stress on land and marine ecosystems and increase environmental pollution and its impacts on heath and biodiversity[5]. These problems will be further exacerbated by global warming[6] and the likely impacts of climate change in the Earth system. These, including rising of the sea level, increasing levels of ocean acidification and more frequent and intense extreme events such as floods, heat waves or draughts, are expected not only to have a significant impact on critical resources, but mainly to endanger human lives and property, especially on most vulnerable populations[7].

Society is reacting to this situation requesting production processes more respectful of the natural resources and the transition of industry towards a decarbonised economy, while most governments worldwide have adhered to international regulations and global processes such as the *Paris Agreement on Climate Change*[8] and the *Agenda 2030 for Sustainable Development*[9].

Europe is also responding to this challenge. The refection paper, *Towards a Sustainable Europe 2030*, published by the EC in 2019[10], set up the vision to advance towards a sustainable EU within the next decade. At the same time, the EC communication *A Clean Planet for All*[11], explores a number of pathways that could be pursued for the transition to a net-zero greenhouse gas emissions economy by mid-century. This comes at the time where the global economy turns into digitalisation in an abrupt way departing from the traditional wealth creation of the 20th and 19th century and making information the fuel of our societies.

Achieving this vision will require a quantum leap in our capacity to observe, understand and predict complex and inter-connected natural and anthropogenic processes occurring at different spatial and temporal scales, where different interactions and feedbacks among different components of the Earth system and human activities have reached a scale where abrupt global environmental change can no longer be excluded.

Earth system science together with Earth Observations are expected to play a major role in this process. In fact, addressing the unique set of global challenges that society is facing at the onset of the 21st century and progressing towards a sustainable climate transition, requires more than ever that scientists advance their understanding of our planet, its processes and its interactions with human activities and translate that knowledge into solutions for society, policy advice and alternative pathways for development within safe and just planetary boundaries for humanity.

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[3] *http://www.worldbank.org/en/topic/water/overview (Access: 16.05.2017).*
[4] *World Bank, High and Dry: Climate Change, Water, and the Economy. Washington, DC: World Bank, 2016.*
[5] *The International Resource Panel, Food Systems and Natural Resources, 2016.*
[6] *World Economic Forum, Global Risks Report 2016, 11th Edition, Geneva, 2016.*
[7] *IPCC, 2014: Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp.*
[8] *https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement*
[9] *https://www.un.org/sustainabledevelopment/development-agenda/*
[10] *European Commission COM(2019)22 of 30 January 2019*
[11] *European Commission COM(2018)773 final of 28 November 2018*

Europe has now an unique opportunity to lead the global scientific efforts to address these challenges. In the next decade Europe will rely on the most comprehensive and sophisticated space-based observation infrastructure in the world, including an extraordinary and complementary suit of sensors on board of the Copernicus Sentinels series, the ESA's Earth Explorers, the coming meteorological missions and different EO observation satellites planned to be launched by national space agencies and private operators in Europe.

The unprecedented potential of this exceptional system of systems is far from being reached and the huge synergistic opportunities offered by the combination of the wide range of different observations that will be concurrently available in the coming decade are still unexplored.

This exceptional capacity need to be unlocked and further amplified by enhanced in-situ and citizen observations, complementary datasets from CEOS partners, operational organisations (e.g., EEA) and other initiatives and programmes (e.g., the Copernicus services, ESA's CCI), offering a suit of geo-information products and services with a significant potential for scientific use.

Ensure the scientific community takes full advantage from this unique opportunity and maximise its scientific and societal impact is urgent and will require a significant collaborative effort and an integrated approach to science where the synergistic use of EO satellite data, in-situ and citizen observations, advanced modelling capabilities, interdisciplinary research and new technologies will be essential elements.

This can only be achieved by promoting a strong programmatic and institutional collaboration in Europe, where different organisations and funding programmes bring together different expertise, data and resources in a synergistic manner ensuring that the final result may be bigger than the sum of the parts.

Both, the European Commission's Horizon Europe and ESA's FutureEO programmes, today under development, include dedicated provisions to support the scientific community to address these challenges, advancing our basic capabilities to observe and understand our planet and enlarging the foundational scientific knowledge that may boost novel solutions for society and strength the future capabilities of operational institutions or programmes[12]. The alignment of scientific actions funded under both programmes represents an unique opportunity for Europe to ensure that the complementary roles, expertise and funding of both institutions may serve a common purpose: **provide a coordinated response to the grand science challenges of the next decade.**

Sharing this vision, EOP and RTD has started a process to advance towards the definition of a dedicated initiative to be implemented building on EC's Horizon 2020 and ESA's EOEP-5 and on the future Horizon Europe and FutureEO programmes.

3. THE JOINT RTD-EOP EARTH SYSTEM SCIENCE INITIATIVE

3.1. OBJECTIVES AND BASIC PRINCIPLES

With this initiative, RTD and EOP aims at: *establishing an effective alignment of selected scientific activities under Horizon Europe and FutureEO in terms of goals, content, and planning to jointly advance*

[12] *E.g., the Copernicus programme and its services*

Earth system science and its contribution to respond to the global challenges that society is facing in the onset of this century.

