European Space Sciences Committee

REPORT AND RECOMMENDATIONS TO THE EUROPEAN SPACE AGENCY MINISTERIAL COUNCIL 2025

"The only way to define your limits is by going beyond them" – Arthur C. Clarke

We emphatically urge Delegations to fully support the science–driven elements of the ESA Mandatory, Exploration, and Earth Observation programmes at CM25, whilst championing additional European investment in Earth Observation for security purposes.

At a time of rapid and disruptive geopolitical change, this is not just a funding decision but a strategic choice.

By investing boldly in ESA's science programmes today, Europe will position itself as a global leader in scientific discovery, as a guardian of our planet, a pioneer of the new space economy, and a beacon of inspiration for future generations, uplifting European aspirations for a better tomorrow.

Introduction and Summary

Established in 1974, the European Space Sciences Committee (ESSC) serves as Europe's **independent authoritative voice on space science matters.** Drawing on insights from our participation in ESA's science advisory bodies (SSAC, HESAC, and ACEO), briefings from the ESA Directorates (Science, Exploration, and Earth Observation), and analysis of the science components of the Director General's CM25 proposal – *and within the context of a rapidly evolving international space landscape* – we offer the following observations:

- **ESA Delivers** – The Agency boasts a distinguished legacy of pioneering scientific and technological breakthroughs. Recognised as a trusted and reliable partner, ESA remains at the forefront of expanding humanity's knowledge and technological capabilities in space exploration.
- **Science-led** – ESA's core strategy of integrating fundamental science and ambitious engineering drives both innovation and industrial capability. Upholding this model is key to sustaining Europe's 'discovery leadership' and downstream economic returns.
- **Strategically Aligned** – The CM25 proposals prioritise the following strategic imperatives:
  - *Expanding fundamental science at knowledge frontiers*
  - *Accelerating robotic/human exploration for tangible benefits*
  - *Advancing Earth system surveillance to deliver actionable climate insights*
  - *Strengthening European capabilities in critical technologies*
- **Mandatory Science** – This flagship programme probes *the nature of the Universe* – from the cosmic scale to the dawn of time – and seeks to answer *whether life is ubiquitous*. Its discoveries could *prove as revolutionary as those of Galileo and Darwin.* The Voyage 2050 element has been *designed by the science community* to achieve a new era of discovery beyond Cosmic Vision. *We emphatically endorse the critical financial uplift required to launch the former, whilst safeguarding the successful delivery of the latter.*
- **Human & Robotic Exploration** – Humanity's ambitions to advance off-planet rely on *'enabling'* science. At the same time, exploration is driven by *innate curiosity* that can only be fulfilled through *rigorous scientific discovery*. *We strongly endorse the programme's science-centric framework*, its *unified LEO/Moon/Mars research approach*, the *important role of European ground-based space analogue facilities*, and its *robust contingency planning for potential disruptions in key international partnerships.*
- **Earth Observation** – With the planet signalling *'Code Red'* for climate and environmental disruption, *flat-funding* risks eroding Europe's *world leading Earth Observation capabilities*. To meet the urgent demand for *actionable information, we argue that a funding uplift is in fact justified*. While the newly proposed *European Resilience from Space initiative* seeks to transform *critical spatial and temporal coverage* in pursuit of *security applications*, we stress that existing European programmes and planned developments *must not be cannibalised to support it*.
- **Global Leadership** – ESA's transformative scientific endeavours form the *cornerstone of Europe's space competitiveness*. Sustaining this leadership requires *strategic, long-term investment* to maintain the Agency's edge amidst *growing global challenges, competition,* and *emerging opportunities*.
- **Shifting International Landscape** – Current geopolitical events, *including uncertainties about US collaborative commitments*, threaten *key mission deliveries and European astronaut access to LEO and beyond*, underscoring the need for *greater European independence and resilience.* These challenges are a *call to action for ESA* – to seize the moment, through the development of *new European capabilities* and *reworked strategic alliances* to *secure European presence in space* and *to solidify its global scientific leadership*.
- **Disproportionate Impact of Underfunding** – All three proposals are *carefully crafted*; even marginal budget shortfalls would *disproportionately* degrade scientific returns and strategic outcomes.

Strengths, Opportunities, Aspirations, Results (SOAR)

Our analysis addresses the scientific **Strengths** and **Opportunities** of the programme proposals and identifies their forward-looking **Aspirations** and **Results.** Through this approach, we seek to set the ESA programme in the broader context of its **value for science, the benefits to European society, and the imperative to build upon and extend Europe's front-ranking global standing in the field.**

The broader case for supporting an **uplift in ESA science funding** – grounded in **scientific merit, societal benefit, and strategic necessity** – is presented in a companion document[1].

STRENGTHS

- Track record of delivery
- Scientific & technical excellence
- Pioneering missions with historic firsts
- Unique ground-based space analogue facilities
- Global leader in Earth Observation
- Advances fundamental knowledge & delivers societal impact
- Drives innovation via science-tech synergy
- Science-driven from bottom up
- Strong European leadership & global influence
- Inspires STEM talent & public engagement

OPPORTUNITIES

- Lead groundbreaking astrophysics & solar system discoveries
- Pioneer human and robotic exploration beyond Earth
- Serve societal needs through Earth observation & security
- Strengthen Europe's autonomy with cutting-edge technologies and capabilities
- Leverage partnerships to sustain global leadership
- Inspire innovation and foster synergies through scientific and industrial excellence

ASPIRATIONS

- Deliver missions that revolutionize humanity's understanding of the Universe, Solar System, and Earth
- Conquer new frontiers in human and robotic exploration off-planet
- Provide actionable information addressing critical societal challenges
- Excel as the most visionary, reliable, and cost-effective space agency
- Drive innovation through cutting edge missions and partnerships
- Inspire society and promote STEM through transformative discoveries

RESULTS

- Revolutionary science breakthroughs
- Pioneering mission firsts
- Human spaceflight advancements
- Critical intelligence to protect our environment and safeguard societal wellbeing
- Technological and economic dividends
- Strengthened European security and resilience
- Enhanced independence and autonomy
- World-class, future-ready workforce
- Inspired students and public
- Elevated global prestige and influence

[1] "ESSC – Uplifting ESA Science Funding II"
https://www.essc.esf.org/wp-content/uploads/2025/06/Uplifting-Science-II.pdf

1 The ESA Mandatory Science Programme

"Now is the time to understand more, so that we may fear less" – Marie Curie

1.1 Strengths

The ESA mandatory scientific programme forms **the backbone of the Agency** and its **related activities within the national agencies of the Member States.** The programme has a **legacy of scientific and technical excellence, leading the world in key areas of space science** with many **historic firsts.** It has generated a cornucopia of new knowledge and understanding about our Solar System and the Universe. In doing so, it has **established Europe as a world leader in space science.**

Landmark achievements include pioneering X-ray and gamma-ray astronomy, the first comet flyby and soft-landing missions, the first landing on Saturn's moon Titan, comprehensive mapping of the cosmic microwave background radiation, and revolutionary mapping of the Galaxy. Beyond these breakthroughs, the programme has contributed to a fundamental transformation in our understanding of solar-terrestrial interactions, redefined the frontiers of exoplanet research, and has validated critical enabling technologies for future gravitational wave detection in space.

