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Uplifting ESA Science Funding

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EUROPEAN SPACE SCIENCES COMMITTEE

European Space Sciences Committee

UPLIFTING ESA SCIENCE FUNDING

As Chair of the European Science Foundation's European Space Science Committee, I am pleased to present the following briefing on behalf of the European space science community to support our very strongest recommendation for an increase in funding for science across the ESA mandatory and optional programmes at CM25.

The full subscription to the ESA Mandatory programme at the 2022 Ministerial (CM22) was welcome. However, it was insufficient to maintain the Voyage 2050 programme in the long-term. Rising inflation, increasingly sophisticated and challenging scientific investigations, and increasing technical complexity will, unless compensated, materially constrain the future development of the programme. This will limit the flow of major scientific discoveries and the collateral benefits to European excellence in the space domain.

In the meantime, the undersubscriptions at CM22 of the optional Earth Observation and Human and Robotic Exploration programmes have necessitated significant programmatic adjustments with related loss of science. Given the huge value and urgency of Earth observation science and monitoring in addressing the climate and environmental crises and in enabling the Green Transition, plus the high aspirations for European human and robotic exploration, in which science is both an enabler and exploiter, this is damaging and deeply regrettable.

Given these circumstances, we strongly urge increasing funding for ESA science across the mandatory and optional programmes at CM25. The goal is not only to maintain Europe at the forefront of scientific discoveries, but also to harness its potential for societal betterment, industrial strength, prosperity, security, and global prestige. The investment will propel Europe forward, consolidating our commitment to creating new knowledge, progress, and a collective identity and vision.

With two years of planning prior to the Ministerial, we urge that the Delegations work closely with ESA in the intervening period to ensure a secure and vibrant future for science within the space programme. Decisions made at CM25 will have inter-generational consequences.

Summarised in the following sections are the benefits that have accrued from a 50-year programme of space activities, at which science has been the core, and the arguments for supporting science in general and space science in particular. We conclude with, examples of the impact of past ESA scientific investments.

I hope that you will find the document convincing and useful.

"First-class science is absolutely essential for the promotion of European interests and leadership, as it imparts a strong strategic drive to its technological and industrial system". [1]

The European Space Agency (ESA) has been central to developing Europe's capabilities in space science, technology, Earth observation, and human and robotic space exploration for over five decades. Through a combination of visionary leadership and skilful coordination, its achievements have far exceeded what would have been possible through the separate efforts of the 22 member states. **This accomplishment is widely respected and admired in the rest of the world**. Scientific research within the Mandatory Programme, the optional Earth Observation programme, and the optional Human and Robotic exploration activities, has formed the bedrock upon which ESA's capabilities and successes have been built.

To ensure that in the next fifty years **Europe will remain in a leadership position**, we urge the delegations of the European Space Agency to **bolster science funding across the ESA programmes** and ensure robust development and evolution of the programmes.

This isn't just an investment in ESA or space but an **investment in Europe's future and in our collective dream of a progressive and culturally vibrant society**. In the case of Earth Observation science there is **an additional dimension of urgency**, given the increasingly rapid and damaging changes taking place in the global climate system and environment, and the **need for informed societal action**.

The Case for Science

Science advances knowledge and understanding, and benefits our society in a multitude of ways:

1. **Economic Growth, Innovation and Prosperity:** The advancements in technology, industry, and organization enabled by science lead to a wealth of tangible benefits. Commercial applications, job creation, overall prosperity and valuable technical, programmatic and commercial capabilities are direct outcomes of scientific innovation, fostering economic growth, societal well-being, and enhanced resilience to future global developments.
2. **Security:** Scientific insights gained from research underpin essential national security capabilities. By bolstering funding for science, we enhance our ability to develop advanced technologies, skills and capabilities that safeguard European citizens and European geopolitical interests.
3. **Risk Mitigation:** Many challenges and threats, such as natural disasters and climatic and environmental change, can be better anticipated, understood and managed through the outcomes of scientific research.
4. **Prestige:** New scientific discoveries made possible through science captivate the public's imagination, showcasing Europe's capabilities and fostering a sense of collective pride. These achievements also command respect from global partners and competitors.
5. **Seeking Truth:** The scientific method provides our best tool for uncovering universal truths. It offers a systematic approach to overcome human biases and limitations, ensuring the pursuit of accurate and objective knowledge. Increased funding for science will enable us to refine this method and unlock new frontiers of understanding.
6. **Satisfying Curiosity:** Scientific research, driven by innate human curiosity, has consistently been at the forefront of groundbreaking discoveries. It dispels mythology, expands our horizons, and

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[1] *The European White Paper on Space: Enough Support for Basic Science?" J.-C. Worms, G. Haerendel, Space Policy, 20 (2004,) pp73–77*

challenges our intellect. By investing in science, we can continue to push the boundaries of knowledge and enrich our collective understanding.