In particular, the overarching goals of the initiative include:

- Maximise the complementary roles, areas of expertise and funding of EOP and RTD for the benefit of the scientific community and citizens, ensuring that the final result is bigger than the sum of the parts and contributing to reduce inefficiencies and fragmentation in the European research area;
- Joint efforts to ensure the scientific community get full benefit from the unprecedented, diversified and concurrent space-based EO capacity of the next decade and in particular across Horizon Europe, amplifying its scientific and societal impacts;
- Jointly contribute to unlock the full potential of the unique and unexplored synergistic opportunities offered by the coming European an international space-based EO infrastructure, specially, in conjunction with in-situ and citizen observations and existing operational geo-information data and services (e.g., from Copernicus services);
- Line up RTD and ESA scientific activities to expand our basic understanding of our planet, its processes and interactions with human activities, promoting science as an additional resource to meet pressing societal needs;
- Coordinate RTD and EOP efforts to accelerate the transition from science results into the digital economy, boosting novel solutions for society and contributing to strengthening national activities and expanding the services offered by operational programmes, such as Copernicus, in collaboration with DG-GROW and other relevant institutions;
- Foster the scientific excellence of Europe in the international scientific arena, providing an RTD and EOP coordinated contribution to major international scientific efforts, initiatives and programmes;

To this end, the following basic principles will apply:

- All activities shall focus on major scientific challenges and knowledge gaps in Earth system science that may contribute to respond to the urgent societal needs underpinning the European and global environmental and development agendas.
- All activities shall capitalize on the unique and unexplored opportunities offered by the coming space-based observing capacity complemented with in-situ and citizen observations, existing geo-information data and products (e.g., from Copernicus services), advances in modelling and digital technologies following an holistic and integrated approach to science.
- All activities shall ensure a multi-disciplinary and open science approach through collaborative scientific activities involving different scientific domains from Earth science and environmental research to social science, health or economics, where sharing data, results and knowledge is at the core of the scientific value chain.
- All activities shall capitalize on novel and emerging technologies as amplifier and accelerator of science, incorporating Big Data technologies, advances in ICT, Data intensive science, Artificial Intelligence, UAVs and other observing platforms (e.g., HAPs) leveraging on already existing tools, such as DIAS, as integral part of the available resources to boost the scientific output.

3.2. AMPLIFYING THE IMPACT THROUGH COLLABORATION

The initiative will not work in isolation but will complement, seed, cross-fertilize and mutually enrich relevant national, European and international activities and programmes. To facilitate this process, RTD and EOP will establish a series of Science Clusters (See Section 4) as the main mechanism to promote coordination, networking and scientific collaboration among the different ESA and RTD activities and other relevant programmes, projects and institutions. In particular, though the Science Clusters, ESA and RTD aim at:

- **Engaging national research activities**, projects and teams maximising complementarities and synergies. Dedicated efforts will be devoted to foster the participation of activities funded by Member States (MSs) though their national programmes as part of the scientific networking actions promoted through the Science Clusters.
- **Promoting networking** with other relevant initiatives and programmes in Europe: e.g., Copernicus programme and its services, European Research Council (ERC), GEOSS, EuroGEOSS, ESA's Climate Change Initiative (CCI).
- **Engaging with relevant public and private stakeholders**: e.g., operational agencies such as EEA or EUMETSAT, national space agencies and space offices, NGOs, representatives of the civil society, public institutions, economic operators or relevant local communities;
- **Fostering international collaboration**, establishing links with major international scientific programmes (e.g., WCRP, FutureEarth) and partner institutions (e.g., CEOS partners, NSF), capitalising on existing agreements or partnerships (e.g., Galway research alliance for Atlantic Ocean Cooperation, Copernicus international activities).
- **Ensuring coordination with other DGs,** with special attention to DG-GROW for all Copernicus and relevant space research activities under Horizon Europe.

In addition, collaboration with operational agencies and programmes will be an essential element of the strategy to speed up the transition from science into societal impact. Such a collaboration will be twofold, ensuring mutual benefit and complementarity: On the one hand, RTD-ESA activities may benefit from the scientific use of the wide range of geo-information offered by operational agencies and programmes: e.g., EEA, Copernicus services. On the other hand, the scientific results of the Initiative may contribute to further expand and reinforce the scope and capabilities of operational services in the future.

3.3. FOSTERING SCIENTIFIC DISCOVERY AS A TOOL

RTD and EOP will cooperate on the basis of a common Scientific Agenda identifying common goals and scientific challenges to be jointly addressed (See Section 6 below). Objectives will be pursued through coordinated actions addressing gaps and needs across the value chain of science, from scientific discovery to societal impact (Figure 1).