Mission longevity provides exceptional return on investment, with several missions operating beyond twenty years and frequently delivering scientific results far beyond their original objectives.

The **symbiotic relationship between scientific requirements and technological advancement drives continuous innovation.** European industry has achieved **remarkable technical milestones,** including Gaia's unprecedented focal plane in space, with approximately 1 billion pixels across multiple detectors, and Euclid's record-breaking single detector, featuring 600 million pixels. Deep-space solar panel technology has been advanced, exemplified by the massive arrays of the JUpiter ICy Moons Explorer (JUICE), enabling future Jupiter and Saturn exploration. European industry pioneered silicon carbide use in space structures, producing Herschel's 3.5-meter mirror, the largest in orbit until the launch of the James Webb Space Telescope (JWST). This technology has been subsequently adopted across missions including Gaia, Euclid, JWST's Near InfraRed Spectrograph (NIRSpec), and the ESA Earth Observation programme's AEOLUS atmospheric dynamics mission, with applications extending to commercial terrestrial uses. Other spin-offs include higher-resolution digital mammography (derived from Gaia's sensors) and Arctic telecommunication satellites using JUICE's radiation-hardened power systems.

The programme operates on a **bottom-up approach, leveraging Europe's world-leading space science community** through the ESA science advisory structure, including the Space Science Advisory Committee (SSAC) and related Special Committees and Working Groups. This approach efficiently surfaces the best ideas while aligning the European space science community behind shared goals. Simultaneously, it upholds the ***'juste retour'*** principle, ensuring **fair industrial returns for Member States**, whilst successfully delivering missions at the technological frontier.

The CM25 programme's objectives encompass **completing Cosmic Vision** and **embarking on Voyage 2050,** providing a **comprehensive future blueprint** through a balanced portfolio of Large, Medium, Fast, and new mini-Fast missions, delivered in a cadence matching anticipated funds and technological realities, as well as community goals. This framework promotes diversity in leadership distribution across Member States, while ensuring alignment with programmes of other major national entities, and accommodating the growing community of new nations entering space science. The programme's **"soft power"** projection makes Europe **highly attractive to high-profile scientists and engineers, fosters recognition and pride among European citizens, and plays a crucial role in inspiring STEM student flows, ensuring healthy talent pools for European academia and industry.**

Enhanced support for nationally provided payload elements contributes to cost and schedule stability, while reducing procurement risks through early industry engagement via parallel studies and technology development contracts. This approach **builds capacity in space-specialized companies** across Member States, while maintaining competitive processes throughout mission development, **positioning Europe at the forefront of global space science discoveries,** while securing the programme's continued scientific productivity and international leadership.

1.2 Opportunities

The evolving global space-science landscape presents **significant opportunities for ESA to strengthen its position** and expand its scientific leadership. These developments in the international space ecosystem enable ESA to emerge as a protagonist in pioneering scientific experiments, attracting world-class talent and cultivating leading figures in science while fostering **competitive and cutting-edge industry capabilities across Europe.**

ESA is positioned to **continue at the forefront of fundamental astronomy and astrophysics** through the **Cosmic Vision and Voyage 2050 groundbreaking L-class missions**, which will investigate the first instants of our Universe, observe the cosmos from temperate exoplanets to the Milky Way, and pioneer studies of the icy moons of giant planets. These missions will exploit investments made in key technologies developed by European industry for the JUICE mission, including advanced heat and power sources and radiation-tolerant systems. The future LISA space-based Gravitational Wave observatory exemplifies this opportunity, promising to open new discovery windows that could **revolutionize fundamental physics, astrophysics, and cosmology.** We strongly endorse ESA's continued development of the EnVision mission to Venus, and NewAthena, poised to deliver a transformative leap in X-ray astronomy, and fully endorse the identification of **Enceladus** as one of the most **scientifically compelling targets for astrobiology research.**

The programme aims to **maintain and enhance Europe's leading role in exoplanet studies** through PLATO and Ariel, complemented by access to the groundbreaking JWST. In addition, ARRAKHIS will achieve new **cosmological insights**, and the fleet of missions including BepiColumbo, JUICE, EnVision, and Comet Interceptor, MMX (led by JAXA), along with the ExoMars Rosalind Franklin and Mars Sample Return missions planned by the Exploration Directorate, will **open new windows on Solar System bodies, their evolution,** and potentially provide **unequivocal evidence of biosignatures on Mars.** We look forward to the selection of the next M7 mission from the candidates M-MATISSE (investigating the interactions between the solar wind and Mars atmosphere), Plasma Observatory (exploring Earth's plasma environment), and THESEUS (studying high-energy, short-lived events across the cosmos).

It is **critical to maintain operations** for ongoing missions that continue to deliver world-class science, including XMM-Newton, SOHO, Solar Orbiter, Mars Express, and Trace Gas Orbiter. Significant opportunities exist to maximize the stream of invaluable data and new science from the fleet of operational missions. The ability to maintain such missions, given their scientific productivity and cost-effectiveness, requires full consideration, especially given the growth of multi-mission science, where originally unplanned combinations of mission data are opening up new scientific frontiers. This approach maximizes return on investment and contributes to sustainability, while enabling discoveries not anticipated during initial mission planning.

ESA is uniquely positioned to strengthen its role as **partner of choice** for key missions of the next decades on the international stage, building on its proven track record of reliability and mission excellence. The changing geopolitical landscape presents opportunities to **develop new partnerships and diversify collaborative relationships beyond traditional alliances**, whilst ensuring programme resilience and delivery.

The programme has the opportunity to **strengthen European autonomy** and foster a more **robust industrial ecosystem** by addressing financial and geopolitical challenges through targeted financial and programmatic initiatives and optimizations. This includes enabling the ambitious scientific missions of Voyage 2050 and beyond via the development of cutting-edge technologies – such as cold atom interferometry, X-ray interferometry, cryogenic sampling and return, and solar sails – supported by intermediate demonstrator missions that validate these capabilities while expanding industrial expertise across Member States.

1.3 Aspirations

The CM25 proposal's aspirations focus on **maintaining leadership in space science** based on seven strategic goals aligned with the five goals of the ESA Strategy 2024, and characterized by **leadership in science, innovation, and resilience to challenges.** The ambitions of scientific communities translate into new technology challenges that European industries are eager to support, building capacity for European stakeholders and producing wider applications beyond space science while inspiring new generations to pursue STEM fields.

