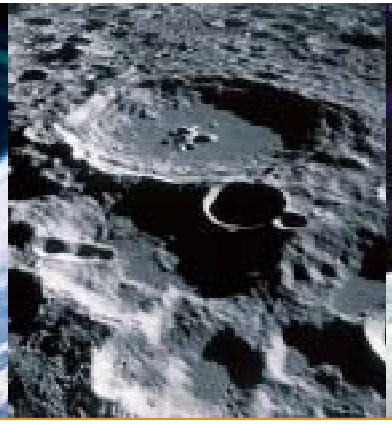


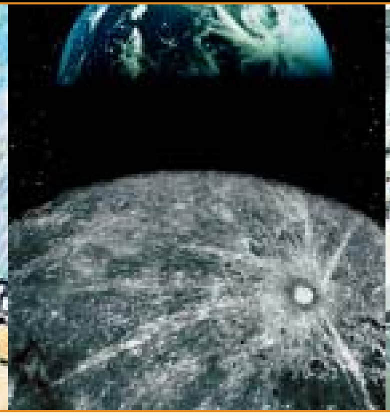




Moon: the 8th continent

HUMAN SPACEFLIGHT 2025

Moon: the 8th continent




HUMAN SPACEFLIGHT 2025

FINAL REPORT OF THE HUMAN SPACEFLIGHT VISION GROUP

11 DECEMBER 2003

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"EARTH IS THE CRADLE OF MANKIND, BUT ONE CANNOT LIVE IN THE CRADLE FOR EVER."

KONSTANTIN TSIOLKOVSKY

11/12/2003

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Foreword

Since the Space Age began less than 50 years ago, the world's leading industrial nations have made tremendous strides in meeting the challenges of sending humans into orbit. There have been many advances, including the introduction of the Space Shuttle, the construction of modular space stations and the successful creation of a European space industry.

Today, the human spaceflight programme is focused on the development and utilisation of the International Space Station (ISS). As one of the five major partners involved in the ISS programme, Europe can look forward to a decade of groundbreaking research with the Columbus laboratory and other space station facilities.

However, as with any major endeavour, it takes many years to plan and prepare the next steps in such a complex, collaborative enterprise. With the ISS programme now well under way, governments and space agencies around the world are already beginning to consider future space policies and priorities, including the various options for human spaceflight development in the decades to come.

At the same time, Europe is in a phase of political transformation, with the prospect of enlargement of the European Union coinciding with the search for new governance structures and greater European cohesion and integration.

The way forward has been indicated by a recent European Commission White Paper, which declared the need for a quantitative leap in the development of space sciences, technologies and applications, allied to an increase in overall expenditure in the medium and long term. Such a policy would exploit the special benefits that space technologies can deliver, including faster economic growth, job creation, industrial competitiveness, sustainable development and security.

Against this background, a multidisciplinary team of European experts was asked to develop an inspirational but realistic vision for the European human spaceflight enterprise in the period 2005 to 2025.

After some months of discussion and analysis, the Human Spaceflight Vision Group (HSVG) has produced a compelling case for the step-by-step establishment of a permanent human base on the Moon by 2025.

It is an ambitious vision which goes far beyond the parochial requirements of the human spaceflight programme and addresses the ways in which our political and cultural heritage, allied to our technological and scientific talents, can be used in the service of Europe and its citizens.

I am sure that the HSVG report will provide a valuable reference document that will assist ESA's deliberations on the future evolution of European space activities.

I would like to express my thanks to all of the HSVG members for participating in this important endeavour, for their remarkable motivation and tremendous team spirit, and for their imaginative contributions which made this report possible.

J. Feustel-Büechl
Director of Human Spaceflight
European Space Agency

The Human Spaceflight Vision Group

The Human Spaceflight Vision Group (HSVG) was established by Mr. J. Feustel-Büechl, ESA Director of Human Spaceflight, in recognition of the fact that, after decades of pursuing human spaceflight for its political, engineering and scientific benefits, **it is now time to critically reflect upon the fundamental motivations that lead to such endeavours.**

The Group's remit was to develop a clear vision for the role of human spaceflight during the next quarter of the century that could receive broad support from key European stakeholders, particularly national leaders and influential politicians.