7. **Societal Vitality:** The knowledge and capabilities science generates are integral to a culturally vibrant and advanced society. By investing in science, we empower ourselves to address complex challenges, make informed decisions, and drive sustainable progress.
8. **Inspiration and Education:** Science has the unique power to inspire and engage people across age groups and backgrounds. By investing in this field, we can ignite interest in science, technology, engineering, and mathematics (STEM), building invaluable social capital for the future .
9. **Unifying Force**: Science generates universal truths that transcend cultural, national and language barriers. In doing so, it serves as a unifying force, fostering collaboration among professionals, organizations, institutions, and nations. Increased funding will strengthen international partnerships, driving cooperation and collective progress.

Space Science in particular can offer some additional benefits:

10. **Unique Location:** Space offers an unparalleled laboratory for studying fundamental processes and testing cutting-edge ideas in both the physical and biological sciences.
11. **Vista:** The perspective provided by space opens new windows on the Universe and our planet. It inspires new generations of scientists, engineers, and the general public, altering worldviews and fostering 'out of the box' innovation.
12. **Engineering Challenges:** The demanding conditions of space necessitate the development of cutting-edge instrumentation and facilities, driving technological advancements that benefit industries more generally.
13. **Addressing Contemporary Challenges:** Observations from space are critical for tackling urgent societal issues such as climate change, disaster response, and resource management.

The Value of ESA Science

Europe's collaborative efforts in space science, uniting 22 member states, exemplify a remarkable achievement. This unity not only **reinforces political and industrial strength** but also **enhances collective purpose**, **international influence** and a **European sense of identity and pride**. Science plays a critical role across ESA's programmes in shaping inspiring discoveries, catalysing technological advancements, developing workforce talents, industrial competencies, and infrastructure assets, all of which lie at the leading edge of international space efforts:

Facilitating Scientific Discoveries and Advancements: The ESA mandatory and optional programmes have facilitated research that spans from understanding the origins of the Universe through astronomy and astrophysics to unravelling Earth's complex processes, enabling physical access to a growing number of solar system bodies and the scientific exploitation of the human occupation of zero gravity. The stream of results from missions such as Hubble, Gaia, and the James Web Space Telescope, the rich view of the planet as an integrated whole, and the bravado of human experimentation on the International Space Station, have advanced human knowledge in ways inconceivable even decades ago. European scientific prowess, cultural richness, and worldwide prestige have been thus elevated.

Developing Skilled Workforce, Industrial, Technical, and Scientific Capabilities: The science enabled by the ESA Mandatory, Earth Observation and Exploration programmes has nurtured the growth of a European academic community at the global forefront, and a highly skilled space-based workforce, attracting and developing talent from across Europe and worldwide. In doing so, it has catalysed the creation of world leading scientific, industrial, technical, and programmatic capabilities. The development and execution of ambitious missions, exploring the realms of feasibility, have necessitated collaboration among various sectors, promoting cross-disciplinary expertise and the development of programmatic capabilities that have underpinned Europe's position as a global leader in space technology.

Creating Infrastructure for Hugely Technically Demanding Missions: The foundation laid by the demands of space science projects has played a pivotal role in building essential infrastructure for designing, testing, launching, and operating technically demanding missions. This has resulted in the establishment of world-class facilities, research centres, and manufacturing and programmatic capabilities. The collective experience gained from these endeavours has enabled ESA to undertake complex, technically challenging, and costly missions, such as robotic and human exploration of other celestial bodies, the pinpoint placing of hugely complex observatories at gravitational neutral points, and the construction of spacecraft capable of skimming the atmosphere of the Sun.