Corridor 1 of the programme entails **completing the Cosmic Vision programme**, which promises groundbreaking discoveries – from revolutionizing astrophysics, astrobiology, and gravitational wave research, to visiting a comet, probing the mysteries of Venus, and testing cosmological models. Building on this legacy, **Corridor 2** comprises **embarkation on the Voyage 2050 programme,** which represents the next ambitious leap. Meanwhile, the introduction of **agile mini-Fast missions aims** to establish innovative formats of cooperation with different stakeholders and new space actors across Member States, responding to requests for enhanced participation and visibility, while providing opportunities to develop **innovative implementation schemes.** The resulting technological challenges will push European Space Industry to **new standards of excellence**, creating conditions for an autonomous and technologically independent European Union while strengthening collaboration between Member States. This approach embodies the principle that **'today's science becomes tomorrow's technology, prosperity, wellbeing, and power'.**

A key goal is to **reduce European dependence in critical domains** – such as space access and key enabling technologies – **ensuring ESA remains a global leader in space science while securing Europe's strategic autonomy.**

1.4 Results

The Programme aims to **deliver world-class missions** covering a comprehensive range of space science topics, generating groundbreaking scientific production and maintaining Europe's position at the global scientific leading edge. It will provide new insights into the nature of the Universe, establishing pathways to future astronomy and fundamental physics through missions such as the NewAthena X-ray astronomy mission, and the recently adopted LISA mission, which aims to be the first ever orbiting Gravitational Wave (GW) observatory. LISA is designed to uncover the mHz regime of the GW spectrum, which is inaccessible with ground-based detectors. Thus, LISA is expected to generate revolutionary scientific insights, constraining our Astrophysical and Cosmological models.

Current missions demonstrate **Europe's scientific leadership** through EUCLID's dark energy exploration, JUICE's Jupiter system investigation, EnVision's Venus mapping capabilities, and SMILE's study of Earth's magnetosphere-solar wind interactions (in collaboration with the Chinese Academy of Sciences). Advances continue through SOHO's ongoing observations of solar activity, identification of over 5,000 Sun-grazing comets, and comprehensive space weather research capabilities, while missions like Solar Orbiter transform our understanding of solar dynamics and Earth's space environment interactions.

The programme will generate **substantial contributions to European prosperity** through multipliers that propagate to increase Gross Domestic Product, and potential uptake of new technologies, while more directly developing social capital, catalysing international relationships, and making European high-tech industry increasingly competitive on the world stage. Job creation, technological knowhow, and enabling scientific knowledge result from European company engagement in ESA missions, preparing tomorrow's workforce through young engineers and scientists entering STEM education inspired by current scientific and technological accomplishments.

ESA scientific missions serve as **pillars for the European scientific community**, fostering collaboration and creating communities around them, while cultivating a healthy and advanced space industry ecosystem. The programme's technological investments will yield spillover effects to other sectors beyond space, contributing to the creation of a sustainable and growing ecosystem of technological industry in Europe.

1.5 Observations and Recommendations

The ESSC recognizes the **ESA mandatory science programme** as a **high-prestige gem** of scientific and technical cooperation despite the complexity of coordinating the interests of 23 sovereign nations. With new national and commercial actors entering the rapidly evolving space ecosystem, we view this as the **opportune moment to build upon past achievements and grow Europe's capabilities in space science**, particularly during times of geopolitical and economic stress, when forward-looking science investments better position nations to prosper.

We explicitly endorse the programme, and strongly recommend that it is funded in full to complete the Cosmic Vision programme and launch Voyage 2050. We encourage additional future financial allocations to ensure that the Voyage 2050 programme is delivered as envisaged.

This is a **critical moment**. A reduced financial provision would risk a **"Desert Effect"** – a gap between the Cosmic Vision completion and Voyage 2050 mission commencement. This would **jeopardize capabilities and continuity within the scientific community, weaken its global standing, and diminish the programme's ability to drive excellence, attract talent, and inspire the public, potentially leading to significantly reduced European contributions to scientific advances in the 2040s.**

1.6 Comments and Recommendations concerning the NASA situation

Recent uncertainties in the NASA FY26 budget, if enacted**, would place at risk many ESA science missions** – including those in development, advanced implementation, or operation – through partial or complete withdrawal. While the Science Directorate is confident of its ability to mitigate the impact for 16 of the 19 affected missions using existing project flexibility and contingencies, **EnVision, LISA, and NewAthena** would require **additional mitigation strategies.** Though this development poses challenges, it also **presents a pivotal opportunity for ESA and Europe to strengthen autonomy and technological sovereignty.** By **leveraging the support of its Member States and Europe's robust space industry**, ESA can sustain and advance flagship science missions **independently.** Furthermore, it **creates opportunities to cultivate strategic partnerships with new collaborators**, while recognising the need to ensure resilience in an evolving space landscape.

2 The ESA Human and Robotic Exploration Programme

"It's human nature to stretch, to go, to see, to understand. Exploration is not a choice really; it's an imperative" – Apollo astronaut Michael Collins

2.1 Strengths

The **'Terrae Novae' Period 4 (E3P4) programme** proposal builds on a **legacy of scientific excellence and operational success.** Past achievements across physical sciences, life support systems, crew health, and astrobiology (highlighted in a companion ESSC publication[2]) position ESA as a **global leader in the field.** The programme guarantees the **continuity of core activities,** while introducing **new initiatives to strengthen European strategic autonomy and technological sovereignty.** Simultaneously, it **broadens opportunities for international collaboration.** Flagship new projects such as Low Earth Orbit Cargo Return Service (LCRS), ArgoNET, and small, independent lunar pilot missions, exemplify this **dual commitment to self-reliance and global partnership. Aligned with ESA's *Explore2040* strategy**, the programme delivers key elements for the three strategic destinations: Low Earth Orbit (LEO), the Moon, and Mars. **Its high-level goals are clear and compelling: to sustain human presence and utilisation in LEO, to enable European lunar exploration in the 2030s, and to prepare to take Europeans to explore Mars by the late 2040s.**

Science is central to these objectives. The programme embeds exploration science as a cross-cutting endeavour. Two complementary scientific streams underpin the implementation plan: **Exploration-focused science** aligned with mission-driven needs, advancing technologies critical for human exploration, whilst **Exploration-enabled science** is driven by scientific curiosity. Both streams follow a shared strategic roadmap with the **Exploration Preparation, Research and Technology (ExPeRT) programme,** ensuring coordinated development of enabling technologies and mission design.

In LEO, exploration-enabled science will **capitalise on the unique conditions of the ISS and other platforms such as free flyers (e.g., LCRS, Space Rider, CubeSats)** to deliver breakthroughs. Europe's well-developed portfolio of high-fidelity ground-based and diverse sub-orbital space analogue facilities will further amplify these efforts, helping translate space-derived knowledge into **terrestrial benefits.** Meanwhile, the Moon and Mars programmes will **drive scientific discovery, boost European autonomy and competitiveness, and inspire future generations.** After decades of orbital missions, surface exploration-enabled by mobility and in-situ assets like the **Argonaut lander and Rosalind Franklin rover** – will unlock new insights. The **LightShip programme** offers frequent Mars orbital access, supporting surface missions with complementary science and communications. Enhanced navigation and communications infrastructure will lay the groundwork for future human exploration.

A defining strength of this proposal is its **strategic flexibility.** In a shifting geopolitical landscape, it offers a resilient and adaptable European exploration architecture, upholding the principles of **Ambition, Uniqueness and Achievability set forth in the Seville Resolution and *Explore2040*.** Together, these elements make the Period 4 proposal a **forward-looking, science-driven, and strategically sound programme** – poised to deliver impact through exploration, innovation, and international collaboration.