Visionaries

"Visionaries" from eight European countries formed the core of the HSVG, supported by "experts" in the field of human spaceflight. They were assembled from many different fields, including space- and non-space industry, communications, marketing, research, and academic institutes supported by ESA.

Their task was to analyse the global challenges that will affect the citizens of Europe during the present century, and to assess the needs and interests of the various stakeholders with regard to human spaceflight. These deliberations have enabled the group to develop a pioneering Vision that ensures that Europe continues to play a leading geopolitical, economic, social and scientific role in the decades to come.

Since the Vision Group was established as an independent entity, its members were asked to express their individual opinions, rather than the interests of the organisations to which they belonged. They were invited to develop ideas unconstrained by today's environment, including the ESA Programmatic framework, the role of today's actors in space, and budget issues.

In order to meet these objectives, three workshops were held in different venues and various intersession activities were also undertaken. The first of these meetings was the **Exploration Workshop**, which took place in Berlin 11–13 June 2003, which was followed by a **Vision Workshop** at Frascati 7–9 July 2003. Throughout the process various visions, with different target destinations were considered. The final vision proposal and a roadmap to achieve the vision were developed at a **Roadmap Workshop** in Paris, 9–10 September 2003.

The Brief and the Vision

The brief

"To develop a clear vision and realistic implementation planning for the European human spaceflight enterprise in the time period 2005 to 2025 which excites interest and generates the support of key stakeholders and decision makers."

The vision

"In 2025, Europe will begin to operate a permanently manned outpost on the Moon as part of a multi-decade, international exploration effort to serve humanity, thus increasing our knowledge and helping us to address the global challenges of the future."

SOME EUROPEAN ROLE MODELS AS REALISTIC DREAMERS

ROBERT SCHUMANN

PAUL-HENRI SPAAK

JEAN MONNET

KONRAD ADENAUER

ALCIDE DE GASPERI

Human Spaceflight: The Story So Far

Since the historic orbital mission of Yuri Gagarin in 1961, more than 400 people from many nations have experienced the wonders of seeing our blue planet from space. Although the human exploration and exploitation of space during the second half of the 20th century were dominated by the former Soviet Union and the United States, this fairly exclusive club has recently been joined by China, the third nation to launch humans into orbit. Meanwhile, Europe, Japan and Canada have also contributed important technologies and expertise, notably through their involvement in the International Space Station (ISS).

Europe has been actively participating in human spaceflight since the flight of German Sigmund Jähn to the Salyut 6 space station in 1978. Starting with the construction of the Spacelab modules and the first flight of an ESA astronaut in 1983, ESA has played a significant role in the development of human capabilities in near-Earth orbit. In particular, the agency has been involved in several dozen human space missions, during which citizens from most ESA member states have flown on the American Space Shuttle and the Russian Soyuz, in addition to several long-duration flights on the Mir space station.

Today, ESA's human spaceflight activities are based primarily on Europe's involvement in the International Space Station programme. Major European contributions to the ISS include the Columbus laboratory and its pressurised facilities, the Automated Transfer Vehicle, and an ISS utilisation programme which encompasses research in life and physical sciences, space sciences and technology demonstration as well as education and commercial activities. Additionally Europe has developed the Multi-Purpose Logistics Modules for NASA and major ISS infrastructure elements and equipment including two Nodes, the European Robotic Arm and laboratory support equipment. Amongst the European-developed elements currently on-orbit are the Data Management System for the Russian Service Module "Zvezda", which has been operational since mid-2000, and the Microgravity Science Glovebox, which was installed in the U.S. Laboratory "Destiny" in mid-2002.

Six European astronauts have visited the ISS to-date (2001-2003), either to participate in the construction of the space station or to conduct programmes of scientific experiments. At least one further visit by a European astronaut is planned in 2004.

With the overall assembly of the ISS now about half completed, development of European contributions to the programme is nearing completion and an initial ISS utilisation programme has been implemented. However, the loss of the Space Shuttle Columbia in February 2003 has led to significant delays and caused a crisis in the ISS programme, leading to a review in the United States of its human spaceflight policy.

