→ EXPLORING TOGETHER

ESA Space Exploration Strategy

European Space Agency

European Space Agency

From the beginnings of the ‘space age’, Europe has been actively involved in spaceflight. Today it launches satellites for Earth observation, navigation, telecommunications and astronomy, sends probes to the far reaches of the Solar System, and cooperates in the human exploration of space.

Space is a key asset for Europe, providing essential information needed by decision-makers to respond to global challenges. Space provides indispensable technologies and services, and increases our understanding of our planet and the Universe. Since 1975, the European Space Agency (ESA) has been shaping the development of this space capability.

By pooling the resources of 21 Member States, ESA undertakes programmes and activities far beyond the scope of any single European country, developing the launchers, spacecraft and ground facilities needed to keep Europe at the forefront of global space activities.

The Member States are: 19 states of the EU (Austria, Belgium, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Poland, Portugal, Romania, Spain, Sweden and the United Kingdom) plus Norway and Switzerland.

Seven other EU states have Cooperation Agreements with ESA: Slovenia, Hungary, Cyprus, Latvia, Lithuania, Malta and the Slovak Republic. Croatia and Bulgaria are negotiating Cooperation Agreements. Canada takes part in some programmes under a Cooperation Agreement.

Cover image: This colour-coded overhead view is based on an ESA Mars Express High-Resolution Stereo Camera.
The colour coding emphasises the superposed craters.
Credit: ESA/DLR/FU Berlin

Published by the Strategic Planning and Outreach Office of the ESA Directorate of Human Spaceflight and Operations.

ESTEC, PO Box 299
2200 AG Noordwijk
The Netherlands

email: explorationstrategy@esa.int

www.esa.int

@esa

youtube.com/ESA

facebook.com/europeanspaceagency

→ FOREWORDS

A shared journey of space exploration

Whenever you start a voyage, your final destination shapes your path. It conditions your planning, the time and resources invested in it. And it gives you the motivation to keep going, to stay focused.

Space exploration missions are not different. After more than 50 years since humans ventured into orbit for the very first time, space exploration has evolved in terms of destinations, duration, objectives and partnerships. The challenges encountered on the way and the number of participants involved added to the level of complexity, but significantly increased their sustainability and their relevance to our common future on planet Earth. Exploration of low Earth orbit, the Moon and Mars is accomplished through a sequence of missions, each building on previous results. Missions to Mars are the ultimate challenge, including the return of samples and the close cooperation between robots and humans on the surface of the Red Planet.

There is a driving force behind it all – the ambition to explore further, to expand our knowledge and to drive global cooperation on Earth. Over many years, ESA together with its international partners has defined its exploration undertakings and the future of human spaceflight. ESA Space Exploration Strategy aims to reflect the outcome of those discussions.

More than 50 years of space exploration has not only satisfied human curiosity and built up international cooperation, but also improved life on Earth. The challenge has driven scientific and technological innovations that benefit people around the globe every day. ESA's strategy ensures that investments in space exploration are beneficial to society at large.

At Ministerial level, the ESA Council held in Luxembourg in December 2014 acknowledged the significant role of space exploration in the coming years. One of its resolutions on ESA evolution stated that the Agency should "maintain its role as one of the world-leading institutions within the fields of space science, Earth observation, space exploration, and related technology development."

Sustainable space exploration is beyond the capabilities of a single country. The European strategy strongly relies on the ambitions, capabilities and commitments of ESA Member States, as well as on opportunities offered by global cooperation with international partners. This strategy has been iterated with its Member States throughout 2014, and ESA is already preparing exploration proposals in line with this document for the next Council at Ministerial level, planned for 2016.

At this promising stage of the space exploration endeavour, ESA invites stakeholders to engage with the implementation of this strategy. Please join the voyage and help us turn our ambitions into reality.

Jean-Jacques Dordain, ESA Director General
Directors Committee for Exploration (DC-E)

Exploring the Solar System

The HESAC Committee looks forward to the expanded programme of Solar System exploration outlined in this new strategic plan, based on the exploitation of near-Earth orbit infrastructure, the access to the surface of the Moon for intensive in-situ exploration by robotic and human missions, and the revisit of Mars and its moons for new levels of scientific study.

ESA works with a range of international agencies as a prominent partner in the development of exploration strategies, seeking appropriate roles for European technology and science, as well as challenging engineering developments.

The scope of this new strategy will expand our knowledge of the Solar System and its early history over the next decades, building on the benefits of international collaboration expressed through the Global Exploration Roadmap (GER) and active participation in the International Space Exploration Coordination Group (ISECG).

The development of new robotic techniques, together with human-assisted robotic instruments, will bring data from new planetary locations. In addition, the prospect of analysing returned samples in sophisticated terrestrial laboratories will allow the study of the physical processes underlying the evolution of our immediate environment in the Cosmos.

The human exploration of Mars is the long-term objective of this programme, and it is therefore vital to embed the development of the necessary technologies for human spaceflight into this comprehensive strategy. This will provide both a means of achieving the Mars exploration goals and act as a focus for public engagement in this long-term international endeavour.

Human spaceflight and Exploration Science Advisory Committee (HESAC)

→ INTRODUCTION

The future of space exploration has been subject to intense debate throughout the last years, within Europe and internationally at political level, as well as among space agencies and other stakeholders. This debate demonstrated broad consensus on the potential of space exploration to produce societal, intellectual and economic progress for the benefit of our citizens. Space exploration is a political and global endeavour.

The European Space Agency is pursuing an independent strategic planning process for consolidating a destination-driven space exploration strategy to low Earth orbit, the Moon and Mars. International cooperation is a key pillar of ESA's strategy as it is considered both an enabler for realising the strategic interest of ESA and a benefit, opening new perspectives for addressing future challenges.

International cooperation does not prevent competition, an essential factor for fostering innovation and for the future of space exploration. ESA has already developed some critical capabilities, identified its future focus areas for space exploration and invested in selected research and development areas with a view to secure attractive roles in the global space exploration endeavour.

Various international fora exist today for exchanging information on national space exploration policies and plans, and for coordinating related planning activities.

International Fora

- The International Space Exploration Forum (ISEF). It fosters political-level dialogue. The last meeting took place in January 2014 in Washington, and the next one is scheduled to take place in 2016/2017
- The International Space Exploration Coordination Group (ISECG). This is the space agencies' forum for advancing a common vision on the next steps for global space exploration. It has produced a Global Exploration Roadmap (GER) as a result of the joint work of 14 space agencies.
- The International Mars Exploration Working Group (IMEWG). Space agencies advance the definition of a common international Design Reference Mission for returning samples from Mars.
- The United Nations Office for Outer Space Affairs (UNOOSA). The Office promotes the engagement of emerging space faring nations in the future global space exploration endeavour.

From all these discussions, three common mission goals for the next decades are emerging:

- Exploitation of human-tended infrastructures in Low Earth Orbit (LEO) beyond 2020 for advancing research and enabling human exploration of deep space
- Returning samples from the Moon and Mars
- Extending human presence to the Moon and Mars in a step-wise approach

ESA and its Member States are making progress in their current space exploration programmes, focused on the exploitation of the International Space Station (ISS) and the robotic exploration of Mars.

The implementation of the Space Station programme and the ExoMars missions are the focus for investments up to 2020. These programmes, together with investments in the development of lunar exploration products and the Mars Robotic Exploration Preparatory Programme (MREP), prepare for an international engagement in the space exploration endeavour for the post-2020 era, strongly leveraging on international cooperation opportunities.