2.2 Opportunities

The proposal offers a **transformative opportunity to secure and expand European leadership.** Realizing this vision demands **sustained investment across multiple programme periods.** The proposal advances this goal by strengthening **European autonomy** in critical domains, **mitigating mission and programmatic risks**, and **diversifying strategic and commercial partnerships.**

[2] ESSC brochure: "Human and Robotic Exploration Science Discoveries"

Europe's **world-leading** position in **analogue research infrastructure** is exemplified by the **ESA-DLR LUNA facility** at the European Astronaut Centre in Cologne. This cutting-edge lunar simulation environment provides unmatched capabilities for validating technologies, refining operational protocols, testing scientific payloads, and conducting Extra Vehicular Activity preparations. The facility will play a pivotal role in developing the Argonaut mission, evaluating rover mobility systems, training astronauts, and supporting scientific investigations. When combined with ESA's proven suborbital platforms – including **Parabolic Flight campaigns and Sounding Rocket missions** – LUNA completes a comprehensive, entirely European-controlled research ecosystem that substantially strengthens both exploration-driven and exploration-enabled scientific independence.

The development of **LCRS** through initial demonstration missions represents a strategic leap toward autonomous **European access and return capabilities in LEO**. This system will provide critical logistics services for the ISS and future post-ISS infrastructure, with the prospect of future human rating, cementing Europe's autonomous capabilities while maintaining its role as a reliable global partner.

Risk mitigation takes a significant step forward through the integration of **autonomous robotic platforms,** especially reusable free-flyers with docking capabilities. These systems offer dual benefits: superior microgravity conditions for scientific research and operational advantages that enable low-cost, low-risk access to space. Serving as both technology demonstrators and commercial platforms, they reduce reliance on human-tended systems while maintaining Europe's presence in LEO.

Future mission resilience to the Moon, Mars, and beyond will require accelerated development of European **Radioisotope Heater Units (RHU) and certified launch capacity for radioactive materials.**

The proposal strategically positions **LEO as a vital destination for exploration and science in the post-ISS era.** Europe's sustained LEO presence ensures continuity in crewed missions, advances research in human biology and physical sciences, and fosters collaboration with emerging commercial entities. European industry is particularly well-equipped to contribute to **Commercial LEO Destinations (CLDs)**. Innovative approaches like standardized "ready-to-fly" payloads will accelerate scientific experimentation across multiple platforms, driving agility and innovation.

For lunar exploration, the programme **expands Europe's autonomous infrastructure while honouring Artemis commitments through European Service Modules and Gateway contributions.** These efforts secure ESA astronaut participation in lunar missions and create new science utilization pathways. The **Argonaut lander marks Europe's transition from contributor to leader in lunar surface exploration,** supporting both independent and international missions with increasing complexity.

Mars exploration architecture synergizes **technological advancement with scientific discovery,** enhancing European capabilities in propulsion, power generation, and environmental understanding – critical steps toward human missions in the 2040s. The **ExoMars Rosalind Franklin rover** represents a watershed moment, demonstrating advanced robotics, autonomous systems, and heavy payload landing capabilities. Initiatives like **LightShip – ESA's proposed Mars transfer service,** present a major opportunity for technological development, scientific return, and international visibility.

Strategic alignment with both national and EU science priorities will optimize scientific outcomes while accelerating the development of Europe's commercial space sector.

2.3 Aspirations

Science forms the cornerstone of the E3P4 proposal, seamlessly integrated across all exploration destinations. The unique environments of LEO, the Moon, and Mars enable groundbreaking research in human health, life sciences, physical sciences, and planetary exploration. Simultaneously, targeted scientific and technological developments address the fundamental challenges of space exploration – from characterizing extreme environments to creating sustainable systems for long-duration missions. The programme's **dual scientific approach** balances strategic imperatives with scientific curiosity. **Exploration-focused science** directly supports mission needs through **environmental characterization, in-situ resource utilization, crew health research, and sustainable habitat development**, whilst **Exploration-enabled science** pushes the boundaries of knowledge across **physics, biology, human physiology, and planetary sciences.**

ESA's lunar strategy positions the Moon as both a **scientific destination and technology testbed.** Initial science missions will focus on: Systematic characterization of landing sites and lunar environmental conditions; Analysis of space radiation effects through ERSA and IDA instruments; Assessment of local resources including water ice and regolith. As infrastructure matures, the Moon will emerge as a unique platform for planetary science, astronomy, and future deep space missions, while preserving access to the Solar System's most ancient geological records. Martian exploration science pursues two parallel objectives: the search for evidence of past or present life, and the characterization of environmental conditions affecting future human missions. The **Rosalind Franklin rover mission represents a pivotal milestone**, establishing Europe's autonomous surface access capability while conducting transformative science. Key priorities include: Precise landing technologies for heavier payloads; In-situ resource identification and mapping; Atmospheric and geological studies informing human mission planning. ESA's Trace Gas Orbiter continues its decade-long legacy of world-class science and vital communications relay, while the future LightShip programme will extend these strategic capabilities.

2.4 Results

Period 4 will **cement Europe's position at the forefront of space exploration through world-class science.** The programme will drive transformative discoveries – from unlocking the secrets of astrobiology and planetary evolution to pioneering advances in precision medicine and quantum physics. The **microgravity and radiation environment** of LEO will enable deeper understanding of biological, physiological, and physical phenomena. Such insights will have **far-reaching benefits** for healthcare, advanced manufacturing, and materials development, directly contributing to Europe's innovation ecosystem and economic resilience.

Europe's cutting-edge ground and sub-orbital facilities – including our first galactic cosmic ray simulator, analogue habitats, and parabolic flight campaigns – form a comprehensive research network. This integrated system enables **early-stage science, risk reduction, and technology validation** while ensuring Europe maintains a full-spectrum of capabilities for exploration research.

Through Terrae Novae and the Argonaut programme, Europe is transitioning to a **key actor** in lunar exploration. The strategic development of service modules for Artemis and autonomous European landers will open new scientific frontiers – from cis-lunar research to surface operations and sample return. These capabilities will position ESA as both a key international partner and will **enable large European-led surface science missions.**

The Rosalind Franklin rover mission marks Europe's arrival as a **premier Mars exploration power.** Success will demonstrate end-to-end capabilities in Martian surface science while achieving the **long-standing search for signatures of past and present life.** Coupled with the **LightShip programme's orbital access**, Europe will possess unmatched flexibility – able to conduct autonomous missions or lead international collaborations. By fostering domestic expertise while maintaining global partnerships, the programme supports the development of **sovereign capabilities across destinations, reducing strategic dependencies.**

Through public engagement, educational initiatives, and international visibility, the programme will reinforce Europe's identity as a **knowledge-driven, globally connected society.** Outreach and STEM promotion activities tied to astronaut missions, lunar operations, and flagship Mars milestones will help **inspire young Europeans**, enhance media visibility, and boost public support for science and exploration.