A number of important lessons have been learned from this unprecedented international collaboration. Until now Europe has been dependent on its international partners for human spaceflight core functions. The impact and implications of such dependency are now reflected in the light of the Columbia accident. Against this background, **it is now time to critically review Europe's ambition in human spaceflight and to identify new objectives and challenges for the future, while capitalising on the significant European capability and experience in human spaceflight that has been established during the past three decades.**

Other important considerations must include the role of international co-operation, which has been a key driver for public investment in human spaceflight in the past, and the desire for enhanced European autonomy in human spaceflight. Traditional partners, such as the United States, Russia, Japan and Canada may be joined by China and India.

Meanwhile, preliminary activities have already been initiated by ESA to prepare for the future, focusing on enhancement of the ISS capabilities as well as preparation for the robotic and human exploration of the Solar System.

The Future Vision

Europeans have a long history of **exploration, settlement and innovation**. Over many centuries, European expeditions set out to discover what lay beyond the known world, sailing through uncharted waters to circumnavigate the globe and chart new lands.

Although there are now few opportunities to explore uncharted areas on our planet, this does not mean that the human drive to seek new challenges must be stifled in the decades to come. The Human Spaceflight Vision will build upon Europe's historical legacy by inspiring the next generation of Europeans to follow in the footsteps of their predecessors by exploring a new frontier, beyond the Earth. It offers one of the most exciting opportunities for human advancement and innovation by envisaging a time when **humans (including Europeans) will be living and working on the Moon.**

This Vision can be achieved if Europe decides by 2005 to begin a major societal undertaking to build a permanent base on our celestial neighbour within 20 years.

In order to solve the unique challenges that will arise during a Moon programme, it will be essential to utilise in full the creative resources of Europe – political, social, economic, cultural and academic. This will lead to the creation of a more integrated Europe whose member states will be better placed to face the global issues of the 21st century.

Since multinational co-operation will be essential in order to achieve such an ambitious Vision, Europe's democratic ideals and cultural influence will spread around the world through its leading role in an international Moon Base programme. By encouraging the participation of partners throughout the world – including the new spacefaring nations such as India and China – Europe's global influence will be considerably enhanced.

The Vision will maximise use of the core skills of each partner, while ensuring that they receive full recognition for their contributions and achievements, thereby boosting public interest in each partner country.

Certainly, the Moon Base programme will provide a window of opportunity for increasing the autonomous human spaceflight capabilities of a larger Europe through integration of the capabilities of Russia and the Ukraine. Both States have already indicated a willingness to enter into long-term strategic partnerships with Europe in key areas such as human spaceflight, launchers, applications, navigation and global monitoring.

The establishment of the Moon Base is not the sole purpose of this vision. Rather, it should be seen as a means of meeting new challenges and advancing a much broader set of European aims and objectives.

By pursuing this initiative, Europe will be able to achieve the following benefits:

- To learn how to deal with the global economic and environmental challenges that will face Europe and the world in the 21st century;
- To meet long-term goals, such as the fostering of European values and the creation of a knowledge-based, global society.

Future geo-political challenges	*European objectives*	*Strategic cornerstones*
Multitude of geo-political actors	**Strengthen the emerging European identity**	Boost European leadership through enhanced integration and an appreciation of diversity.
Small and aged populations	**Enhance its citizens' economic security**	Boost economic growth through innovation (social and technological).
Low economic growth rates	**Enhance societal security**	Create the world's leading knowledge-based society through education and research.
Environmental stress and high resource import dependencies	**Increase Europe's strategic independence**	Improve Europe's ability to manage hostile and fragile environments.

BY CONFRONTING EUROPE WITH A MAJOR PRACTICAL CHALLENGE – TO BUILD A PERMANENTLY INHABITED BASE ON THE MOON - THE HUMAN SPACEFLIGHT VISION WILL GUIDE AND FOCUS EFFORTS TOWARDS ACHIEVING EUROPEAN STRATEGIC OBJECTIVES.

The Vision and Europe

At a special meeting held in Lisbon on 23-24 March 2000, the European Council established a new strategic goal – that the European Union should "become the most competitive and dynamic knowledge-based economy in the world, capable of sustainable economic growth with more and better jobs and greater social cohesion."