Benefiting the European Economy: The space industry has shown itself to be a significant economic driver, spawning entirely new and lucrative industries. Within Europe, studies have demonstrated a 'multiplier' of x6 to x10 in terms of Euros generated for Euros invested. Data and insights generated from Earth Observation missions especially have been leveraged for environmental monitoring, disaster management, agriculture, urban planning, and more, contributing to economic growth, sustainability, and informed decision-making. The technological spin-offs and advancements resulting from the science missions have also stimulated the growth of commercial space ventures and innovation-driven industries.

Inspiring the public: The accomplishments of ESA's Science Programme and Exploration missions have not only advanced our understanding of the Universe and our planet, but have also served as a wellspring of inspiration for future generations. These endeavours ignite curiosity, drive STEM education, and inspire young minds to pursue careers in science, technology, engineering, and mathematics. Moreover, the iconic images and ground-breaking discoveries captured by these missions captivate the public's imagination, fostering a sense of wonder and unity.

Enhancing Influence and Security: ESA's achievements in space science, technology, and exploration contribute significantly to Europe's geopolitical influence and security. The agency's capabilities enable independent access to space, satellite-based communication, navigation, and observation, which are vital for national security, disaster response, and international collaboration. By advancing its space-based contributions to the Green Transition, ESA enhances its global standing and reinforces its role as a reliable partner in addressing global challenges.

The **European Space Agency's foundational programmes**, including the mandatory Science Programme, and the optional Earth Observation, and Exploration initiatives, have been **instrumental in shaping its capabilities and achievements**. These programmes have fuelled inspiring scientific discoveries, cultivated a skilled workforce, advanced industrial and technical capabilities, and established critical infrastructure. Recognizing the **paramount importance of ESA sustaining and uplifting support for science in the programme**, will ensure a continuing wellspring of innovation, enabling Europe to remain at the forefront of space technology, scientific exploration, and the realization of a sustainable, inspiring future.

Without these foundations and a steadfast commitment to science, ESA's ability to contribute to the Green Transition, achieve human-rated space access, and embark on ambitious exploration missions would be severely constrained.

The next sections highlight major achievements of Europe and ESA in the scientific field, using past and current missions as examples.

Gaia

The European Space Agency (ESA) Gaia mission is a pre-eminent example of scientific success, European leadership, and international cooperation in space science. It is the result of Europe's **long and sustained investment** in a specific area of space science: space astrometry. This investment started in the 1970s, with the first steps of the Hipparcos mission. It was a bold choice, since astrometry was at the time a languishing area of astronomy, but the success of Hipparcos was unparalleled at the time and paved the path for Gaia, which was adopted as a cornerstone mission in 2000. Thanks to Hipparcos and Gaia, Europe has today a thriving astrometric community, considered as **the absolute and uncontested leader in this area**.

Even more, Gaia has been an outstanding technological success. The European industry has developed **unique technologies** to make the mission possible, including among others the **largest CCD focal plane in space**, a **high-stability silicon carbide structure and mirrors**, and an **ultra precise attitude control system**. These developments have paved the way for other key missions of ESA, and in particular for the Euclid VIS focal plane.

Gaia is considered one of the more successful scientific missions in history, if not the most successful one. Its 2-billion object catalogue includes a wealth of data for astrometry, photometry and spectroscopy. As the main mission goal, Gaia has revolutionized our understanding of the Milky Way, providing for the first time a detailed account of its formation history from mergers, its kinematics, dynamics and structure and the stellar populations composing it. But beyond this very important result, Gaia has also made key contributions in many areas of astrophysics; it has significantly improved our knowledge of the minor objects of the Solar System, providing more precise orbits, physical characterization and many new discoveries; it has fostered significant advances in stellar physics; it has defined in an extremely robust and precise way the celestial reference frame at optical wavelengths, with applications that range from interplanetary navigation to the development of star-trackers; it has also contributed to cosmology, including key issues such as the improvement of the cosmic distance ladder, the determination of the Hubble constant and the discovery of new gravitational lenses; and in the upcoming releases it will also make contributions to exoplanet science.

Furthermore, **Gaia is a wonderful example of an open science strategy**; its catalogues are provided openly as soon as they are produced, including detailed documentation and tutorials. Even more, the Gaia archive is open to the public and it has been used to generate a wealth of outreach and educational material to engage the public in science. Gaia has generated a large variety of outreach papers, videos, images and other tools that are significantly contributing to the engagement of the public in science.