Besides ESA, the European Commission, through the "Horizon 2020" research programme, and national space agencies are investing in space exploration. While ESA and the European Union are further developing their relations, careful coordination between these two organisations and the Member States will be critical for securing a strong role for Europe within this international endeavour.

The ESA strategy outlines the long-term planning for Europe's participation in space exploration, focusing on the next ten years but also taking into account longer-term perspectives.

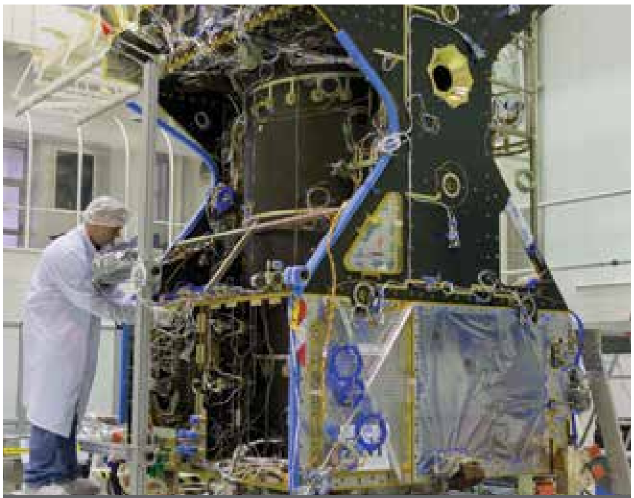
The strategy describes a coherent approach for an ESA-wide policy on space exploration. Its aim is also to articulate a European position on planning for space exploration to inform decision-makers, international partners and other stakeholders, such as the scientific community, industry and the general public.

↑ ESA Meeting at Ministerial Level, Luxembourg, on 2 December 2014. Ministers in charge of space activities within the ESA Member States and Canada discussed the future European strategy for exploration

→ WHY EXPLORE

ESA space exploration vision

Space exploration is an open-ended process which started 50 years ago. It enables access to unknown terrains with robots and humans, thereby opening new frontiers. It is an international endeavour as it benefits society at large, addresses fundamental questions related to the history, existence and future of life and fosters international partnerships. Space exploration stimulates knowledge gain, innovation and inspiration. A global space exploration endeavour creates new opportunities for addressing humanity's future global challenges.



↑ ESA ExoMars Trace Gas Orbiter

Science

Strengthening European excellence in scientific research and knowledge gain through opportunities for in-situ investigations and the development of advanced instrumentation and enabling technologies.

Economics

Contributing to the competitiveness and growth of the European industrial sector by pushing the frontiers of knowledge and developing new technologies in other fields of economic value.

ESA Strategic Goals

Global cooperation

Establishing a global cooperative framework to carry out space exploration projects, involving in each case interested partners, and pursuing common goals relevant for humanity as a whole.

Inspiration

Attracting society, in particular young generations to expand our knowledge and capabilities, to the study of natural sciences and engineering, to the values of global cooperation in space, and to the preparation of sustainable human presence in the Solar System.

→ WHERE EXPLORE

ESA activities and planning in space exploration are focused on three priority destinations: low Earth orbit, the Moon and Mars.

Destinations

Low Earth orbit: This is currently the only destination within reach by humans. The International Space Station has been permanently inhabited since 2000. The current crews consist of six astronauts of different nationalities.

Moon: A total of 12 US astronauts visited the lunar surface from 1968 to 1972 during the Apollo programme.

Mars: Achieving human missions to Mars is considered at international level the common goal for human exploration in this century, to be achieved in a step-wise approach, through robotic scouting of the Martian surface and human missions to the Moon as a stepping stone and destination in its own right.

Selection criteria

- Accessibility and ability to implement a series of robotic and/or human missions, each mission building on the results achieved by the previous one
- Ability to land humans on the Moon and Mars within the next 20 to 30 years
- Potential for advancing knowledge gain and addressing priority science questions
- Opportunity for establishing international partnerships

Each of those three destinations offers unique opportunities for gaining knowledge. Research onboard the International Space Station advances scientific knowledge in many domains, in particular in the fields of life and physical sciences and the ability for humans to work and live in extreme environments. The International Space Station also hosts payloads for Earth observation, astrophysics and technology.

Missions to the Moon and Mars allow to learn more about the resources, hazards for humans and environment of these destinations. Those missions advance broader scientific questions related to the history of the Solar System and the emergence and co-evolution of life on Earth within its planetary environment.

Three destinations, one roadmap

Human missions to low Earth orbit and the lunar vicinity play an important role in the step-wise extension of human presence. Low Earth orbit has proven to be an ideal location for advancing human research, demonstrating operational concepts and technologies, and maturing capabilities in preparation for deep space exploration.

The international architecture that supports future human exploration and the associated roles and responsibilities of partners, will be shaped during an early exploration phase to the lunar vicinity. Early human missions in the vicinity of the Moon, taking place at the same time as robots operating on the lunar surface, will enable to advance human/robotic partnership and foster innovative mission concepts.

Recent discoveries of volatiles at the lunar South Pole regions make the Moon an ideal place for demonstrating the potential resulting from in-situ resources utilisation in support of human exploration. Volatiles are chemical components that sublimate at relatively low temperatures (i.e. nitrogen, water, carbon dioxide, ammonia, hydrogen, and methane). Furthermore, human missions to the lunar surface are a key component in reducing risks for human long-duration missions on the surface of Mars.

The Global Exploration Roadmap developed and maintained by ISECG provides a thorough account of current international plans for missions to those exploration destinations.

Exploitation of human infrastructures in low Earth orbit will continue well beyond 2020. A significant international fleet of robotic missions to the Moon and Mars is in operation, under development or planned. At the same time, work on new transportation capabilities has been initiated which will allow humans to venture beyond low Earth orbit in the early 2020s for the first time since 1972.

LEO	Moon	Mars
INTERNATIONAL MISSION GOALS		
• Sustained exploitation of human-tended infrastructures beyond 2020, with increased cost-efficiency and responsiveness to utilisation interests (ISS, Chinese Space Station)	• Robotic exploration • Sample return • Human exploration and human-assisted robotic exploration	• Robotic exploration • Sample return • Human exploration
STRATEGIC ASPECTS		
• Gradual transition towards an enhanced role of the private sector (Space X, Sierra Nevada, Orbital) • Cooperation with China	• Opportunity for advancing human-robotic partnership concept during early human missions beyond LEO • Natural platform for advancing science and technology objectives • Resource potential for continued exploration and long-term economic development of the Moon and cis-lunar space	• Extension of human activity beyond the Earth-Moon system
ACCESSIBILITY		
• Reachable within hours • Daily launch windows	• Reachable in a few days • Launch windows every 9–12 days	• Reachable within < 1 year • Launch windows every 26 months
OPPORTUNITIES FOR KNOWLEDGE GAINS		
• Research in life and physical sciences • Earth and space science	• History of the Solar System, including the cosmic context for understanding the origin of life on Earth • Using the Moon as a platform for investigations in planetary science, astrobiology, life sciences and fundamental physics, radio-astronomy and astrophysics	• Search for life • Planetary evolution
PROGRAMMATIC ASPECTS		
• Preparation of human space exploration and of European roles in international exploration missions	• First destination of humans beyond LEO • Shapes international roles and partnership	• Demonstration of Mars Sample Return (MSR) capabilities • Long term destination for humans
SUPPORTING ESA PROGRAMMES		
• ISS up to 2020 • Post 2020 still to be determined	• Development of Multi-Purpose Crew Vehicle - European Service Module (MPCV-ESV) • Development of lunar exploration products	• ExoMars • Mars Robotic Exploration Preparation Programme (MREP)

Supporting ESA Programmes

The International Space Station and the European Programme for Life and Physical Sciences in Space (ELIPS)

The International Space Station is a shining example of global cooperation, uniting Europe, USA, Russia, Japan and Canada in one of the largest partnerships in the history of science. Fully assembled and operational since 2011, the Station has received nearly seven tonnes of supplies from the fifth and last Automated Transfer Vehicle (ATV-5). In 2015, three ESA astronauts are set to live and work onboard. ESA utilisation of the Space Station continues with a large number of experimental activities successfully performed. Most of the human research, radiation, biological and astrobiological experiments are of scientific significance for human exploration preparation as they elaborate on the adverse effects of space on the human well-being and performance during long-duration missions.