Speaking in London just one week later, Erkki Liikanen, European Enterprise and Information Society Commissioner, stressed the strategic significance of the Council's decisions.

"European Heads of State and government have given their strong commitment to ensure that Europe catches up in the digital economy and becomes a competitive and entrepreneurial economy," he said.

"The powerful message from Lisbon is that delay is not an option. We must move fast to accelerate Europe's transformation."

This statement was reinforced at the March 2002 meeting of the European Council in Barcelona, when it was recommended that 3% of GDP should be invested in R&D and technological innovation.

The Human Spaceflight Vision is offered as a response to these challenges. In particular, **the Vision has been explicitly aligned to the long-term strategic objectives of the European Union.**

These may be summarised as:

1. **Strengthen the emerging European identity;**
2. **Enhance its citizens' economic security;**
3. **Enhance societal security;**
4. **Increase Europe's strategic independence.**

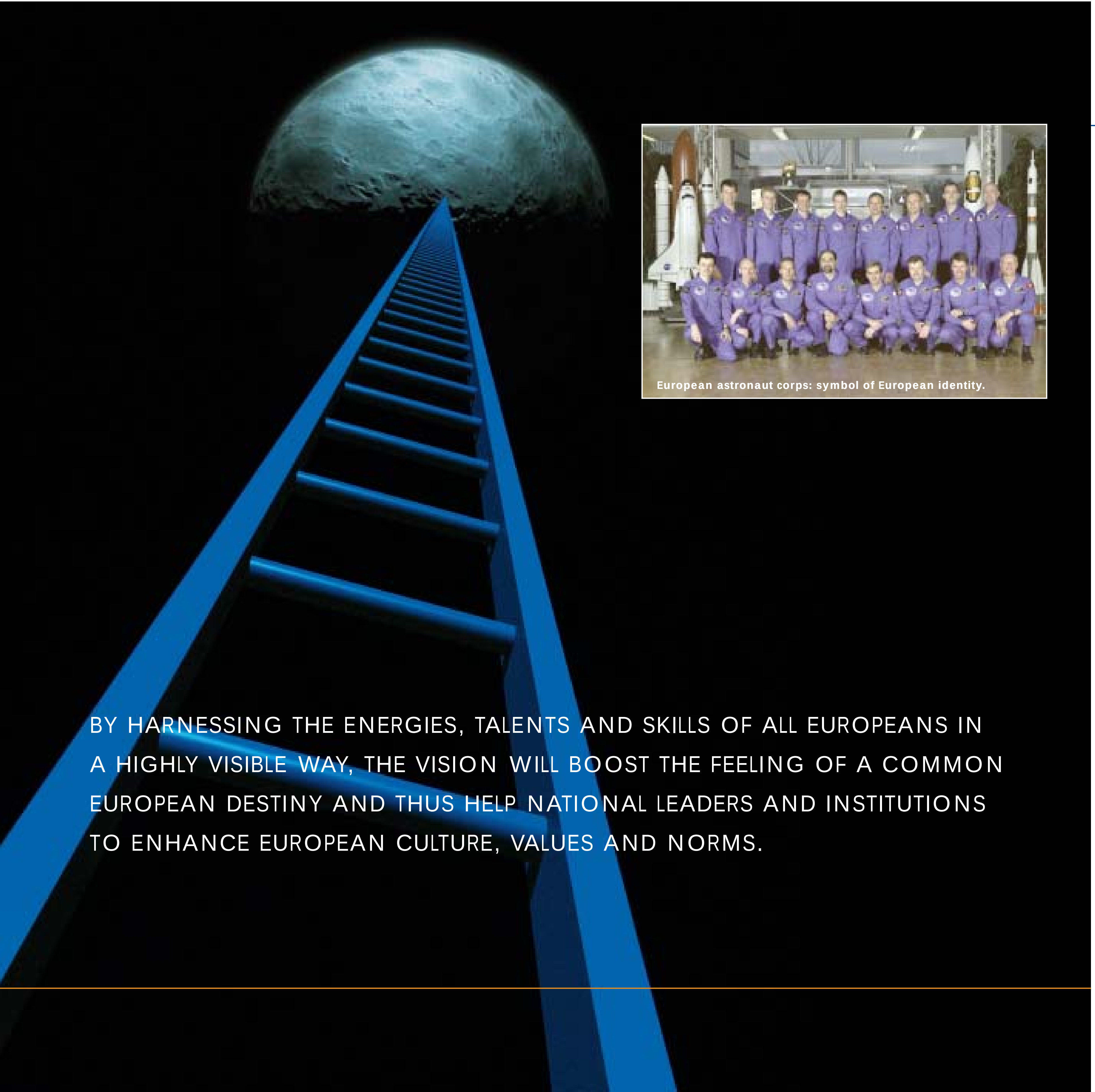
Four strategic cornerstones

To achieve these objectives, Europe is pursuing a variety of strategies that can be summarised in four strategic cornerstones:

1. **Boost European leadership through enhanced integration and an appreciation of diversity.**
2. **Boost economic growth through innovation (social and technological).**
3. **Create the world's leading knowledge-based society through education and research.**
4. **Improve Europe's ability to manage hostile and fragile environments.**

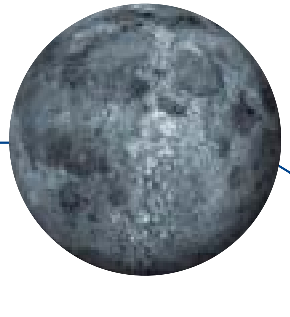
By confronting Europe with a major practical challenge – to build a permanently inhabited base on the Moon - the Human Spaceflight Vision will guide and focus efforts towards achieving these four strategic goals.

Each citizen of the European Community contributes an average of just € 2,- per year towards the space programme - equivalent to the price of one cup of coffee. In return for this relatively modest investment, Europe is buying into a vision that promises advances on many fronts – geopolitical, social, economic and educational.



European astronaut corps: symbol of European identity.

Realising Europe's Strategic Objectives



Shaping a European Identity Through Integration and Appreciation of Diversity

Although the European Union has been in existence for almost half a century, the leaders and citizens of EU member states have yet to achieve the full potential of capabilities promised by our emerging European identity. At the institutional level, the EU is seeking a new, more effective, governance structure with discussions concerning a future constitution. Meanwhile, the EU member states struggle to find a common position in a wide range of policy areas. This divergence of policies and attitudes will be exacerbated by enlargement of the European Union, when 10 countries from Central and Eastern Europe join in 2004.