2.5 Observations and Recommendations

The increased **budget allocation for research** clearly demonstrates ESA's strong commitment to **uplift science.** This not only reinforces the central role of science within ESA's overall mission but also sends a **positive signal** to the scientific community across Europe. Maximizing the value of existing infrastructure depends on selecting the highest quality scientific experiments. For exploration-enabled research, this requires open announcements of opportunity and independent peer review. In contrast, exploration-focused research will follow predefined objectives aligned with programmatic and operational goals, with invitations to tender issued to scientific institutions. Proposals will be evaluated based on quality, relevance, and cost. A continuous effort should ensure **a balanced portfolio between exploration-focused and exploration-enabled research**, as well as between **curiosity-driven** and **applied science**, within available resources.

Europe's ground-based space analogue facilities offer a **cost-effective platform for exploration-enabled science**, supporting both technology development and discovery. Integrating and strengthening these assets into ESA's exploration roadmap will enhance Europe's readiness, autonomy, attractiveness as a partner, and overall leadership. The unified approach across LEO, the Moon, and Mars provides strategic coherence, maximizing investment returns, and fostering technological continuity.

Europe must **sustain a vibrant scientific community,** maintaining momentum by leveraging existing and emerging assets such as ISS, ExoMars, and Argonaut. Ensuring access to commercial platforms in LEO and on the Moon is critical. **Close coordination between ESA's Science and Exploration directorates,** including advisory bodies like HESAC and SSAC, is essential. Given geopolitical uncertainties, **ESA should diversify international partnerships to mitigate risks while increasing self-reliance – a strategy we strongly endorse.** Accelerating European capabilities, such as launch and re-entry capabilities, RHU development and launch systems certified for radioactive materials, is essential for long-term autonomy.

The Rosalind Franklin mission's unique ability to detect extra-terrestrial life and advance European Mars exploration technology makes it irreplaceable. In addition, **we strongly support the ongoing actions by ESA to address the impacts of the potential cancellation of the Mars Sample Return campaign**, including the study of a **European-only ERO backup mission.** Any capabilities and knowledge developed and gained in the framework of MSR should be reused for **future sample return programmes (across ESA directorates).**

Despite geopolitical challenges, ESA's programme remains ambitious, timely, and well-prepared, with clear international relevance. We fully endorse it, and recommend unwavering support.

2.6 Comments and Recommendations specifically concerning the NASA situation

Potential changes in NASA's budget and future collaborative engagement models **put at risk ESA's core exploration activities, including access to LEO and beyond.** Whilst challenging, this **offers Europe a strategic opportunity.** ESA can redefine its global role by pursuing autonomy and multipolar leadership. The E3P4 plan aligns with this vision, fostering a distinct European identity while rebalancing international partnerships. The proposal prioritises contingency measures to **safeguard ESA's human and robotic space presence.** It also champions **non-dependence and diversified collaborations**, emphasizing the need for European-led key capabilities, alongside engagement with emerging global and commercial partners. In short, while U.S. uncertainties pose risks, they also underscore Europe's imperative to **assert itself as a strategic, autonomous, and science-driven exploration actor.** The proposal **strikes the right balance**: preserving critical cooperation where possible while advancing European resilience and ambition.

3 The ESA Earth Observation Programme

"Man must rise above the Earth, to the top of the atmosphere and beyond, for only thus will he fully understand the world in which he lives" (attributed to Socrates)

Earth observation (EO) satellites serve as **vital sentinels for human wellbeing**, providing indispensable data on climate change, environmental degradation, natural disasters, resource management, and food security. These capabilities extend beyond environmental monitoring to deliver crucial dual-use applications – **strengthening Europe's security** through maritime surveillance, border protection, and crisis response in conflict zones. As the cornerstone of this capability, **ESA's Earth Observation programme furnishes the critical intelligence** needed to simultaneously protect our environment, bolster European resilience, and safeguard the prosperity of citizens across the continent.

3.1 Strengths

Since its inception in the 1980s, ESA has **pioneered groundbreaking missions** that have revolutionized our ability to monitor Earth as an integrated whole, while transitioning scientific breakthroughs into operational services. **These achievements have established Europe's global pre-eminence in satellite remote sensing and Earth system science[3].** This science-first philosophy has been further strengthened through the **new ESA EO Science Strategy**, which forms the core foundation of the ambitious FutureEO programme.

The Earth Explorer (EE) missions, developed under the FutureEO framework, exemplify this leadership. From GOCE's precision gravity mapping and SMOS's tracking of soil moisture and ocean salinity, to CryoSat-2's polar ice insights, SWARM's decoding of Earth's magnetic field, Aeolus's pioneering global wind profiles, and EarthCARE's profiling of clouds and aerosols – alongside Biomass's mapping of tropical forest carbon stocks, the EE programme has consistently delivered first-of-their-kind scientific capabilities.

The upcoming generation of Earth Explorers continue this trajectory: FLEX will measure vegetation photosynthesis, FORUM will assess Earth's outgoing longwave radiation, and Harmony will reveal dynamic interactions at the ocean-atmosphere interface. The EE family will soon expand with EE-11 when either CAIRT (atmospheric profiles) or WIVERN (winds) is selected for implementation.

The EU Copernicus programme's Sentinel satellites, for which ESA has the responsibility of the space segment, form a central pillar of European Earth Observation. Beyond their operational environmental monitoring role, they have also delivered groundbreaking scientific value, advancing our understanding of the Earth system through initiatives such as the highly successful Science4Society open calls. **The Copernicus Expansion Missions represent an ambitious step forward, further advancing the scientific potential of the Copernicus programme.**

While **TRUTHS** will provide traceable radiometry for climate studies, **MAGIC** (Mass change And Geosciences International Constellation), will track changes in terrestrial water storage, ice mass, and global mass redistribution – **critical for understanding climate-driven hydrological shifts and informing adaptation strategies.** These missions are complemented by the low-cost, rapid-turnaround **Scout missions**, including **HydroGNSS, NanoMagSat and TANGO**, and a steady flow of new concepts, that are fostered under the **New Earth Explorer Missions (NEOMI)** initiative.

[3] The science discoveries and successes enabled by ESA EO satellites have been recently described in a companion ESSC brochure "Earth Observation Groundbreaking Science Discoveries" https://www.essc.esf.org/2025/01/21/news-eo-brochure/

The highly successful **Climate Change Initiative (CCI) and Climate Space programme** have generated long-term data records of Essential Climate Variables for international assessments, including IPCC reports. **This legacy provides a strong foundation for expanding developments within the new Earth Action Pillar of FutureEO**, including new activities for biodiversity, pollution, and built environments.

ESA's **integrated, science-led approach**, informed by its formal advisory structure (ACEO), and co-developed with the community through **Living Planet Symposia** (with more than 6500 participants in Vienna in 2025), User Consultation Meetings, and Open Calls, underpins both scientific innovation and societal value.