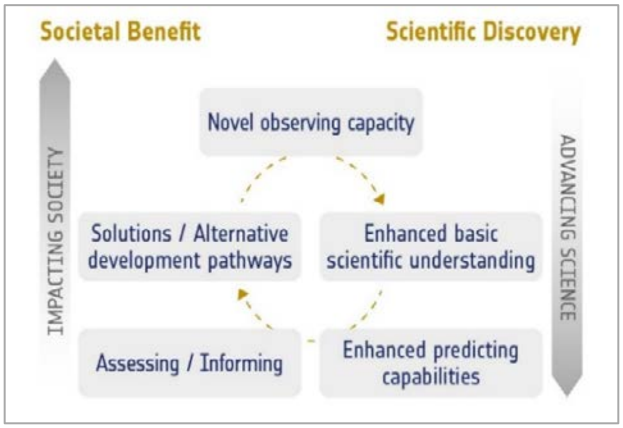

Figure 1. Value chain of science from scientific discovery to societal benefits

With this approach, expanding our understanding of the Earth system can play the role of a public service, where basic science is not driven by curiosity but represents a tool to design new solutions for society or identify development pathways within safe and fair planetary boundaries[13].

In particular, potential areas of cooperation, at present under discussion, may include[14]:

Advance our observing capacity: e.g., Advancing the scientific foundations for the next generation of EO space-based methods, algorithms and data products; Contributing to develop the next generation of fit-for-purpose observing systems that may integrate in an holistic manner advanced space-based observations, in-situ networks, citizen science and latest technologies (e.g., UASs); Supporting large-scale multidisciplinary field campaigns and experiments (e.g., supporting process studies or validation of new retrieval methods

[13] *Rockström, Johan, et al. "A safe operating space for humanity." nature 461.7263 (2009): 472.*
[14] *All activities shall be implemented in line with the coordination, collaboration and complementarity principles described in Section 3.2.*

and science results); Facilitate wide access to Earth observations (in the broadest sense) for science, capitalising on the latest developments in ICTs (e.g., European Open Science Cloud, DIAS);

Advance our basic understanding of the Earth system: e.g., Supporting large-scale scientific endeavours advancing our basic understanding of the complex interactions among the different components of the Earth system and human activities; Bringing together scientists from different sectors to jointly undertake far-reaching interdisciplinary research connecting Earth processes and society; Promoting large-scale scientific assessments of vulnerable ecosystems; Advancing the foundational understanding of the planetary boundaries (see Figure 2) and their associated knowledge gaps;

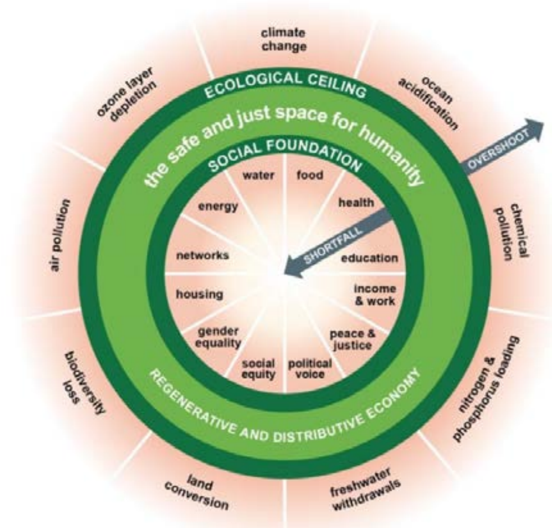

Figure 2. The planetary boundaries framework is based on a set of processes that regulate the stability and resilience of the Earth system and proposed quantitative planetary boundaries within which humanity can continue to develop and thrive for generations to come. Crossing these boundaries increases the risk of large-scale abrupt or irreversible changes.

Advance models and predictive capabilities: e.g., Advance physical–based model descriptions and parameterizations of complex not-well resolved processes; Enhancing modelling capacity to assimilate multiple and new satellite data sources; Exploring the potential of AI to complement physical based models;

Synthesis, informing society and knowledge dissemination: e.g., Promoting scientific advice to policy and decision making ensuring scientific results are reported though dedicated synthesis reports providing accessible and comprehensive information; Support wide-spread know-how, education and skills in Europe with major focus on higher education and early carrier scientists; Supporting a wide communication of scientific results to the general public promoting scientific knowledge within citizens.

Designing novel solutions for society and alternative development pathways: e.g., Inter-disciplinary research to explore and design alternative development pathways to transit towards a sustainable and climate-neutral society; Involving early adopters (e.g., economic operators, public institutions, local communities) from the initial phases of the science process to accelerate the transition from science into actionable opportunities for society; Ensure the transfer of scientific results into operational contexts, through the relevant programmes and institutions (e.g., Copernicus services, national programmes, other RTD or ESA's activities).

4. PRELINIMARY MODALITIES OF COOPERATION & IMPLEMENTATION

The initiative will be based on a **co-programmed approach**, where both institutions may pursuit a common goal by ensuring the coordination of activities funded under their own programmes and respecting their own mandates, rules and procedures.

Priorities and resulting EOP's and RTD's Work Plan proposals will be submitted for review and approval/endorsement, as appropriate, by their respective MSs through the corresponding

programmatic governing bodies (e.g., ESA's Earth Observation Programme Board) following the provisions envisaged by Horizon Europe and FutureEO, respectively.

At this stage, four main mechanisms are under consideration as main elements of the implementation approach:

a. **Joint Planning Working Group (JPWG):** RTD and EOP will establish a joint planning and coordination body (e.g., in the form of a Working Group or Task Force) as the main mechanism to ensure the objectives of the initiative are reached. The Working Group will be co-chaired by RTD and ESA and comprise of ESA and RTD representatives from the relevant services. The JPWG will also meet as appropriate at the highest levels (Director level) to assess progress and provide directions.