One of the important contributions of the Vision will be its role in helping Europeans to accommodate their differences and forge a common identity, through the joint practical pursuit of a common, challenging goal. By harnessing the energies, talents and skills of all Europeans in a highly visible way, the Vision will boost the feeling of a common European destiny and thus help national leaders and institutions to enhance European culture, values and norms.

Europe's position as a major strategic partner in an international Moon Base programme would encourage integration, not only at a political level, but also within European society as a whole, through widespread involvement of industry, scientific establishments and societal institutions. It will reinforce political and industrial cohesion while, at the same time, continuing the tradition of social development achieved through integration of diversity.

Political Innovation and Leadership

By adopting the Vision and pursuing it as a major European goal, Europe will set an example of leadership for the rest of the world. However, by inviting global participation, Europe will also be seen as a visionary leader of an international effort that can provide great benefits to mankind.

The unique European experience with diversity will enable the Moon Base programme to offer a sensitive management style adapted to the diverse cultures of the partners. By integrating participants from across the globe - in particular Russia, the United States, Canada, Japan, China and India - while respecting their diversity, the Moon Base programme will be a practical demonstration of the cultural values and key principles on which Europe is founded.

This showcasing of the virtues of the European leadership and co-operation model will strengthen our continent's international position. The Vision will strengthen alliances with the United States, Japan and Canada, foster even closer co-operation with Russia, Europe's neighbour, and encourage the forging of closer ties with China and India.

Implementing the Vision may also offer an opportunity to evolve new governance structures, e.g. in the social organisation of the Moon Base inhabitants. Unable to return quickly to Earth and more dependent on their own resources and initiative than previous spacefarers, the crews would have considerable autonomy. Long-duration visits to the Moon would require co-operation and teamwork, and an allocation of responsibilities to each crew member. There may also be international political implications for utilisation and exploitation of lunar resources, which would require re-examination of current space treaties.