Multi-Purpose Crew Vehicle - European Service Module (MPCV-ESM)

ESA is developing the European Service Module for Orion, NASA's new crewed spacecraft. The official name of Orion is 'Multi-Purpose Crew Vehicle' and will carry astronauts beyond Earth orbit. The European Service Module will be located directly under Orion's crew module. It will provide four major system functions to the capsule: propulsion, power, thermal control, and vital resources for the astronauts, such as water and breathable atmosphere. It is the first time that Europe will provide system-critical elements for an American space transportation vehicle, enabling human missions to the Moon's vicinity.

Lunar Exploration

The ESA approach for "Destination Moon" focuses on developing core exploration products for precursor robotic missions: PILOT for landing, PROSPECT for investigating resources and SPECTRUM for communicating. A first flight opportunity has been identified on the Roscosmos lunar missions. Related preparatory activities are ongoing in European institutes and industry. ESA is paving the way for a more important contribution to a joint Lunar Polar Sample Return mission.

Mars Exploration

The ESA-Roscosmos ExoMars programme consists of two missions to be launched in 2016 and 2018, respectively. ExoMars will deliver world-class science in the "search for life" theme, and provide Europe with essential exploration technologies, such as landing, roving and drilling on Mars. In the context of the Mars Robotic Exploration Preparation programme (MREP), exploration technologies are developed and candidate missions are being studied for post-ExoMars launch opportunities to the Red Planet. MREP prepares the ground for a significant European contribution to an international Mars Sample Return campaign.

Technology

Several critical technologies are being developed for a future potential European participation to a Mars sample return mission, such as those related to precision landing, the sampling chain (including sample capture and sealing in orbit and the sample receiving facility), and the Earth return capsule. Technology demonstrations for closed-loop life support systems include the Micro-Ecological Life Support System Alternative (MELiSSA) and the Advanced Closed-Loop System (ACLS) aboard the International Space Station. Europe's ATV-5 mission included a fly-around of the Space Station for testing optical-sensor prototypes for rendezvous and docking with non-co-operative targets. To help turn robotics and remote operations into a standard tool for space missions, ESA is linking the Space Station with Earth. As an example of human-robotic partnership, the Multi-purpose, End-to-End Robotic Operations Network (METERON) experiments are preparing to send robotic explorers to "test the waters" ahead of humans on uncharted planets. The ESA technology roadmaps for space exploration are currently updated to serve as a crucial tool for setting investment priorities in this field.

→ HOW TO EXPLORE

Preparing a long-term plan

The most visible milestones in the exploration process are the accomplishments of missions. However, space exploration benefits from taking a long-term perspective and applying long-term planning.

Progress in exploration is achieved in a step-wise manner, with each step having its unique value and playing a critical role in preparing future steps.

ESA structures its long-term plan around missions to low Earth orbit, the Moon and Mars which most effectively advance the ESA strategic goals for space exploration.

How to achieve a robust plan?

- Identifying and exploiting synergies between:
  - Missions targeting different exploration destinations and conducted with robotic and/or human means
  - ESA's exploration and other space activities enabling cross-fertilisation
- Selecting roles consistent with European potential and priorities in coordination with ESA activities, the European Commission and national agencies of the Member States
- Allowing for continuity of European roles and the evolution of capabilities and budgets
- Enabling sustainable and flexible planning to timely respond to emerging challenges and cooperation opportunities
- Assessing major programmatic risks

Working together

Exploration of space is a global undertaking. Already today, all ESA space exploration activities are implemented in international cooperation. ESA with its 21 Member States represents an effective model for international cooperation.

International cooperation

International cooperation is not only a necessity for realising future exploration missions but it also allows for achieving more value for money by pooling resources, complementing each other's capabilities and sharing resulting benefits.

To date ESA has no autonomous capabilities in human spaceflight. However, the European Space Agency is capable of implementing end-to-end robotic exploration missions.

The complexity of future exploration missions and the associated resource requirements prevent ESA from implementing autonomous missions within the current and foreseen budget.

ESA principles for international partnership

- Ensure robust cooperation through occupying critical path roles
- Structure partnerships based on complementarity and mutual benefits
- Build incremental long-term strategic partnerships
- Become the partner of choice through demonstrating areas of excellence, a track record of mission successes and reliability in delivering on commitments
- Create a strong foundation for future partnerships and global engagement through promoting a flexible cooperation framework

Partnership opportunities

The combination of cooperative activities, on-going or in preparation with NASA, Roscosmos and the other ISS partners consolidates the strategic partnership with these actors.

Current exchanges with the China Manned Space Agency related to astronaut training and ISS utilisation open perspectives for establishing concrete cooperative activities in low Earth orbit. The Chinese space agency (CNSA) has also indicated an interest to cooperate in the field of robotic exploration of the Moon and Mars, in particular for sample return missions.

In future, opportunities may also materialise with the private sector. ESA will continue to monitor international space exploration policies and plans for identifying cooperation opportunities.

ESA is open to establishing partnerships with all space agencies active in its programmatic lines of interest, and pending concrete and attractive cooperation opportunities.

Criteria for assessing the attractiveness of cooperation opportunities for ESA

- Alignment with goals and objectives
- Complementary capabilities
- Opportunity to play a role on the critical paths of exploration missions
- Opportunity to extend cooperation beyond a single mission, taking a long-term perspective

	NASA	Roscosmos	CSA	JAXA	CNSA	Private Sector
LEO exploitation - ISS						
LEO exploitation - post ISS					Station	Capsules
Human missions beyond LEO	MPCV-ESM					
Robotic Moon exploration		Luna 25-28			Science	
Robotic Mars exploration		ExoMars	ExoMars			

on-going · in preparation · potential

↑ Partnership opportunities by programmatic lines and partners

NASA: National Aeronautics and Space Administration (US)
Roscosmos: Russian Federal Space Agency
CSA: Canadian Space Agency
JAXA: Japan Aerospace Exploration Agency
CNSA: China National Space Administration

→ MISSION ROADMAP

ESA perspectives in future space exploration

Funded and planned activities open perspectives for the future role of ESA in the international space exploration endeavour:

- Sustained exploitation of LEO post-2020, including ISS extension and/or other human-tended platforms
- Participation in sustained Moon exploration. ESA would participate in two strategic areas related to getting access to the lunar surface:
  - Crew transportation capabilities to the vicinity of the Moon with NASA
  - Access and sample return capabilities from the lunar surface with Russia
- Participation in the first mission to return samples from Mars