   The JPWG address *inter alia* confidentiality, transparency and collaboration with other stakeholders (e.g., representatives from the scientific communities, other relevant DGs, relevant national, European and international programme and institutions). Coordination with MSs and other relevant stakeholders will be also facilitated through existing programmatic arrangements (e.g., ESA's DOSTAG) or dedicated bilateral or multilateral mechanisms. In this respect, special attention will be given to ensure a continuous dialogue and a regular exchange of information with DG-GROW.

b. **Common Scientific Agenda**: RTD and EOP will cooperate on the basis of a common Scientific Agenda. The Agenda, including a set of common scientific priorities, will be regularly reviewed and further developed through a continuous consultation process with the scientific community and relevant stakeholders (as above).

   The Agenda shall focus on ambitious scientific goals of common interest for ESA and RTD where an integrated approach to science (involving EO satellite data, in-situ observations, advancements in modelling, and interdisciplinary research) is needed to reach common goals (see Section 6).

c. **Flagship Actions:** As a response to the Scientific Agenda, a set of Flagship Actions will be defined to be implemented through a coordinated multi-year set of studies, projects and actions to be funded by both RTD and ESA following their own areas of expertise, competences and funding and programmatic mechanisms.

d. **Science Clusters:** The Initiative will further facilitate the dialogue, networking, cross fertilisation and coordination across different projects and teams making part of the Flagship Activities by establishing a number of Science Clusters focussed on common scientific goals and major scientific thematic domains. EOP and RDT will set up dedicated tools and mechanisms to facilitate collaborative research promoting and Open Science approach and fostering the sharing of data, knowledge and results among partners. Science Clusters will be open and inclusive promoting cooperation with additional science groups, national activities, international initiatives and relevant stakeholders addressing common scientific objectives.

5. PHASING

The initiative is proposed to be implemented following a phasing approach:

- Consolidation Phase (2019-2020): This phase, currently on-going, is focused on the definition of the Scientific Agenda in consultation with the scientific community and stakeholders, on implementing ad-hoc coordinated precursor activities building on Horizon 2020 and EOEP-5 and on exploring the alternatives and consolidating the modalities for cooperation and implementation mechanisms of the initiative.

- Pilot Phase (2021-2022): The Pilot phase will serve as a test bed for the Initiative. It will focus on an initial set of Flagship Actions to be launched by RTD and ESA taking advantage of the opportunities under Horizon Europe and ESA's FutureEO programmes.

- Full Implementation Phase (2023-2026): On the basis of the results and lessons learned from the Pilot Phase the Full Implementation Phase will be defined and launched in 2023.

- Assessment and follow-on (2027): This phase will be mainly dedicated to assess the progress and results of the initiative based on a thorough analysis of the scientific results obtained, dedicated KPIs and impacts and to define, if appropriate and agreed by both institutions, a follow-on of the programme in line with the RTD and EOP science strategies for the post 2027 period.

6. TOWARDS A JOINT SCIENTIFIC AGENDA

RTD and EOP are engaged in a process to define a common Scientific Agenda outlining the initial set of joint activities to be undertaken by RTD and ESA, especially during the early phases of the initiative (2021-2022).

In the following a preliminary, hence incomplete, set of scientific challenges under discussion (to be further developed) during 2019 and early 2020 is provided. They have been identified based on a trade-off analysis of different factors, with particular attention to the common priorities and converging interest between the proposal for the next EU's framework programme for research and innovation, Horizon Europe[15], and the EO science strategy for ESA[16] and its scientific challenges[17].

In particular, the following elements have been taken into consideration as key drivers to define the preliminary priority areas of the joint Scientific Agenda:

- Common priorities between EC's Horizon Europe, its clusters and areas of intervention and the scientific challenges of ESA's EO science strategy;

[15] *COM(2018) 436 final, 7-6-2018, Brussels*
[16] *https://esamultimedia.esa.int/multimedia/publications/SP-1329_1/*
[17] *https://esamultimedia.esa.int/multimedia/publications/SP-1329_2/*

- The scientific potential offered by the novel EO capabilities that will be available in the time frame 2021-2027;
- An analysis of the scientific challenges expressed by major international science programmes and initiatives (e.g., WCRP, FutureEarth) vs. the relevant EC's Horizon Europe priorities;
- Emerging scientific results and recommendations from precursor scientific activities and scientific consultation processes promoted by both RTD and ESA;
- Feedback and recommendations collected during the preliminary consultation process (e.g., seminar organized in Brussel the 29th March, Town-Hall meeting at EGU 2019).

The priority areas identified below will be further consolidated in the coming months. Other domains (e.g. energy, cities) may be included in the future as new potential areas for collaboration to be jointly developed.

Finally, a Table is included (see below) mapping the main relevant Horizon Europe's clusters and areas of intervention, ESA's scientific challenges and the preliminary elements of the common Scientific Agenda.