"THE TIME HAS COME TO PUT SPACE ACTIVITIES ON THE EU POLITICAL AGENDA, AT THE HEART OF THE PROCESS OF EUROPEAN CONSTRUCTION, AT THE SERVICE OF AN ENLARGED EUROPE AND OF ITS CITIZENS." PHILIPPE BUSQUIN, EUROPEAN COMMISSIONER IN CHARGE OF RESEARCH.

THE HUMAN SPACEFLIGHT VISION WILL BOOST ECONOMIC GROWTH THROUGH TECHNOLOGICAL INNOVATION, NOT ONLY THROUGH DEVELOPMENT OF SPACE TECHNOLOGIES, BUT ALSO THROUGH MEDICAL AND INDUSTRIAL SPIN-OFFS THAT WILL BENEFIT HUMAN-KIND AS A WHOLE.

Technological Innovation

Achieving the Vision will lead to the development and acquisition by Europeans of **new skills and technologies.**

In order to meet the challenges of constructing a habitable base 400,000 km from home, it will be essential to secure, through internal development or partnerships, **European autonomous capabilities for strategic advanced technologies.** These would not only enable humans to survive on the Moon, but also provide the necessary transportation and support infrastructure.

This approach would minimise the waste and expense associated with the independent re-development of non-strategic technologies already available through other partners. In this way, it would be possible to **boost economic growth through technological innovation**, focusing European R&D efforts on both strategic and genuinely new technologies (e.g. lunar resource utilisation and autonomous surface operations).

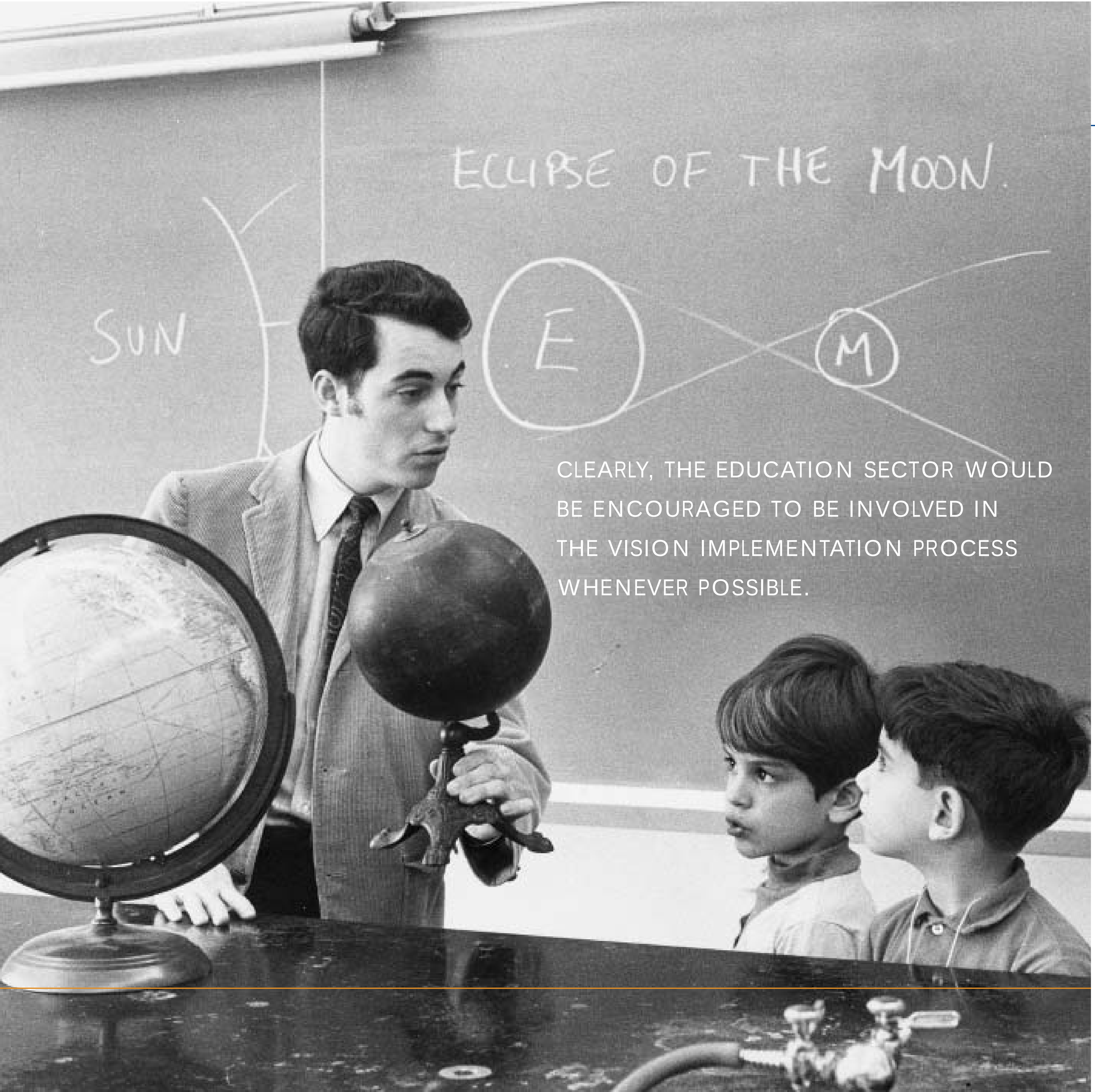
At the same time, the long-term investment of substantial public and private funds would inevitably lead to the creation of highly paid, highly skilled jobs. A number of industrial spin off companies would also be expected to evolve in order to develop and promote technologies originating in the Moon Base programme. Such developments would ensure a high return on initial investments and help to stimulate the economies of the partner nations.