Destination approaches

LEO

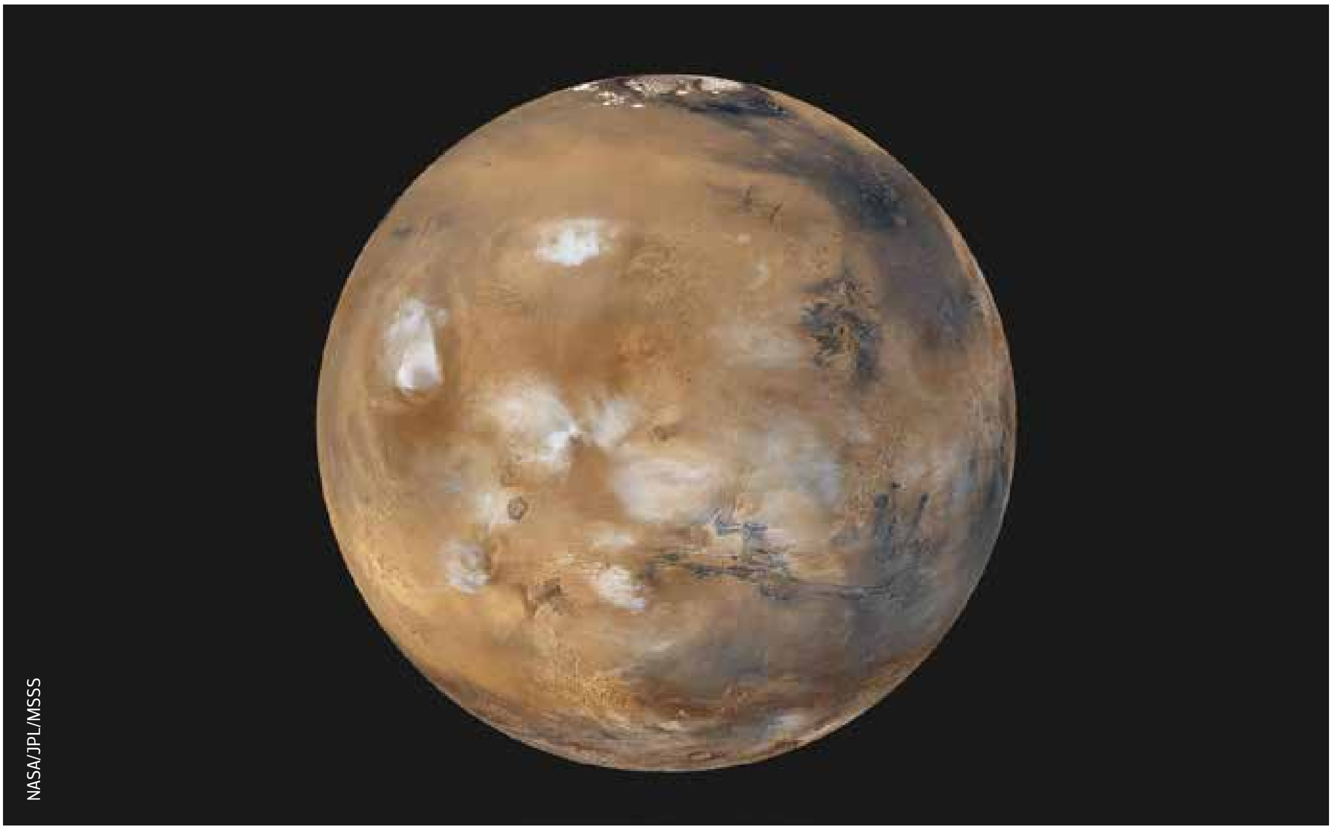
Sustained exploitation of low Earth orbit can be achieved through an extension of the International Space Station lifetime. It can also rely on other private sector (e.g. automated platforms potentially derived from transportation systems developed by SpaceX, Orbital, Sierra Nevada Corporation, Blue Origin or Boing) and government-owned platforms (e.g. Chinese Space Station). Latter platforms will exist long beyond the ISS and ensure a long-term perspective and user-driven LEO exploitation.

MOON

The European engagement in the Russian-led Luna-Resurs and the Lunar Polar Sample Return missions will create opportunities for technologically attractive ESA roles in human lunar exploration.

Current considerations and conceptual work reflected in the ISECG Global Exploration Roadmap foresee the development of a staging post in the lunar vicinity. Such a staging post advances lunar surface exploration capabilities and deep space exploration. It opens up options for innovative approaches and mission scenarios for lunar exploration, such as human-assisted robotic surface operations (e.g. tele-operations of automated lunar surface infrastructures), as well as refurbishment of re-usable lunar lander. Furthermore, it allows for integrating international capabilities in the architecture for lunar exploration and enhances its overall robustness.

The European development of the service module for NASA's Orion crew transportation vehicle together with the development of an international lunar landing capability with Roscosmos provides a sustained role for ESA in such architecture.



MARS

The ExoMars missions and the follow-on post-ExoMars mission pave the way for a significant ESA contribution to an international Mars Sample Return campaign. This is the most important medium-term objective for Mars exploration. These missions also prepare for human missions to Mars.

Synergies

The implementation of an integrated plan for space exploration is based on the smart exploitation of synergies. Identification and exploitation of synergies is a key element of the ESA-wide plans for space exploration. Such synergies exist between:

- Missions to different destinations in the area of technologies, research on human health and performance risks associated to working in space, transportation, science as well as maturation of space operations, systems and capabilities. The gradual evolution of capabilities will allow to implement more demanding and complex exploration missions in a step-wise approach.
- Human and robotic missions in the area of technologies as well as acquisition of knowledge critical for future human missions. Robotic missions may generate specific knowledge that helps to characterize the environment, identify hazards, and assess resources. While in the early phases the focus will be on the exploitation of synergies between human and robotic missions, humans and robots will eventually become complementary elements of an integrated mission concept. A possible milestone in the near future of such integrated mission concepts could be the presence of robots on the lunar surface assisted by humans in the lunar vicinity, enabling also the return of samples with the crew transportation system.

The development of capabilities for space exploration will also benefit from investments in other space activities (e.g. in the field of communication, science and transportation).

Human presence in the Earth-Moon-Mars space will create new possibilities for advancing science objectives, protecting planet Earth against natural threats from space and servicing space infrastructures for terrestrial applications.

DESTINATION LEO

STRATEGIC OBJECTIVES

- Make optimum use of ISS, autonomous missions platforms and complementary ground-based platforms for research and in preparation of future exploration and sustainable human presence in space
- Further optimise international cooperation on ISS utilisation to maximise the output by exploiting synergies in joint research objectives and assets
- Attract new users for ISS and future utilisation platforms
- Secure continued combined access to LEO infrastructures for European astronauts and the user community beyond ISS at sustainable cost levels

CONTRIBUTING FACTORS

- Life and physical sciences, space and Earth sciences → Science
- Technology demonstration, evolution of ESA relation with private sector → Economics
- Astronaut missions, education activities → Inspiration
- ISS partnership, collaborative utilisation projects → Cooperation

STRATEGIC GOALS

- Science
- Economics
- Inspiration
- Cooperation

DESTINATION MOON

STRATEGIC OBJECTIVES

- Acquire access to lunar surface for advancing knowledge of the Moon, understanding role of its resources for future human space exploration and advancing fundamental scientific questions related to the history of the Solar System and the origin of life on Earth
- Secure a role on the critical path in the international architecture that supports human exploration of the Moon and beyond
- Advance human-robotic partnership in space establishing human and robots as integral elements of lunar exploration missions
- Promote establishment of multi-lateral cooperation framework for lunar exploration