Finally, **Gaia has generated an extensive, vibrant and active scientific community**. The Gaia data processing consortium alone gathers more than 400 scientists from 24 countries, and is an outstanding example of pan-European cooperation. But the European and worldwide scientific community using Gaia is much larger, as demonstrated by nearly 10000 refereed papers based on Gaia data published up to now, or the many doctoral theses based on Gaia.

Summarizing it all, Gaia is a shining example of how a space scientific mission can, at the same time, **produce outstanding science, foster the advance of European technology and the capabilities of its industry, inspire European society, and cement Europe's leadership on the world stage**.

Rosetta

Inspired by the upcoming appearance of Halley (in 1986), preparation for the Rosetta mission started in 1985 with an idea, to send a spacecraft to a comet and bring back samples, hence the original name of Comet Nucleus Sample Return (CNSR). After the Challenger Space Shuttle disaster, NASA involvement was withdrawn, leading the mission to be solely led by ESA and European national space agencies. The original concept was revisited, redesigned and approved in 1993.

The mission was an **astounding technical challenge**; to "catch a comet" is no small feat. The Rosetta spacecraft would need to travel through space for 10 years to catch any of its potential targets. The already challenging mission was made even more complicated when an Ariane 5 launch failed in 2002, a couple of weeks before Rosetta was supposed to launch with all 21 instruments (including 3 NASA instruments after re-engagement with the mission) and a target: Comet 46P/Wirtanen. The launch window for their initial target missed, the team had to select a new one, 67P/Churyumov-Gerasimenko, and Rosetta left Earth on the 2nd of March 2004. After 5 years in space, using the Earth, Mars, and asteroids fly-bys to control its trajectory and keep the critical fuel for the cometary approach, Rosetta was set to sleep in 2010 and for 31 months to save power.

Rosetta woke up the 20th of January 2014. From mid-March, it started capturing images of the comet as it approached before successfully getting in flight formation with 67P in August. The Philae Lander descended towards the comet on the 12th of November 2014.

The Rosetta mission's success cannot be overstated. With Rosetta, **Europe had the first ever spacecraft to orbit a comet nucleus**; Philae send **the first images of a comet surface**; Rosetta was also the **first spacecraft to reach Jupiter's orbit using solar sails**.

Regarding science, Philae sent back a trove of data from its 10 instruments. It provided **essential information on the composition and structure of the comet surface and interior**, such as the presence of organic molecules. It provided invaluable information on the origin of cometary ices, or the evolution of cometary activity.

Important discoveries are still emerging from the diverse datasets collected by both lander and orbiter instruments. More than 1401 publications have been released so far with, no doubt, more to come. There was also a large communication campaign surrounding Rosetta, for instance through the creation of animated films, or participation to in-person events to share information and the result of this fascinating mission with a wider audience, inciting wonder and marvelment for current and future generations, with 10 million people watching the landing stream alone.

Rosetta involved more than 2000 people across research institutions, ESA, and industry. It is estimated than it contributed to the creation of hundreds of jobs over the years.

The Rosetta mission is a prime example of international collaboration on European space projects. It shows the **resourcefulness of research teams in the face of major challenges and how they could overcome them to still produce world leading science results and discoveries**.

Aeolus

The Aeolus satellite stands as a testament to scientific achievement, technological innovation, and international collaboration in the realm of Earth observation. It was the **first satellite to acquire profiles of Earth’s wind on a global scale and provided much-needed information to improve the quality of weather forecasting**. Aeolus represents a strategic investment in a better understanding of the atmospheric dynamics, responding to the pressing need for improved knowledge of Earth's wind patterns. Originally known as ADM (Atmospheric Dynamic Mission), Aeolus was selected by ESA for implementation as the second Earth Explorer Core mission in 1999 for a tentative launch in 2008 in the frame of the ESA Living Planet programme. The mission experienced substantial delays due to the huge technological challenges. It was finally launched using VEGA on 22 August 2018. Since then, **Aeolus has become one of the most “impact-per-observation” instruments in existence, with an estimated 3.5 billion Euros return according to a recent report**. Surpassing scientific expectations and exceeding its planned life in orbit by 18 months, the mission ended on 28 July 2023.