3.2 Opportunities

To nurture, strengthen, and deliver FutureEO; to ensure a community of **intellectually vibrant, scientifically and technologically capable researchers**; to deliver the **planned programme** of Earth Explorers, Sentinels (in collaboration with the EC), and meteorological missions (in collaboration with EUMETSAT); and to develop the levels of maturity of excellent EO candidate missions from which to select future EO missions. In doing so, to ensure that the **FutureEO programme** – including now the former CCI and Climate-Space initiatives – supports the ongoing needs of climate science, whilst addressing society's urgent need for **actionable information,** and at the same time ensuring European autonomy in space data acquisition and preservation.

In the current geopolitical situation, ESA EO programmes, particularly FutureEO, should ensure European autonomy in terms of space data acquisition and preservation. **Besides, as the Global South is becoming more and more important, these programmes should play a key role in routinely providing observations** where in-situ networks are basically missing or too sparse, together with capacity building. This could also provide an alternative solution, instead of American or Chinese approaches, for many developing countries which would demonstrate European soft power.

To enhance the continuity of the Copernicus Space Component (CSC) infrastructure, ensuring it meets the needs of current and prospective users while maintaining Europe's competitive edge in a rapidly evolving global EO market. Together with the Member States national EO missions, the Sentinel missions of the Copernicus project are crucial for monitoring changes of the Earth System in response to natural phenomena and anthropogenic forcing, hence increasing scientific knowledge on how our planet is functioning. They also provide essential support to decision-makers in their efforts to mitigate and adapt to global change.

To foster the delivery of advances in the field of civil security and resilience, where satellite data have already demonstrated their critical value, particularly in rapid damage assessment during floods, wildfires, and conflict scenarios. These proven applications should serve as precursors to the European Resilience from Space (ERS) programme, equipping European stakeholders with the autonomous decision-making tools needed to respond decisively to emerging crises – a capability that is both urgent and essential for Europe's security and defence. The complementary relationship between FutureEO, ERS, and the EC's Earth Observation Governmental Service (EOGS) should be fully leveraged. While these programmes reinforce Europe's world-leading security services through science, ERS's advanced observing capabilities also offer significant potential for scientifically and societally relevant applications. **FutureEO should function as the innovation engine for ERS**, and conversely, **ERS can feed valuable insights back to FutureEO's Science and Society initiatives.**

3.3 Aspirations

To be the world-leading space agency in EO technology and data products for environmental monitoring, security, and protection – ensuring Europe remains at the forefront of scientific discovery and policy-relevant climate action. To achieve this, ESA should, prepare, develop, and operate **unique new science demonstration missions,** pioneering new frontiers in Earth system observation and technology and enabling transformative research and applications. Such missions should enhance forecasting and early warning capabilities for natural hazards, by accelerating deployment of 'fast-track' satellites and innovative sensor technologies.

Future EO should ensure the continued success and legacy of the Aeolus mission by enabling its follow-on mission to transform meteorological forecasting capabilities at both regional and global scales. Additionally, ESA should expand the role of EO in monitoring the poorly observed middle atmosphere, enabling new insights into climate change effects, atmospheric circulation, space weather, and the potential implications of geoengineering.

In parallel with developing cutting-edge space technology, **ESA should fully exploit existing and new data streams to expand the number and utility of core products**, to support the scientific community, operational end-users and decision-makers through the provision of **high-quality, timely, and actionable EO data, products and intelligence.** To achieve this, new methods in AI should be developed to maximise the information content and value of existing and new datasets. This will underpin and support the development of **Digital Twin Earth (DTE) capabilities**, positioning DTE as a powerful EO-driven tool for counterfactual policy planning and for assessing risks to water, food, and energy security. This will help build stronger connections between users, educators, data producers, and value-added companies, enhancing the accessibility, usability, and societal penetration of Earth observation data and services.

3.4 Results

Through its Earth Observation programmes, ESA has delivered critical advances in climate science, technology, and societal preparedness**, directly supporting the European Green Deal, the UNFCCC Paris Agreement, and the UN Sustainable Development Goals.** Building on strategic priorities identified by the global EO community and the IPCC, ESA's efforts have **markedly improved our understanding of global cycles – energy, water, and carbon – as well as our capacity to detect, understand, and forecast Tipping Points, extreme weather, and climate sensitivity.**

A major achievement has been ESA's contribution to the **global carbon cycle** through the ongoing operation and early results from **Sentinel missions**, along with preparatory data from upcoming missions like **CO2M.** Through coordinated efforts with the **Copernicus Atmosphere Monitoring Service (CAMS)**, EO data have been integrated into near-real-time emission tracking, contributing to policy-relevant applications such as monitoring progress towards the Paris Agreement goals. The successful launch of the **Biomass, the first P-band polarimetric SAR system in space**, has provided unprecedented insights into tropical forest carbon stocks – a game-changer for biodiversity conservation and climate policy.

ESA's GRACE and SMOS missions, as well as precursor activities to the **Next Generation Gravity Mission (NGGM)**, have enabled **transformative insights into terrestrial water storage, groundwater depletion, and the changing mass of glaciers and ice sheets.** They have also been essential in tracking land-ice mass loss, with direct implications for sea level rise projections. NGGM's mission definition and system design phase has already laid the foundation for a new generation of high-resolution, high-frequency gravity measurements, expected to dramatically improve **early detection of cryospheric Tipping Points.**

In its first year, the **EarthCARE** mission has delivered **major advances in understanding cloud and aerosol dynamics, Earth's radiation balance, and atmospheric processes.** EarthCARE has also detected intermittent phenomena like polar stratospheric clouds and volcanic aerosols, as well as unexpected ecological signals such as insect swarms and phytoplankton blooms, demonstrating its broader environmental monitoring potential.

In addition, **ESA's calibration and validation activities**, such as those tied to **TRUTHS** and **Fiducial Reference Measurements (FRMs),** are strengthening the traceability and reliability of EO data, ensuring that Europe sets the gold standard for climate monitoring. These activities have supported European and global efforts to improve climate benchmark records and are increasingly being used by the commercial EO sector to validate data products.

On the downstream side, to fully exploit the very large amount of EO data acquired, ESA has made substantial progress in **integrating AI with physical modelling.** Several pilot projects under the **AI4EO** initiative have demonstrated how machine learning, when combined with physical constraints, can enhance pattern recognition, anomaly detection, and predictive capability across EO domains.

3.5 Observations and Recommendations

ESA's Earth Observation (EO) programmes exemplify a **unique fusion of scientific ambition, technological leadership, strategic relevance, and societal impact** – a foundation for Europe's future autonomy and excellence in EO. These programmes deliver tangible results, bridging the dual priorities of climate science advancement and societal resilience. Through pioneering missions, innovative methodologies, and cross-sectoral applications, ESA transforms scientific vision into operational capabilities with global reach.

The **proposed EO programme**, structured around the **FutureEO core**, is rigorously formulated. **The ESSC assesses its scientific, technological, and programmatic foundations as excellent.** It effectively confronts societal challenges posed by climate and environmental crises while pioneering new frontiers in Earth system understanding. **FutureEO** – the cornerstone of Europe's Earth Explorer missions – epitomizes cutting-edge space science and technology, driving unprecedented observational capabilities. As the engine of European Earth science R&D, it sustains our competitive edge in space. In the meantime, the **'Earth Action' pillar** boldly unites climate change, biodiversity, and resilience under a cohesive strategy, while promoting the interactions with partners, stakeholders and end users.