6.1. PRELIMINARY COMMON SCIENTIFIC PRIORITIES

Polar changes and global Impacts: *Enhance the observation capabilities, basic understanding and prediction capacity of the different changes taken place in Polar regions, the root causes of those changes, its interactions and feedbacks with the Earth and climate systems and its expected impacts from regional to global scales. Initial potential priorities include:*

- *Antarctic and Greenland ice sheets processes (e.g., surface and sub-surface hydrology), interactions (e.g., solid Earth, ocean, atmosphere) and impacts and feedbacks with the Earth system and climate;*
- *Arctic and Antarctic sea-ice processes, interactions (i.e., ocean-atmosphere-sea ice) and impacts on and feedbacks with the Earth and climate system (e.g., Arctic amplification, radiation budget);*
- *Arctic small caps, their processes and future evolution;*
- *Southern ocean and its interactions with the atmosphere, the Antarctic sea-ice and ice shelves, ocean biology and the planetary energy and carbon cycles;*
- *Freshwater fluxes in the Arctic and their impacts (e.g., ocean circulation, water, carbon and energy cycles, ecosystems and biology);*
- *Arctic land processes and changes (e.g. permafrost, snow, river/lake ice, anthropogenic factors) and its impacts and feedbacks with the climate system, natural ecosystems and local populations;*
- *Overcoming current observational gaps (e.g., space-based snow on sea ice, snow/ice albedo, heat fluxes, carbon fluxes, snow water equivalent, surface mass balance, southern ocean sea ice);*

Carbon cycle as a tool towards a carbon neutral society: *Enhance Earth observing capabilities (space-based, in-situ networks, citizen observations), basic scientific understanding and prediction capacity of the different components of the carbon cycle as a solid scientific basis to advance towards a carbon-neutral society. Potential priorities include:*

- *The terrestrial carbon cycle (pools and fluxes), its impacts and feedbacks with the Earth and climate system, anthropogenic factors, extreme events and vegetation stressors;*

- *The ocean carbon budget (e.g., air-sea fluxes, biological pump, inorganic component, land-ocean transports, ocean circulation component) and its impacts and feedbacks with the Earth system, climate and marine ecosystems;*
- *Methane emissions, its natural and anthropogenic sources and its future evolution;*

Regional and Local sea level: Local sea level is governed by different processes including the global sea level fluctuations, changes in land elevation, winds, coastal wave setup and ocean circulation patterns. Understanding those process and enhancing our capabilities to observe, characterize and predict local sea level is critical to better assess the potential for storm surges and coastal flooding, as well as projected frequency and duration of flood events at hypothetical sea level rise scenarios and inform vulnerable populations and local economies that might be affected by sea level rise.

Knowledge gaps in climate science and planetary boundaries: Enhance our observation capacity and advance our scientific understanding to overcome current knowledge gaps in climate research (with special attention to the science gaps associated to the Global Stocktake process of the Paris agreement and the knowledge gaps identified by IPCC) as well as the weaknesses and intrinsic uncertainties in the planetary boundaries framework, contributing to stablish a solid scientific basis to define a safe operating space for humanity based on the physical biophysical processes that regulate the stability of the Earth system: e.g., Clouds-aerosol interactions and impacts on the climate system; Stratospheric ozone dynamics and future evolution, Closing the planetary energy budget, Atmospheric chemistry and dynamics under a changing climate; Ocean-climate nexus; Addressing the science gaps associated to the Global Stocktake process of the Paris agreement;

Acidification: Concentrations of carbon dioxide (CO2) in seawater have been increasing measurably over the last 35 years. This absorption (sink) of CO2 into lowers the pH of the ocean with the potential to alter biogeochemical cycles and ecosystem function in the future. This gradual and long-term lowering of pH, termed ocean acidification, is measurable on multi-annual time scales. However, short-term episodic events can also occur (e.g., upwelling of low pH and potentially corrosive waters or ocean heat waves and compound events), which can have catastrophic impacts on marine life and ecosystems. Improving our ability to monitor and understand the ocean carbonate system, has therefore become a priority as the ocean continues to absorb carbon dioxide from the atmosphere.

Oceans health: The impact of multiple stressors on the ocean is projected to increase as the human population grows towards the expected 9 billion by 2050. ***Adaptation strategies and science-informed policy responses to climate and global changes are urgently needed.*** *Advanced observations and enhance scientific understanding of the ocean's role in the climate system and its responses to pressures and management action is fundamental for sustainable development. This will also contribute to the UN Decade on Ocean Science for Sustainable Development in support UN efforts to reverse the cycle of decline in ocean health and ensure ocean science can contribute to create improved conditions for sustainable development of the Ocean.*

Freshwater availability: *Enhance our observing capacity, basic scientific knowledge and predicting capabilities of the water cycle at global, regional and basin scales and its impacts on and feedbacks with the climate and Earth systems, food systems and society. Preliminary potential priorities include:*

- *Characterize the anthropogenic impacts on and feedback with the water cycle from global to local (basin) scales;*
- *Enhance our understanding of the climate impacts on and feedback with the water cycle, its trends and its variability from global to local (basin) scales;*
- *Advance towards a consistent set of novel water cycle observations (integrating space-based observations, in-situ networks, citizen science, UAVs) at spatial and temporal scales compatible with water management needs.*