Technologically, Aeolus has pushed the boundaries thanks to a very innovative and state-of-the-art Doppler wind lidar known as ALADIN (Atmospheric LAser Doppler INstrument). The instrument directly measures horizontal wind profiles in the troposphere and the lower stratosphere, to determine the wind speed at various altitudes below the satellite, from the surface up to 30 Km. **The first of its kind and the most sophisticated Doppler wind lidar flown in space**, ALADIN was initially considered as a demonstrator in the frame of the ESA Earth Explorer missions. However, the quality of the measurements led to the use of the data in operations. The Met-Offices, via the European Centre for Medium-Range Weather Forecasts (ECMWF), were eagerly waiting for the new capabilities offered by the instruments and have quickly adopted it in their daily data operations. The success of Aeolus has not only fulfilled its primary objective but has also paved the way for future missions, **demonstrating the European space industry's prowess in developing groundbreaking technologies**.

Aeolus has become a milestone in Earth observation, providing invaluable data on global wind patterns. Its impact extends beyond meteorology, offering insights into atmospheric dynamics, climate change, and related scientific endeavours. The mission's contributions include **enhancing weather forecasting accuracy** and expanding our **understanding of the intricate interactions within Earth's atmosphere**. Aeolus improved short-range forecasts, especially in mid-latitudes. It enabled ECMWF to compensate for the reduced measurements of commercial aircrafts during the COVID-19 pandemic and was used to track events in near real-time, such as the Hunga Tonga volcanic eruption in 2022. Aeolus data offered major improvements at the poles and the equator. In these regions, the mean error between predictions and observations was reduced by more than 4%.

In the spirit of the ESA Earth Observation Envelope Programme (EOEP) and FutureEO, Aeolus has made its findings and datasets accessible to the global scientific community and the public based on the open science guideline. This transparency has facilitated collaborative research and educational initiatives, fostering engagement with Earth science on a broader scale. Moreover, Aeolus has cultivated a vibrant and collaborative scientific community. Aeolus thus stands as **a shining example of how a dedicated space mission can transcend its initial objectives, providing crucial data for Earth science, advancing technology, and fostering international collaboration**. With its pioneering contributions to atmospheric research, Aeolus has become a cornerstone in ESA’s portfolio, contributing to the broader understanding of our planet and its complex systems. Aeolus has also demonstrated how an ESA Earth Explorer research mission, based on cutting-edge technology, can be transformed from an Earth observation science mission into an operational programme, continuing to directly benefit society through the improvement of weather and climate information.

International Space Station (ISS)

The International Space Station is a project summarised by superlatives. **It is the largest single structure humans ever built in space, the third most bright object as seen from Earth, and the longest permanently inhabited space station**. Moreover, it is often hailed as the **biggest international technological cooperation project, with 15 nations participating**. Conceived to satisfy a manifold of national and international objectives, science, technology and exploration have always been identified as the main user categories of the ISS. By supporting a host of small-to-medium experiments it is a perfect counterpart to free-flying 'mega missions' with more specific purpose. Indeed, it can be seen as a life sciences / physical sciences equivalent of an Hubble or James Webb Space Telescope in that it opens up opportunities for a community of scientists addressing a range of scientific questions at the research frontier. To date, more than **2500 individual experiments have been performed, across many disciplines in physics, life sciences, technology, earth and space sciences etc**. Europe's contributions to the ISS are numerous and include ESA's Columbus Laboratory, the Automated Transfer Vehicle and many other structural elements either provided by ESA or individual European nations. Virtually every astronaut of the European Astronaut Corps has visited the ISS as part of the crew, many even more than once and several of them in the capacity of ISS commander. A wealth of scientific instruments has been provided by Europe, many of which are still in use by the global scientific community. Finally, many of the 2500 experiments flown underwent also an "Earth-bound-evolution", helping shape a very important European heritage across the many disciplines that utilise ISS as a test bed. The range of scientific themes addressed on the ISS is vast, extending from Biology through Human Physiology to Fluid Physics and Material Sciences. Here we have selected specific examples to illustrate the groundbreaking new knowledge that the programme has enabled:

Biology: The ESA-provided **Kubik facility** is a small, flexible biological incubator that was first flown in 2004. It can host several experimental containers at the same time, each containing different biological samples, and offers programmable temperature and other environmental parameters to best suit the experiments. Since 2004, there has always been a Kubik incubator on board the ISS, of which by now 7 versions were developed. In total almost 60 different biological experiments have been performed, using a wide range of organisms and cellular systems. In view of the intentionally low development costs, this makes Kubik probably one of the best 'science per euro' facility built for the ISS. Typical examples include:

- The **AMPHIBODY experiment**, in which amphibian cells were used as a model of the human immune system. Pathways were identified that explain the observed immunosuppressive effects of spaceflight, due to the modified gravity levels experienced by the cells.
- The **BioAsteroid experiment**, biomining of minerals from actual asteroid material was tested. The experiment demonstrated that not only is it possible for microbes to mine elements in space, but some microbes may even perform their task better under microgravity conditions. These results are important for future use of regolith to sustain human outposts on Moon or Mars.