The other EO Programmes tabled at CM25, including **CSC- 4, TRUTHS, DTE, and InCubed-3,** are all evaluated of exceptional interest, particularly to further expand the Copernicus Sentinel missions, to enable cross-calibration of satellites, to develop operational digital twins of the Earth, and to foster industrial innovation. Moreover, **Earthnet, to be funded by the ESA General Budget,** ensures vital long-term data archiving and accessibility. Noting that the **ERS programme** addresses key European geopolitical issues and should be supported by the relevant ministries, **its funding must however not compromise FutureEO**, as both are indispensable to Europe's strategic autonomy. Sacrificing science-driven missions would erode Europe's EO leadership.

Given the climate crisis's urgency and Europe's dependence on EO for security and sustainability, the **ESSC emphatically urges ESA Member States to fully fund the ESA EO programmes at CM25. Reductions would jeopardize Europe's capacity to lead in Earth system science and climate action.**

3.6 Comments and Recommendations concerning the NASA situation

Given current uncertainties surrounding the USA's commitment to Earth observation and climate research – with potentially dramatic consequences for the FY26 budget, **including the possible premature termination of key EO missions – ESA's role in sustaining global climate monitoring becomes even more critical.** Europe must step up to fill this gap or risk that vital climate data are uncollected. In this context, **ESSC emphasizes the need to capitalise on ESA's global leadership in EO,** whilst maintaining essential partnerships in the domain of EO applications (e.g. IMBIE, in-situ data networks, joint airborne campaigns, etc...) as well as joint open-source platforms such as the Multi-Mission Algorithm and Analysis Platform (MAAP).

Where appropriate, **we recommend proactive engagement with both established and emerging space actors, including private sector partners, to strengthen international cooperation and uphold open data access as a fundamental principle of global Earth observation efforts.**

4 Transverse Issues

"Everything connects to Everything Else" – Leonardo DaVinci

4.1 System Science and Space Weather

Already widely adopted in space research, **System Science** – the integration of data from multiple spacecraft and instruments to yield insights beyond what single missions achieve – is indispensable for heliophysics. This approach enables both **fundamental science** and **operational space weather monitoring**, where solar activity propagates dynamically across the heliosphere, posing risks to human spaceflight, satellites, and terrestrial infrastructure. ESA's comprehensive heliophysics programme, including Solar Orbiter, Proba-3, the Swarm constellation, and the upcoming SMILE and Vigil missions, demonstrates the **cross-directorate** nature of this research.

Within this framework, **Vigil** (a mission of the ESA Space Safety Programme, launching in 2031), will provide unique solar monitoring from the L5 Lagrange point, revolutionizing early warnings. When combined with existing assets, it exemplifies how distributed observations (e.g., the Grand Heliospheric Orchestra concept) create **system-level understanding** and **operational capability.** Beyond **endorsing Vigil**, we **further recommend equipping all operational and future missions** with **space weather sensors**, effectively transforming individual spacecraft into nodes of a **global warning network.** The coordination of these efforts across ESA Directorates through **ESA's Heliophysics Working Group** is essential to ensure that advances in **heliospheric system science** translate into actionable **space weather preparedness.**

4.2 Future Enabling Systems and Technologies

ESA's scientific programmes are often unique, requiring the development of new **enabling systems and technologies.** These innovations expand mission capabilities to new destinations, enhance data quality and acquisition rates, and create opportunities for groundbreaking discoveries. ESSC has identified **Future Enabling Systems and Technologies (FEST)** critical to achieving High-Level Science Goals. These FEST needs have been compiled into a set of strategic roadmaps, essential for supporting future ESA missions beyond currently selected candidates.

Increased funding for such technological developments would ensure the timely completion of instruments and missions vital for scientific breakthroughs. Beyond their scientific value, these FEST initiatives address Europe's strategic autonomy by **closing gaps in critical capabilities, reinforcing sovereignty and independence in an evolving geopolitical landscape.** Strengthening European resilience also requires fostering synergies between ESA and the European Commission (e.g., through ERS/EOGS), as well as bridging industry competitiveness with scientific needs – evident in applications such as Very High-Resolution systems, Telecommunications, Navigation, Security, and Defence.

History has repeatedly demonstrated that **space-derived technologies yield far-reaching benefits**, finding applications in other industries and delivering tangible returns to society.

The ESSC **strongly encourages ESA to prioritize the development and funding of strategic Systems and Technology capabilities.** We welcome further collaboration to align the outcomes of the **ESA Technology 2040** strategy with ESSC FEST priorities, ensuring a shared long-term vision for Europe's space ambitions.

4.3 Atmospheric Impact of Re-entry and Launches

ESSC is leading and coordinating a working group with ESA representatives, composed of mandated experts from national bodies (DLR, CNES, CNRS, NASA, NOAA), academic institutions (University College London, Leeds University, and international space organizations (COSPAR, IAA, EC). Their goal: to address the **escalating environmental risks from the unprecedented surge in human space activities** over the past decade. Recent findings reveal that stratospheric particles now contain metals like aluminium and copper from spacecraft re-entries – with these anthropogenic fluxes matching or exceeding natural cosmic dust levels. **This raises critical questions about the long-term viability of current 'Design for Demise' approaches, which ESA and other space actors have adopted as a cornerstone of space sustainability.**

With re-entry rates now reaching five spacecraft per week – and projected to grow exponentially – **the impacts on the ozone layer, upper atmosphere, and climate systems require urgent assessment.** The working group has reached consensus on the most pressing risks and identified key knowledge gaps. Proposed research actions include targeted in situ measurements using existing or minimally modified platforms (stratospheric balloons, launchers, High Altitude Platform Stations) and advanced analysis of current satellite datasets.

These efforts aim to quantify and characterize emissions from space operations and their atmospheric effects. The findings may **necessitate a fundamental re-evaluation of 'Design for Demise' paradigms**, as current practices appear insufficient to prevent significant atmospheric contamination. The Working Group will soon issue guidelines outlining these challenges and prioritizing the most urgent research needs. Implementing these recommendations will require substantial institutional commitment, dedicated funding streams, and integration into agency planning cycles (2025+). The outcomes could reshape core space sustainability policies, potentially requiring alternative approaches to spacecraft end-of-life management that better address both orbital debris and atmospheric protection.

4.4 Strengthening Public Awareness and Support

Finally, while we **applaud the exceptional work of ESA's communications team** – across traditional media, social platforms, and public outreach – **we urge even greater coordination and cooperation between ESA, the European space science community, and all relevant government, commercial, and NGO stakeholders. Working together**, we can more effectively communicate to European citizens and policymakers why space science matters: its role in driving innovation, protecting our planet, and securing Europe's technological sovereignty.

ESA's achievements – from groundbreaking missions to cutting-edge research – deserve **wider recognition** as a testament to Europe's leadership in space. The European astronaut corps, with their unique ability to inspire and educate, represent a potent asset in this effort. Their voices humanize complex science, bridge the gap between research and public understanding, and strengthen support for sustained investment in space exploration.