Food systems under pressure: *Enhance our observation capabilities and advance the scientific foundations to support resilience of food systems and global agricultural productivity to impacts of climate change and other stressors, contributing to develop sustainable climate-neutral agricultural practices and transferring science advances to enhanced management tools. Preliminary priorities include:*

- *Advance yield forecasting, food production and agricultural models;*
- *Determining the response of crops and food production to many co-occurring stressors…*
- *Design sustainable strategies to respond to water scarcity and extreme weather events e.g. flooding, heatwaves, storms;*

Biodiversity and vulnerable ecosystems: *Improve our observation capabilities (including space-based, in-situ, etc..) and the basic scientific understanding of the natural and anthropogenic pressures on biodiversity and vulnerable ecosystems (e.g., coral reefs, costal ecosystems), the connections between biodiversity and ecosystem stability, ecological complexity and planetary boundaries as well as the ecosystem feedbacks to the Earth system. Preliminary potential priority include:*

- *Undertake a global assessment of coral reefs status and vulnerability to anthropogenic and natural stressors;*
- *Exploring the potential of the novel EO capabilities to better characterise and understand the natural and anthropogenic pressures on biodiversity and its connection with ecosystem stability within safe planetary boundaries.*

Extremes: *Enhance our observing capacity, basic scientific understanding and predicting capabilities of weather and climate extremes and their compound events in order to limit their effects on lives and livelihoods. Potential priorities include:*

- *Understanding and prediction of water extremes (draughts, heatwaves, floods) are their compound impacts (e.g., forest fires, land degradation and other natural disaster);*
- *Understanding and prediction of ocean extremes (hurricanes, storms, polar lows, marine heatwaves) and their impacts on the Earth system, society and marine and coastal ecosystems;*

<u>Geo-hazards:</u> Enhance our observation capacity, basic scientific understanding and modelling of the complex dynamic process driven geo-hazards (earthquakes, volcanoes) to prevent and reduce the loss of life, harm to health and the environment, economic and material damage from disasters as well as to improve the understanding and reduction of disaster risks and post-disaster lesson learning. Potential priorities include:

- *Advance towards an integrated dynamic model of the solid Earth connecting core-mantle and lithosphere processes with surface dynamics exploiting in a synergic manner space, airborne and in-situ gravity, geo-magnetic and seismic information;*
- *Advance towards an effective integration of volcano (earthquakes) multi-source observations (satellite, in-situ) and advance Earth system models.*
- *Advancing our undertaking and modelling of ionosphere processes and its interactions with solar activity in view of enhancing our capacity to better characterise and predict space weather and its impacts on human activities;*

<u>Health:</u> Improved understanding of health drivers and risk factors determined by the physical environment (e.g., pollution, climate change and other environmental issues). Preliminary priorities include:

- *Improved understanding of climate and environmental impacts on infectious diseases and cross-border health threats;*
- *Improved observations, enhanced scientific foundations and predicting capacity of pollution (e.g., air pollution) and its impacts on population health, ecosystems and food production.*