CONTRIBUTING FACTORS

- History of Solar System including cosmic context for understanding the origin of life on Earth, using the Moon as a research platform → Science
- Technology demonstration, evolution of ESA relation with private sector → Economics
- Astronaut missions, education activities, operations of human and robotic elements in partnership → Inspiration
- Evolution of ISS partnership toward flexible framework, open to new partners → Cooperation

STRATEGIC GOALS

- Science
- Economics
- Inspiration
- Cooperation

DESTINATION MARS

STRATEGIC OBJECTIVES

- Develop critical exploration technologies and enable world-class science through the ExoMars missions
- Prepare for a significant European role in an international Mars Sample Return campaign by building on ExoMars, developing new key technologies and preparing and implementing post-ExoMars missions
- Build strategic partnerships with Roscosmos and NASA for implementing and international Mars Sample Return campaign

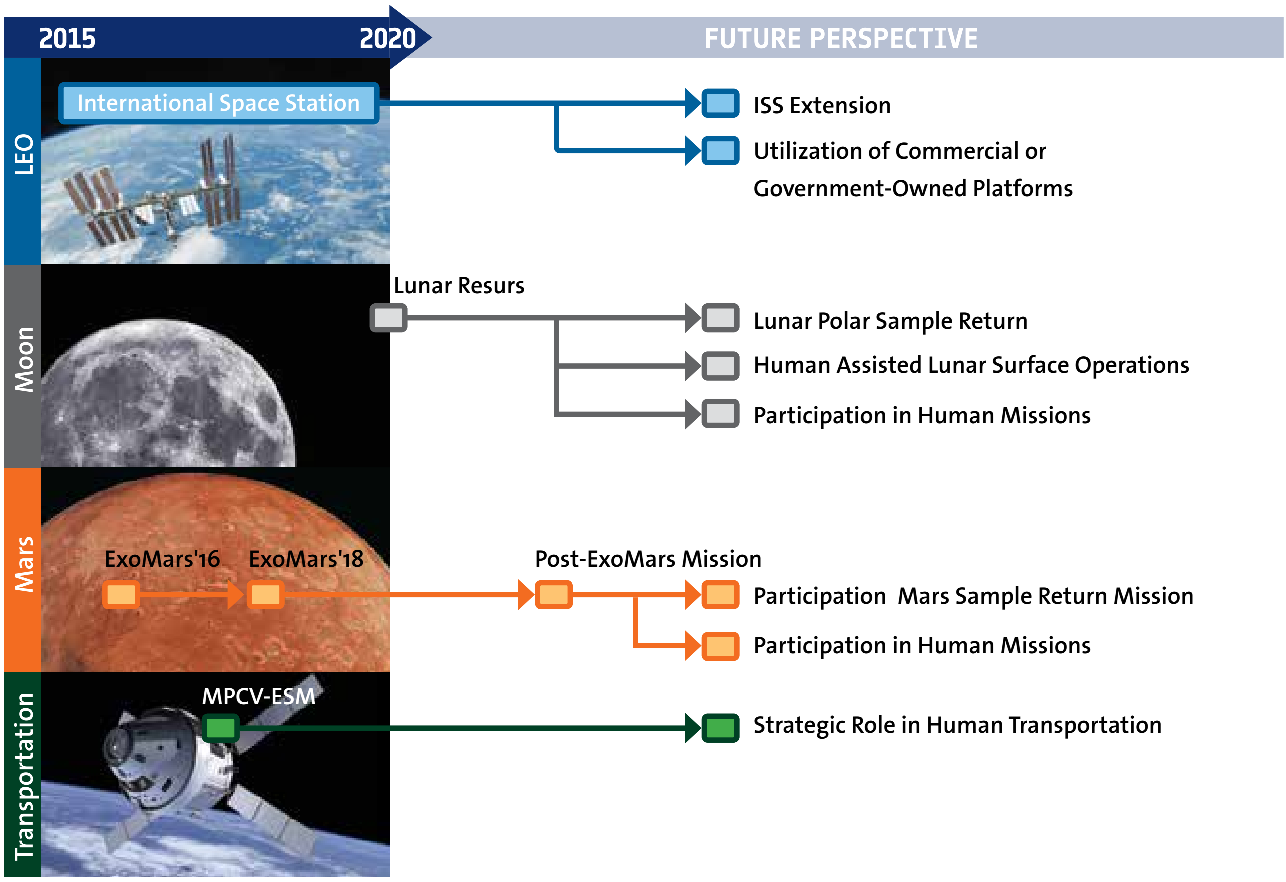
CONTRIBUTING FACTORS

- Search for life planetary evolution → Science
- Technology demonstrations → Economics
- Education activities → Inspiration
- Multi-lateral framework for Mars Sample Return, building on ExoMars cooperation → Cooperation

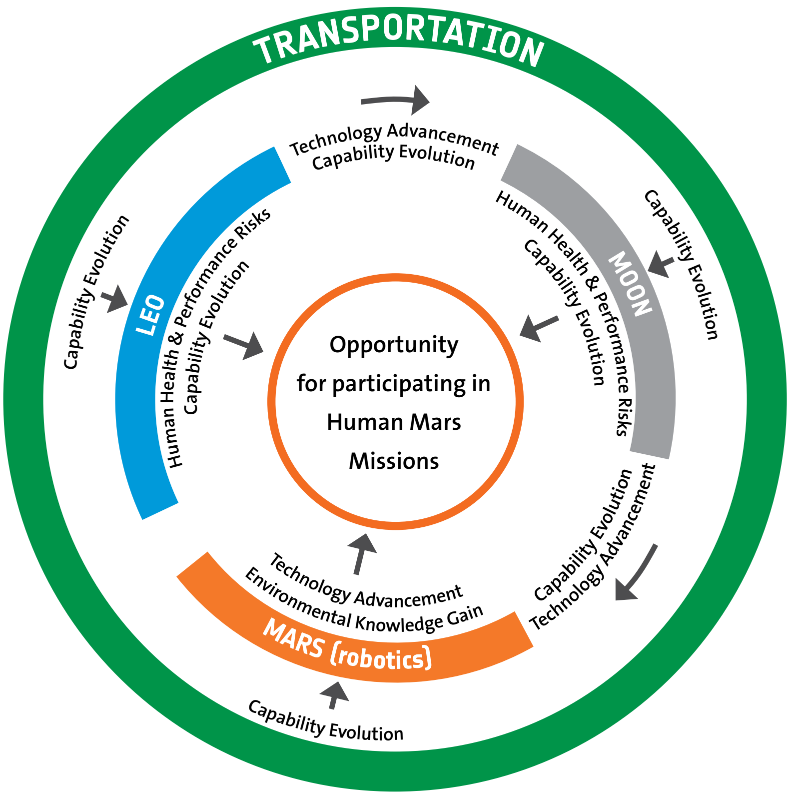
STRATEGIC GOALS

- Science
- Economics
- Inspiration
- Cooperation

↑ ESA's strategic approach per destination



↑ Enabled future perspectives for ESA



↑ Exchange factors between programmatic lines

→ EUROPEAN CONTRIBUTIONS

Approaches

Europe acts as global player in space exploration within an international cooperation framework balancing mutual dependence and independence. ESA leverages on the International Space Station and ExoMars investments and further evolution in low Earth orbit activities.

ESA space exploration activities are based on targeted involvement in international missions for achieving the European Space Agency strategic goals, aiming to advance knowledge, inspire and drive innovation.