We recommend **structured campaigns** and **crafted public engagements** that highlight how space science **delivers tangible benefits** (e.g., climate monitoring, medical advancements, economic growth), expand on the leverage of astronauts as ambassadors for science and exploration, engage younger audiences through interactive, digital-first content, and partner with media, educators, and influencers to amplify key messages.

Public enthusiasm translates to political will. By making the case even more compellingly, ESA can **secure long-term commitment to its ambitious goals** – from scientific discoveries at the frontier of knowledge through deep-space exploration to safeguarding our terrestrial and off-planet environments.

5 The Value of ESA Science

Europe's collaborative space science endeavour through ESA stands as one of the continent's **crowning achievements – a testament to what 23 nations can accomplish when united by visionary science.** This partnership not only strengthens Europe's political cohesion and industrial competitiveness but amplifies its global influence, safeguards strategic sovereignty, and fosters a shared sense of identity and pride.

Through its support for ESA's Mandatory Science programme and Optional Exploration and Earth Observation programmes, **Europe has cemented its position as a preeminent global space power.** Maintaining this leadership demands sustained, ambitious investment – not just to preserve our competitive edge in scientific discovery, but to propel breakthrough innovations that solve pressing global challenges while expanding the boundaries of human knowledge and inspiration.

By investing boldly in ESA's science programmes today, Europe will position itself as a global leader in scientific discovery, as a guardian of our planet, a pioneer of the new space economy, and a beacon of inspiration for future generations, uplifting European aspirations for a better tomorrow.

Front cover graphic: A pilgrim peers through an opening in the firmament at the point that the sky touches the land – taken from Camille Flammarion's L'atmosphère: météorologie populaire (Paris: Hachette, 1888)

ROLES	NAME	AFFILIATION
ESSC EXECUTIVE BOARD		
ESSC Chair	**Chris Rapley**	University College London
AFPP Chair	Saskia Hekker	Heidelberg University & Heidelberg Institute for Theoretical Studies
SSEP Chair	Nicole Schmitz	Institute of Space Research, German Aerospace Center (DLR)
LPSP Chair Appointed	Charlot Vandevoorde	GSI Helmholtz Center for Heavy Ion Research
LPSP Chair Departing	Alexander Choukér	Hospital of the Ludwig- Maximilian University (LMU) Munich
ESP Chair	Maurice Borgeaud	Retired, former Head of Department at ESA
STP Chair	Serge Flamenbaum	Senior Advisor Space Systems R&D, Technology and Innovation
ESSC Treasurer	Marc Heppener	Senior Advisor- Research in Microgravity
ASTRONOMY AND FUNDAMENTAL PHYSICS PANEL		
Chair	**Saskia Hekker**	Heidelberg University & Heidelberg Institute for Theoretical Studies
Panel Member	Fabrizio Fiore	National Institute of Astrophysics (INAF – Astronomical Observatory of Trieste)
Panel Member	Ravit Helled	Department of Astrophysics, University of Zurich
Panel Member	Xavier Luri	Institut de Ciències del Cosmos – Universitat de Barcelona – Institut d'Estudis Espacials de Catalunya
Panel Member	Nikolaos Karnesis	Aristotle University of Thessaloniki
Panel Member	Floris van der Tak	Space Research Organization Netherlands (SRON) & University of Groningen
Panel Member	Anne Decourchelle	French Alternative Energies and Atomic Energy Commission (CEA Paris Saclay)
SOLAR SYSTEM AND EXPLORATION PANEL		
Chair	**Nicole Schmitz**	Institute of Space Research, German Aerospace Center (DLR)
Panel Member	Vinciane Debaille	Université Libre de Bruxelles
Panel Member	Sonia Fornasier	Laboratoire d'Etudes Spatiales et Instrumentation en Astrophysique (LESIA), Université Paris Cité
Panel Member	Mauro Messerotti	National Institute of Astrophysics (INAF – Astronomical Observatory of Trieste)
Panel Member	Christina Plainaki	Italian Space Agency (ASI)
Panel Member	Michel Viso	Senior Advisor, Astrobiology
LIFE AND PHYSICAL SCIENCES PANEL		
Chair Appointed	**Charlot Vandevoorde**	GSI Helmholtz Center for Heavy Ion Research
Chair Departing	Alexander Choukér	Hospital of the Ludwig- Maximilian University (LMU) Munich
Panel Member	Luca Cipelletti	University of Montpellier
Panel Member	Roberto Cerbino	University of Vienna
Panel Member	Denise G. Ferravante	Italian National Agency for New Technologies, Energy and Sustainable Economic Development (ENEA), Antarctic Technical Unit
Panel Member	Asuncion Garcia- Escorial	National Centre for Metallurgical Research (CENIM) – Spanish Research Council (CSIC)
Panel Member	Marc Heppener	Senior Advisor- Research in Microgravity
Panel Member	Ann- Iren Kittang Jost	Centre for Interdisciplinary Research in Space (CIRiS),Norwegian University of Science and Technology (NTNU Social Research)
Panel Member	Nicola Montano	University of Milan (UNIMI)
Panel Member	Kai Bongs	Institute for Quantum Technologies
Panel Member	Ruth- Sophie Taubner	Space Research Institute, Austrian Academy of Sciences
EARTH SCIENCES PANEL		
Chair	**Maurice Borgeaud**	Retired, former Head of Department at ESA
Panel Member	Jonathan Bamber	University of Bristol
Panel Member	Anny Cazenave	Laboratoire d'Etudes en Géophysique et Océanographie Spatiales (LEGOS), Centre National d'Etudes Spatiales (CNES)
Panel Member	Veronique Dehant	Royal Observatory of Belgium & Université catholique de Louvain (UCLouvain)
Panel Member	Michaela Hegglin	Forschungszentrum Jülich & University of Reading
Panel Member	Yann Kerr	Centre d'Etudes Spatiales de la Biosphère (CESBIO), Centre National d'Etudes Spatiales (CNES)
Panel Member	Marta Marcos	Mediterranean Institute for Advanced Studies (IMEDEA, UIB – CSIC)
Panel Member	Christian Massari	National Research Council of Italy (CNR), Research Institute for the Geo- hydrological Protection
Panel Member	Johanna Tamminen	Finnish Meteorological Institute
SYSTEM AND TECHNOLOGY PANEL		
STP Chair	**Serge Flamenbaum**	Senior Advisor Space Systems R&D, Technology and Innovation
AFPP representative	Floris van der Tak	Space Research Organization Netherlands (SRON) & University of Groningen
SSEP representative	Michel Viso	Senior Advisor, Astrobiology
LPSP representative	Marc Heppener	Senior Advisor – Research in Microgravity
ESP representative	Yann Kerr	Centre d'Etudes Spatiales de la Biosphère (CESBIO), Centre National d'Etudes Spatiales (CNES)

The support of the ESSC Secretariat in the production of this document is gratefully acknowledged.

ESSC

www.essc.esf.org