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The Challenges of the Cryosphere • *Challenge C1: Regional and seasonal distribution of sea-ice mass and the coupling between sea ice, climate, marine ecosystems and biogeochemical cycling in the ocean.* • *Challenge C2: Mass balance of grounded ice sheets, ice caps and glaciers, their relative contributions to global sea-level change, their current stability and their sensitivity to climate change.* • *Challenge C3: Seasonal snow, lake/river ice and land ice, their effects on the climate system, water resources, energy and carbon cycles; the representation of the terrestrial cryosphere in land surface, atmosphere and climate models.* • *Challenge C4: Effects of changes in the cryosphere on the global oceanic and atmospheric circulation* • *Challenge C5: Changes taking place in permafrost and frozen-ground regimes their feedback to climate system and terrestrial ecosystems (e.g. carbon dioxide and methane fluxes).* **The Challenges of the Atmosphere:** • *Challenge A1: Water vapour, cloud, aerosol and radiation processes and the consequences of their effects on the radiation budget and the hydrological cycle.* • *Challenge A2: Interactions between the atmosphere and Earth's surface involving natural and anthropogenic feedback processes for water, energy and atmospheric composition.* • *Challenge A3: Changes in atmospheric composition and air quality, including interactions with climate.* • *Challenge A4: Interactions between changes in large-scale atmospheric circulation and regional weather and climate.* • *Challenge A5: Impact of transient solar events on Earth's atmosphere.* **The Challenges of Land** • *Challenge L1: Natural processes and human activities and their interactions on the land surface.* • *Challenge L2: Interactions and feedbacks between global change drivers and biogeochemical cycles, water cycles, including rivers and lakes, biodiversity and productivity.* • *Challenge L3: Structural and functional characteristics of land use systems to manage sustainably food, water and energy supplies.* • *Challenge L4: Land resource utilisation and resource conflicts between urbanisation, food and energy production and ecosystem services.* • *Challenge L5: How limiting factors (e.g. freshwater availability) affect processes on the land surface and how this can adequately be represented in prediction models.* **The Challenges of the Oceans:** • *Challenge O1: Evolution of coastal ocean systems including the interactions with land in response to natural and human-induced environmental perturbations.* • *Challenge O2: Mesoscale and submesoscale circulation and the role of the vertical ocean pump and its impact on energy transport and biogeochemical cycles.*	***Polar changes and global Impacts:*** *Enhance the observation capabilities, basic understanding and prediction capacity of the different changes taken place in Polar regions, its interactions and feedbacks with the Earth and climate systems and its expected impacts from regional to global scales.* ***Carbon cycle as a tool towards a carbon neutral society:*** *Enhance Earth observing capabilities (space-based, in-situ networks, citizen observations), basic scientific understanding and prediction capacity of the different components of the carbon cycle as a solid scientific basis to advance towards a carbon-neutral society.* ***Local and regional sea level:*** *Local sea level is governed by different processes including the global sea level fluctuations, changes in land elevation, winds, coastal wave setup and ocean circulation patterns. Understanding those process and enhancing our capabilities to observe, characterize and predict local sea level is critical to better assess the potential for storm surges and coastal flooding, as well as projected frequency and duration of flood events at hypothetical sea level rise scenarios and inform vulnerable populations and local economies that might be affected by sea level rise.* ***Knowledge gaps in climate and planetary boundaries:*** *Enhance our observation capacity and advance our scientific understanding to overcome current knowledge gaps in climate research as well as the weaknesses and intrinsic uncertainties in the planetary boundaries framework, contributing to stablish a solid scientific basis to define a safe operating space for humanity based on the physical biophysical processes that regulate the stability of the Earth system: e.g., Clouds-aerosol interactions and impacts on the climate system; Stratospheric ozone dynamics and future evolution, Closing the planetary energy budget, Atmospheric chemistry and dynamics under a changing climate; Ocean-climate nexus;* ***Biodiversity:*** *Improve our observation capabilities and the basic scientific understanding of the natural and anthropogenic pressures on biodiversity and vulnerable ecosystems (e.g., coral reefs, costal ecosystems), the connections between biodiversity and <u>ecosystem stability</u>, <u>ecological complexity</u> and planetary boundaries as well as the ecosystem feedbacks to the Earth system.* ***Freshwater availability:*** *Enhance our observing capacity, basic scientific knowledge and predicting capabilities of the water cycle at global, regional and basin scales and its impacts on and feedbacks with the climate and Earth systems, food systems and society.* ***Food systems under pressure:*** *Enhance our observation capabilities and basic scientific understanding of the different processes taken place from regional to the field level to better characterise the climate, environment and anthropogenic pressures on food systems including their interactions on and feedbacks with the climate and Earth system.* ***Ocean Acidification:*** *Concentrations of carbon dioxide (CO2) in seawater have been increasing measurably over the last 35 years. This*	***Climate, energy and mobility …*** *The intersection of research and innovation on climate, energy and mobility will address in a highly integrated and effective way, one of the most important global challenges for the sustainability and future of our environment and way of life.* *4.2.1. Climate Science and Solutions: Effective implementation of the Paris Agreement has to be based on science, requiring continuously updating of our knowledge on the climate-earth system, as well as the mitigation and adaptations options available, allowing for a systemic and comprehensive picture of challenges and opportunities for the EU's economy. On this basis, science-based solutions for a cost-effective transition to a low-carbon, climate-resilient and resource-efficient society will be developed.* ***Food and natural resources: …****Human activities are exerting increasing pressure on soils, seas and oceans, water, air, biodiversity and other natural resources…. combined with climate change, humanity's growing demand for natural resources creates environmental pressures that go far beyond sustainable levels, affecting ecosystems and their capacity to provide services for human well-being. Meeting the goals of sustainable development, guaranteeing the production and consumption of safe and healthy food, promoting sustainable practices in agriculture, aquaculture, fisheries and forestry, ensuring access to clean water, soil and air for all, cleaning up the seas and oceans, preserving and restoring the planet's vital natural systems and environment requires that we harness the potential of research and innovation.* *5.2.1. Environmental Observation: The capacity to observe the environment underpins research and innovation for the sustainable use and monitoring of food and natural resources. Improved spatio-temporal coverage and sampling intervals at reduced cost, as well as big data access and integration from multiple sources provide new ways to monitor, understand and predict the Earth system. There is a need for a wider deployment, exploitation and update of new technologies and continued research and innovation to address gaps in Earth Observation (EO) …* *5.2.2. Biodiversity and Natural Capital. Improved understanding of biodiversity and ecosystems, the multiple services they provide and planetary 'boundaries' as well as solutions harnessing nature's power and complexity is needed to address societal challenges, to enhance sustainability and to attain the EU objective of 'Living well within the limits of our planet' by 2050….* *5.2.3. Agriculture, Forestry and Rural Areas …Integrated approaches are needed to promote the multiple functions of agro- and forest (eco)systems taking into account the changing context for primary production, notably in relation to climate and environment, resource availability, demography and consumption patterns…. Climate and environmental impact of activities in the primary sector; potential of agriculture and forestry as carbon sinks and for mitigation of greenhouse gas emissions including negative emissions approaches.*