ESA's capabilities need to be advanced and demonstrated in order to secure future participation on the critical path of individual missions. ESA roles shall be defined with a long-term perspective and considering a sequence of missions.

ESA's roles

- Be consistent with European technical expertise
- Be on the critical path for international space exploration missions, leading to a robust cooperation and ESA influence on the missions definition
- Allow for advancing European scientific interests
- Ensure visibility of Europe by enhancing the outreach potential
- Drive innovation in European priority technology domains
- Allow for exploiting technology synergies with other space and terrestrial applications
- Complement interests of partners, creating opportunities for adding value to their missions

ESA's areas of engagement

- Robotics
- Sample acquisition, analysis, handling and return
- User-driven research
- Transportation
- Operation
- Habitation

Astronauts and operations

Astronauts are the most visible elements of human exploration missions and the key enablers of increasingly complex operations. The experience gained with the International Space Station will prove fundamental to enable beyond low Earth orbit missions, yet a number of technologies and tools should be developed to allow astronauts perform efficiently in deep space.

ESA strong competence and front-rank role in astronauts training and crew operations should be enhanced to extend this European excellence to missions targeting celestial bodies.

Priority technologies for space exploration

Future investments in technologies shall be consistent with envisaged European participation in international missions in the ESA areas of engagement. ESA has identified priority technologies for space exploration and how they apply to missions and ESA roles. Advancing and demonstrating these technologies, and then evolving them throughout a sequence of missions will consolidate ESA technology areas of excellence.

Additional technologies may be identified in the future pending the evolution of ESA roles within the international mission scenarios.

ENVISAGED ROLES	TECHNOLOGY DOMAIN (Marked boxes indicate potential mission applications and planned technology demo's)	INTERNATIONAL MISSION SCENARIO								
		LEO	Luna- Resurs	LPSR	Human Assisted Robotic Lunar Surface Operations	Human Lunar Surface	ExoMars	Post- ExoMars	MSR	Human Mars
User-driven Research	Scientific/Exploration Payload Technologies	■	■	■	■	■	■	■	■	■
Operations, Including Astronauts	Assets tracking	□	■	■	■	■	□	■	■	■
	Earth-Moon Communication Infrastructure	□	■	■	■	■	□	□	□	□
	Proximity communication (UHF link)	□	■	■	■	■	■	■	■	■
	Tele-robotic control of robotic systems	■	□	□	■	■	□	□	□	■
	Astronauts related technologies	■	□	□	■	■	□	□	□	■
Sample Acquisition, Return and Handling	Sampling technologies	□	■	■	■	■	■	■	■	■
	Sample container and bio-sealing	□	□	■	■	■	□	■	■	■
	Re-entry capsule from Moon/Mars system	□	□	■	□	□	□	■	■	□
	Sample receiving facility	□	□	■	■	■	□	■	■	■
Transportation & Navigation	Precision Navigation, HDA sensors & algorithms	□	■	■	■	■	□	■	■	■
	Precision Landing and HDA GNC and avionics	□	■	■	■	■	□	■	■	■
	Advanced GNC technology for ascent	□	□	■	■	■	□	□	■	■
	Chemical propulsion systems for planetary landing and ascent	□	□	■	■	■	□	■	■	□
	Sensors for on-orbit RendezVous and docking	■	□	□	■	■	□	■	■	■
	High Thrust Engine for improving Mars insertion	□	□	□	□	□	□	■	■	■
	Orbiting sample Rendezvous and capture	□	□	□	□	□	□	□	■	□
	Mars Precision Landing technologies	□	□	□	□	□	□	■	■	■
	Surface Mobility	□	□	□	■	■	■	■	■	■
Robotics	Advanced robotic servicing for orbital operations	■	□	□	■	■	□	□	□	■
	In-situ consumables production	□	□	□	□	■	□	□	□	■
	Particulate Countermeasures	□	■	■	■	■	□	■	■	■
Habitation	Atmosphere monitor & control	■	□	□	■	■	□	□	□	■
	Crew Health Monitoring	■	□	□	■	■	□	□	□	■
	Trash Management	■	□	□	■	■	□	□	□	■
	Water Recycling	■	□	□	■	■	□	□	□	■
	Bio-regenerative Life Support Systems	■	□	□	□	□	□	□	□	■

■ contributing □ not contributing

↑ ESA priority technology domains

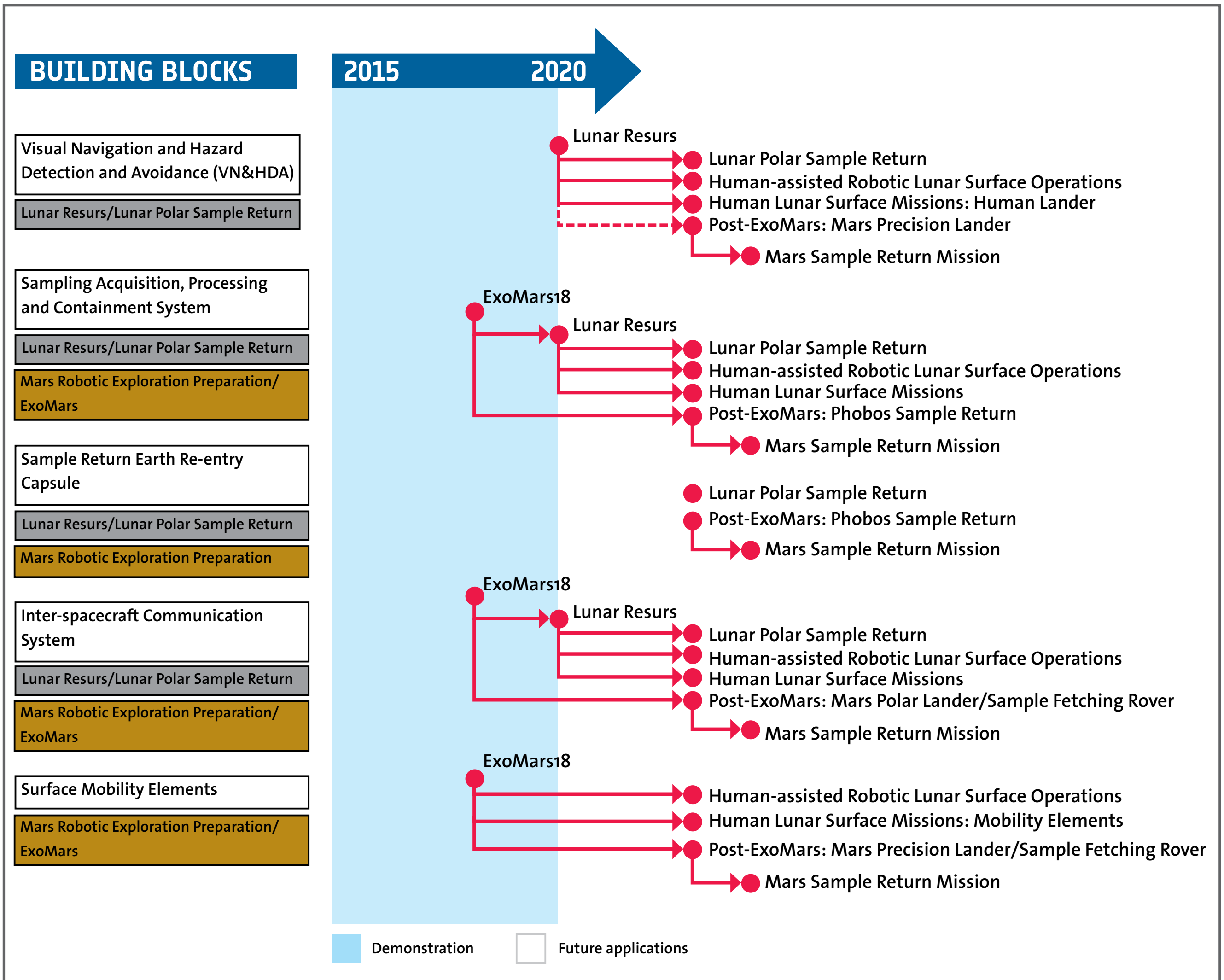
Building blocks

ESA is already maturing some building blocks that are important for post-2020 space exploration missions.