Human Physiology: The research facility of choice in the area of human physiology are the astronauts themselves. Through various techniques such as blood draws, bone densitometry, ECG's and breath analysis, the effects of spaceflight on the human body can be researched in depth. The ISS is important for studying long-term effects, with durations comparable to Moon or Mars exploration missions. Many of these experiments have relevance beyond 'simply' the space domain. For example:

- Experiments focusing on the known effect of (major) **bone loss** during spaceflight, while obviously extremely relevant for long-duration exploration missions, are also directly linked to research into osteoporosis in elderly people. Not only are the underlying mechanisms more easily recognised when studied in otherwise healthy, relatively young, persons, but also the effects of various countermeasures, such as exercise, special nutrition or medication, can be methodically assessed.
- Another area of research drawing much attention is the complex interplay between chronic exposure to **stress factors, human physiology** (the immune system in particular) and **human**

wellbeing and performance. These studies include fundamental science and development of new technologies, and cover the fields of physics, biology, physiology, and psychology. The findings and innovations of space research combined with diagnostics on Earth have mutual benefits and promote the development of *personalized* and *precision* medicine.

Additionally, Europe also has a leading position in offering ground-based simulation facilities (Envihab in Cologne, MEDES in Toulouse, use of the Concordia station on Antarctica) that mimic the effects of near-weightlessness or isolation as experienced in space. These facilities allow for finetuning the parameters of the final space experiments but are also used to corroborate their results and increasing their statistical relevance.

Fluid Physics: The Fluid Science Lab (FSL) was one of the original facilities with which the Columbus laboratory was launched in 2008, and is still in use today. It is equipped with a broad suit of observational techniques to study the dynamic phenomena in fluids without the disturbing influence of gravity-induced convection, which is unavoidable on Earth. The range of samples and phenomena studied on FSL is manifold.

- A typical example is the study and design of **cooling technologies solely depending on capillary flow**, thus not requiring mechanical devices or gravity-induced processes. The resulting heat-pipes are today the technology of choice for many space systems (such as JUICE), but also Earth-based applications in critical areas are in view.
- Another example is the **study of foams**. Liquid foams are used the mining industry, cosmetics, firefighting, decontamination, oil recovery, and once solidified, in heat insulation and sound proofing, shock absorption, etc. On Earth, gravity causes liquid foams to rapidly lose their liquid component and decrease in volume, severely limiting the possibility of observing their behaviour. In space these effects are absent, allowing detailed studies of foam dynamics and properties.

Material Sciences: The Material Science Laboratory Electromagnetic Levitator (MSL-EML) is one of the bigger research facilities developed by Europe, installed in the Columbus module. MSL-EML is a multi-user facility for the melting and solidification of conductive metals, alloys, or semiconductors in ultra-high vacuum, or in high-purity gaseous atmospheres. This is especially important for reactive materials, such as molten metals or alloys, whose properties can be very easily disturbed by contamination from containers, which are unavoidable when doing experiments on Earth. The materials under study, such as iron, cobalt, copper, nickel, titanium and their alloys, have high industrial relevance, and the parameters observed can be directly used to **optimise industrial (casting) processes or making 'designer materials' with dedicated properties**. The work on EML has been awarded the prestigious G.W. Leibniz Award.

Experiments and research opportunities on ISS can be realized end-to-end in most cases in a shorter time than for 'big science' missions, and thus are attractive to young people, who can follow a well-defined path by incrementally doing space research starting from Earth platforms (i.e. space analogues of any kind, sounding rockets) to end up on the station and beyond. This fact, together with the variety of fields and science and technology involved in the ISS, underlines the immense benefit of scientific research on the ISS.

"For if anyone should come to the top of the air or should get wings and fly up, he could lift up his head above it and see, as fishes lift their heads out of the water and see things in our world, so he would see things in the upper world; and if his hold were firm and he continued to watch he would perceive that that is the real sky, the real light and the real Earth."

(attributed to Socrates)

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