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• *Challenge O3: Response of the marine ecosystem and associated ecosystem services to natural and anthropogenic changes.* • *Challenge O4: Physical and biogeochemical air–sea interaction processes on different spatiotemporal scales and their fundamental role in weather and climate.* • *Challenge O5: Sea level changes from global to coastal scales and from days (e.g. storm surges) to centuries (e.g. climate change).* **The Challenges of the Solid Earth** • *Challenge G1: Physical processes associated with volcanoes, earthquakes, tsunamis and landslides in order to better assess natural hazards.* • *Challenge G2: Individual sources of mass transport in the Earth system at various spatiotemporal scales.* • *Challenge G3: Physical properties of the Earth crust and its relation with natural resources.* • *Challenge G4: Physical properties in the deep interior, and their relationship to deep and shallow geodynamic processes.* • *Challenge G5: Different components of the Earth magnetic field and their relation to the dynamics of the charged particles in the outer atmosphere and ionosphere for space weather research.*	*absorption (sink) of CO2 into lowers the pH of the ocean with the potential to alter biogeochemical cycles and ecosystem function in the future. This gradual and long-term lowering of pH, termed ocean acidification, is measurable on multi-annual time scales. However, short-term episodic events can also occur (e.g., upwelling of low pH and potentially corrosive waters or ocean heat waves and compound events), which can have catastrophic impacts on marine life and ecosystems. Improving our ability to monitor and understand the ocean carbonate system, has therefore become a priority as the ocean continues to absorb carbon dioxide from the atmosphere.* ***Oceans health:*** *Enhance our observing capacity, basic scientific knowledge and predicting capabilities of the marine and coastal environment as well as the role of oceans, its impacts on and feedbacks with the climate and Earth systems, food systems and society. Preliminary priorities include: Ocean-atmosphere-biology interactions in the Easter Boundary Upwelling Systems (EBUS);* ***Extremes:*** *Enhance our observing capacity, basic scientific understanding and predicting capabilities of weather and climate extremes and their compound events in order to limit their effects on lives and livelihoods.* ***Geo-hazards:*** *Enhance our observation capacity and basic scientific understanding of geo-hazards (earthquakes, volcanoes) to prevent and reduce the loss of life, harm to health and the environment, economic and material damage from disasters as well as to improve the understanding and reduction of disaster risks and post-disaster lesson learning.* ***Health:*** *Improved understanding of health drivers and risk factors determined by the physical environment (e.g., pollution, climate change and other environmental issues).*	*5.2.4. Sea and Oceans.. Seas and oceans' ...and ecosystem ... is at risk because of the severe pressure from human and natural stressors such as pollution, overfishing, climate change, sea-level rise and extreme weather events. To prevent seas and oceans from reaching a point of no return, it is necessary to strengthen our knowledge and understanding in order to sustainably manage, protect and restore marine and coastal ecosystems and prevent marine pollution.... Technologies for the digital ocean connecting services and communities in land-based, climate, space and weather related activities...Better understanding of the role of oceans for climate change mitigation and adaptation.* *5.2.5. Food Systems ... Future food systems need to deliver sufficient safe, healthy and quality food for all, underpinned by resource efficiency, sustainability (including the reduction of GHG emissions, pollution and waste production). ... Food system mitigation of and adaptation to climate change...* ***Inclusive and secure society:*** *....further efforts are required to limit the effects on lives and livelihoods of extreme weather events which are intensifying due to climate change, such as floods, storms or droughts leading to forest fires, land degradation and other natural disasters, e.g. earthquakes. Disasters, whether natural or man-made, can put at risk important societal functions, such as health, energy supply and government.* *2.2.4. Disaster-Resilient Societies: Disasters arise from multiple sources, whether natural or man-made, including those from terrorist attacks, climate-related and other extreme events (including from sea level rises), from forest fires, heat waves, floods, earthquakes, tsunamis and volcanic events, from water crises, from space weather events, from industrial and transport disasters, from CBRN events, as well as those from resulting cascading risks. The aim is to prevent and reduce the loss of life, harm to health and the environment, economic and material damage from disasters, ensure food security as well as to improve the understanding and reduction of disaster risks and post-disaster lesson learning.* ***Health ...****The EU Pillar of Social Rights asserts that everyone has the right to timely access to affordable, preventive and curative health care of good quality. This underlines the EU's commitment to the UN's Sustainable Development Goals calling for universal health coverage for all at all ages by 2030, leaving no one behind, and ending preventable deaths.* *1.2.2. Environmental and Social Health Determinants: Improved understanding of health drivers and risk factors determined by the social, economic and physical environment in people's everyday life and at the workplace, including the health impact of ...pollution, climate change and other environmental issues; to reducing death and illness from exposure to chemicals and environmental pollution;* *1.2.4. Infectious Diseases:* Protecting people against cross-border health threats..., calling for effective international cooperation at EU and global level. This will involve prevention, preparedness, early detection...

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		1.2.5. Tools, Technologies and Digital Solutions for Health and Care: Health technologies and tools are vital for public health and contributed to a large extent to the important improvements achieved in the quality of life, health and care of people, in the EU.