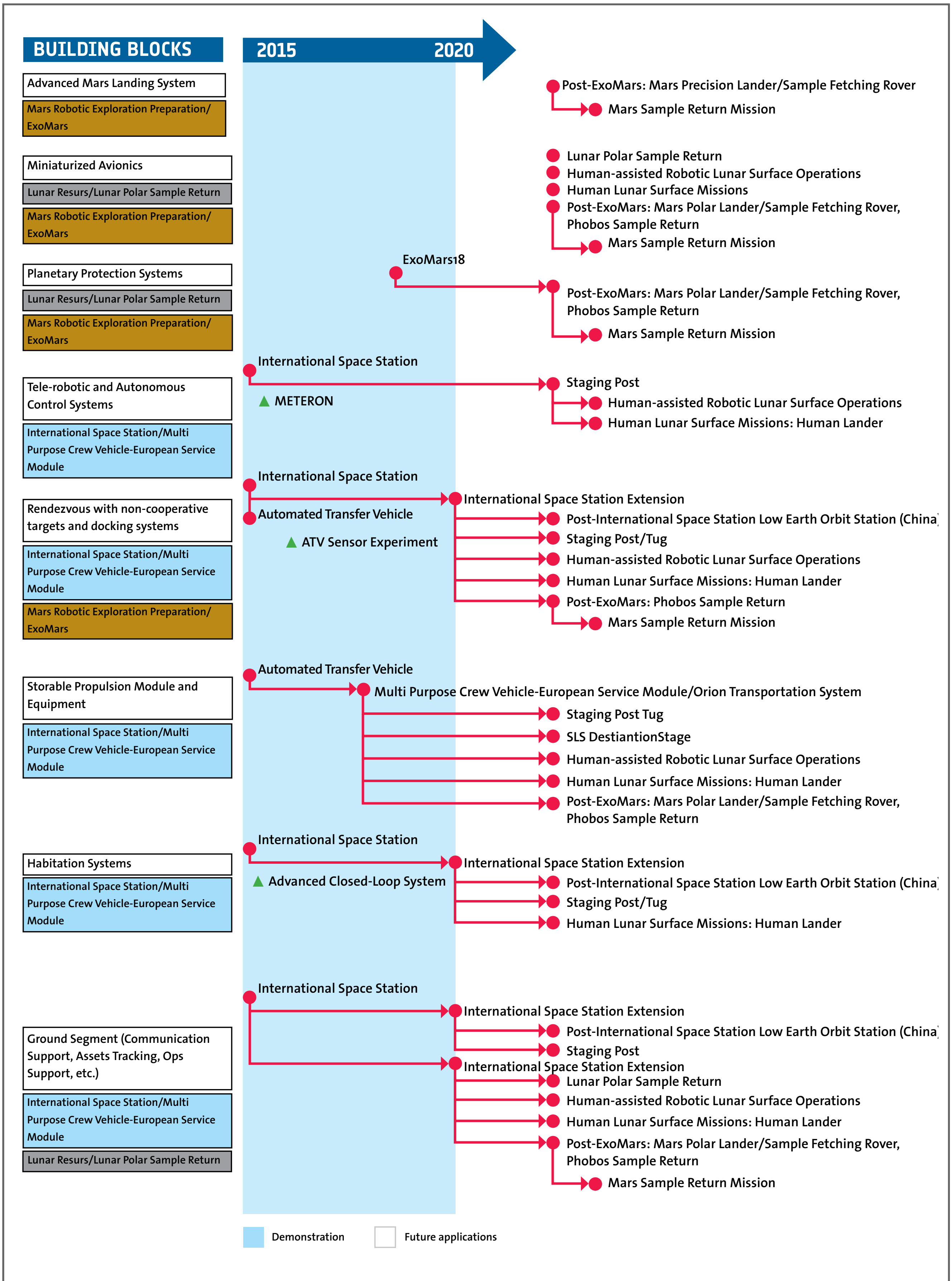
Each building block represents an important capability at mission element, system or sub-system level, and integrates a set of ESA's priority technologies. Therefore, it represents an area of European industrial expertise.

The following graphics show the preparation of these building blocks by the planned missions up to the 2020 timeframe, as well as opportunities for evolving towards securing applications in the international post-2020 exploration scenario.

Additional building blocks may be identified in the coming years as the definition of international mission scenarios, European interests and roles mature.



↑ Building blocks applicability to future missions/mission elements (part 1)



↑ Building blocks applicability to future missions/mission elements (part 2)

Research ambitions

There is a widespread understanding among space faring nations about the unique role of humans in exploring further into space. There are, however, many challenges in research and technology that must be met.

The utilisation of Europe's Columbus laboratory on the International Space Station, together with a variety of autonomous low-gravity platforms and analogue studies on the ground, has placed ESA in a very strong position in space research at international level.

Current research platforms and campaigns

Mars500

ESA participated with two European crewmembers in the full 520-day Mars mission simulation. Isolation and confinement provide challenges for long-term human spaceflight missions.

Bedrest

The physiological effect of lying in bed tilted at six degrees for an extended period with the head lower than the feet produces bone and muscle mass loss and fluid shifts similar to those seen in human spaceflight.

Concordia

Living in complete isolation for around nine months in one of the world's most extreme environments, Antarctica, creates an ideal opportunity to conduct research into the adaptation of human psychology and physiology.

IBER

Particle accelerator facilities testing the effects of radiation in different environments are a vital part of planning for future spaceflight, with the testing of different organic materials, equipment and technologies verifying that a mission can deal with exposure to the different levels of cosmic radiation in orbit.


GSI Helmholtzzentrum für Schwerionenforschung GmbH

Drop Towers

Drop towers are multi-purpose facilities, which enable autonomous experiment packages to be submitted to true free-fall conditions.

Parabolic Flights
Parabolic flights are aircraft flights conducted with specific mission profiles using specially converted aeroplanes. These aircraft execute a series of manoeuvres, called parabolas, each providing up to 22 seconds of reduced gravity (Moon and Mars) or weightlessness. Scientists are able to perform experiments and obtain data that would otherwise not be possible on Earth.

Sounding rockets
ESA sounding rockets follow a parabolic trajectory from launch to landing and provide between six and 13 minutes of microgravity environment.

International Space Station/Columbus
The orbital complex houses a large suite of long-duration life science experiments using the unique space conditions in the domains of human research, radiation and space biology.

A very active European user community is using the full range of research opportunities, helping to pave the way for future human space exploration.

ESA is implementing an increasing number of joint ISS experiments with NASA and Roscosmos in the domains of biology, human research, material sciences and fundamental physics. Collaboration with China for joint life and physical science experiments in low Earth orbit – on the ISS and future Chinese Space Station – is already progressing.

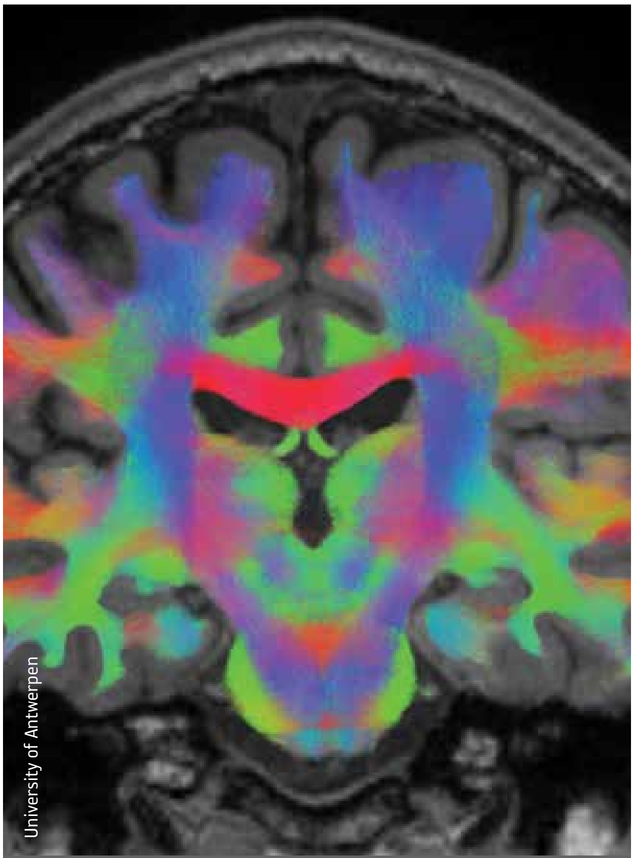
International collaboration with all ISS partners and pooling of resources is an important strategic approach for optimum exploitation of the LEO opportunities and preparation of future missions.

Opportunities should be explored for integrating China into international coordination processes. ESA can and should play an instrumental role in coordinating the complementary utilisation of the future Chinese Space Station and the International Space Station.

Recommended human research topics

Considering the strength of the European user community, the following topics are recommended ESA focus areas for additional research, most of them already in progress or planned. These areas should be addressed with high priority, and could generate critical knowledge that enables future human space exploration.

- Radiation effects and protection strategies
- Long-term exposure of organic species to the harsh conditions of open space
- Ensuring physiological human health and performance
- Maintaining psychological health and performance
- Autonomous medical care and telemedicine
- Detecting the impact of space conditions on cells, plant and animal development in dedicated biological experiments
- Closed-loop life support systems and food production
- On-orbit analysis technologies
- Advanced materials solutions for construction and propulsion
- Heat transfer and power generation systems



↑ An advanced MRI scan of a human encephalon showing brain wiring

↑ ESA astronaut Alexander Gerst examined the burning and extinction characteristics of a wide variety of fuel samples in microgravity during his six-month Blue Dot mission

→ BENEFITS FOR HUMANKIND

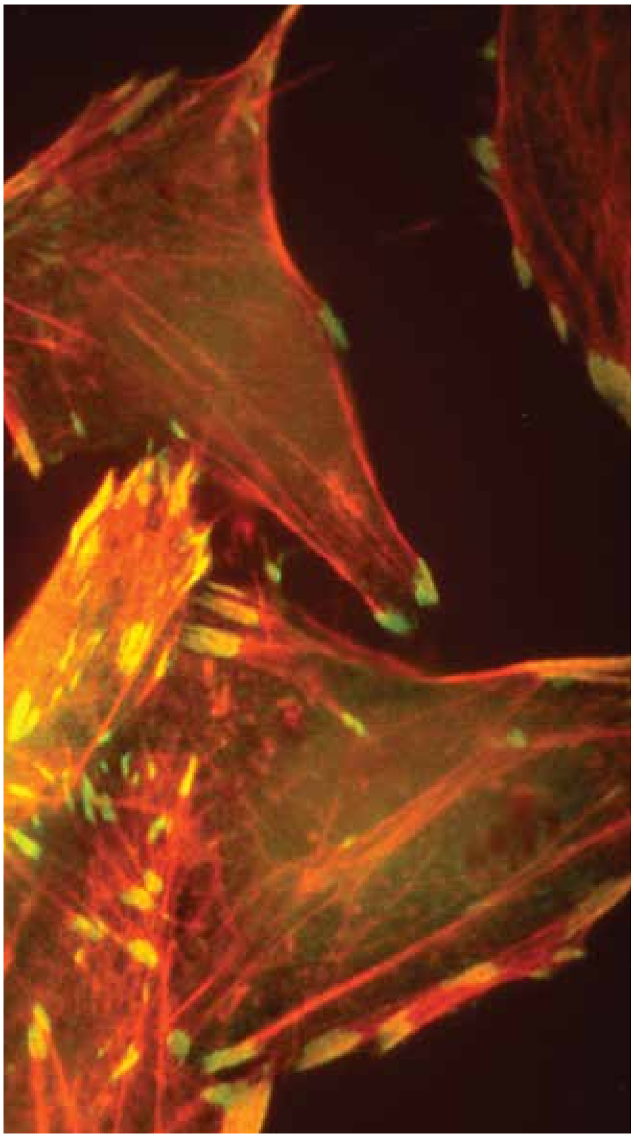
ESA's vision positions space exploration as a global endeavour, which benefits society at large. ESA's strategic goals relate to those areas in which space exploration is creating concrete opportunities to deliver benefits for society.

Initial reflections on some concrete actions per area

Economics

Investments in space exploration may contribute to economic growth in various ways, such as through technological innovation, nurturing of the technical workforce and through enlargement of the economic sphere.

The number of private sector initiatives related to space exploration is growing. ESA intends to opening up new opportunities for partnership with the private sector, complementing its traditional role as a customer.



Science and knowledge gain

The comprehensive brochure "Towards a science-led one ESA" introduced these grand science themes in 2013. The four themes were established by the High-level Science Advisory Committee (HISPAC) through consultation of the science community.

ESA intends to better articulate the unique value of space exploration for advancing ESA's grand science themes:

- Terrestrial and cosmic climate
- Understanding gravity
- Life in the Universe
- Cosmic radiation and magnetism

Inspiration

Space exploration offers a unique and evolving perspective on humanity's place in the Universe as it addresses fundamental human questions about the origin, uniqueness and destiny of humankind. Knowledge gained from space exploration and the shared experience of exploring may inspire and have wide cultural implications. ESA will initiate a dialogue with relevant experts to reflect on ways to fully exploit the inspiration potential resulting from space exploration.

Global cooperation

Today, international cooperation is an integral part of the space policy of most if not all spacefaring nations. International space exploration goals are advanced primarily through the ISS partnership and through various multilateral partnerships. Enhancing this situation to achieve a truly global endeavour remains a major challenge.

The foundation of a multilateral partnership for returning the first samples from Mars is prepared in the International Mars Exploration Working Group (IMEWG), reactivated in view of strong interest in Mars Sample Return. In September 2014 ESA took over the chairmanship of the International Space Exploration Group (ISECG). In its role of chair, ESA will focus on using this forum to make progress, beyond the existing ISS partnership, towards convergence on the next common, multilateral steps.

CONTACT

ESA/ESTEC
explorationstrategy@esa.int

An ESA Human Spaceflight and Operations production