Whenever possible, the newly developed technologies would be applied to the resolution of earthbound challenges, such as climate change, air pollution, waste disposal, and production of clean energy.

In the long-term, the establishment of a permanently occupied lunar base would open the way to a detailed, in-situ assessment of lunar resources. Although it would take many years to complete the inventory and create an infrastructure to exploit such resources, there could eventually come a time when the lunar base would not only be self-supporting, but also be in a position to deliver scarce resources to Earth on a cost-effective basis. One of the more tantalising possibilities is the exploitation of helium-3 as a fuel for nuclear fusion reactors. Development of this technology would provide an almost inexhaustible supply of clean energy, leading to strategic independence and a more secure world.

In a 1992 Nature paper[1] entitled “Sharing out NASA’s spoils”, Bezdek and Wendling analysed the economic consequences for the U.S. economy of NASA’s 1987 procurement budget of $8.6 billion. They found that this generated $17.8 billion in industrial turn-over (i.e. a multiplier effect of 2.1); created 209,000 private sector jobs, and yielded $5.6 billion in federal, state and local taxes. The net cost of the NASA budget to the U.S. tax-payer was only $3 billion, while the economy as a whole grew by 2.1 times the money invested, and many skilled jobs were created.

[1] Roger H.Bezdek, Robert M. Wendling ‘Nature’ 355, 105-106 (09 Jan 1992).



Creating the World's Leading Knowledge-Based Society

By the year 2025, Europe's aging population will be obliged to compete in the global economy with nations such as China and India, which will have a plentiful supply of well-educated young people. In order to maintain its wealth and status, Europe will have to create its own, knowledge-based niche, by concentrating on specialist skills related to advanced science and technology.

One compelling initiative which could act as a driver for such development is the Human Spaceflight Vision. A long-term programme to return to the Moon and create a permanently occupied lunar base will inspire millions of young people, from school pupils to university postgraduates. By encouraging students to take up science and engineering, it will help turn Europe into the world's leading knowledge-based society.

This positive image of science and technology would also be enhanced by the expansion of high-tech industry and the creation of skilled jobs. Through interwoven human and automated space exploration strategies, the ambitious programme will present to the world an image of a continent with a thriving educational sector and a promising future.

Clearly, the education sector would be encouraged to be involved in the Vision implementation process whenever possible. Aspects of space science and technology could be introduced into national curricula for schools, and university research into planetary science, life sciences and many other fields would be encouraged.

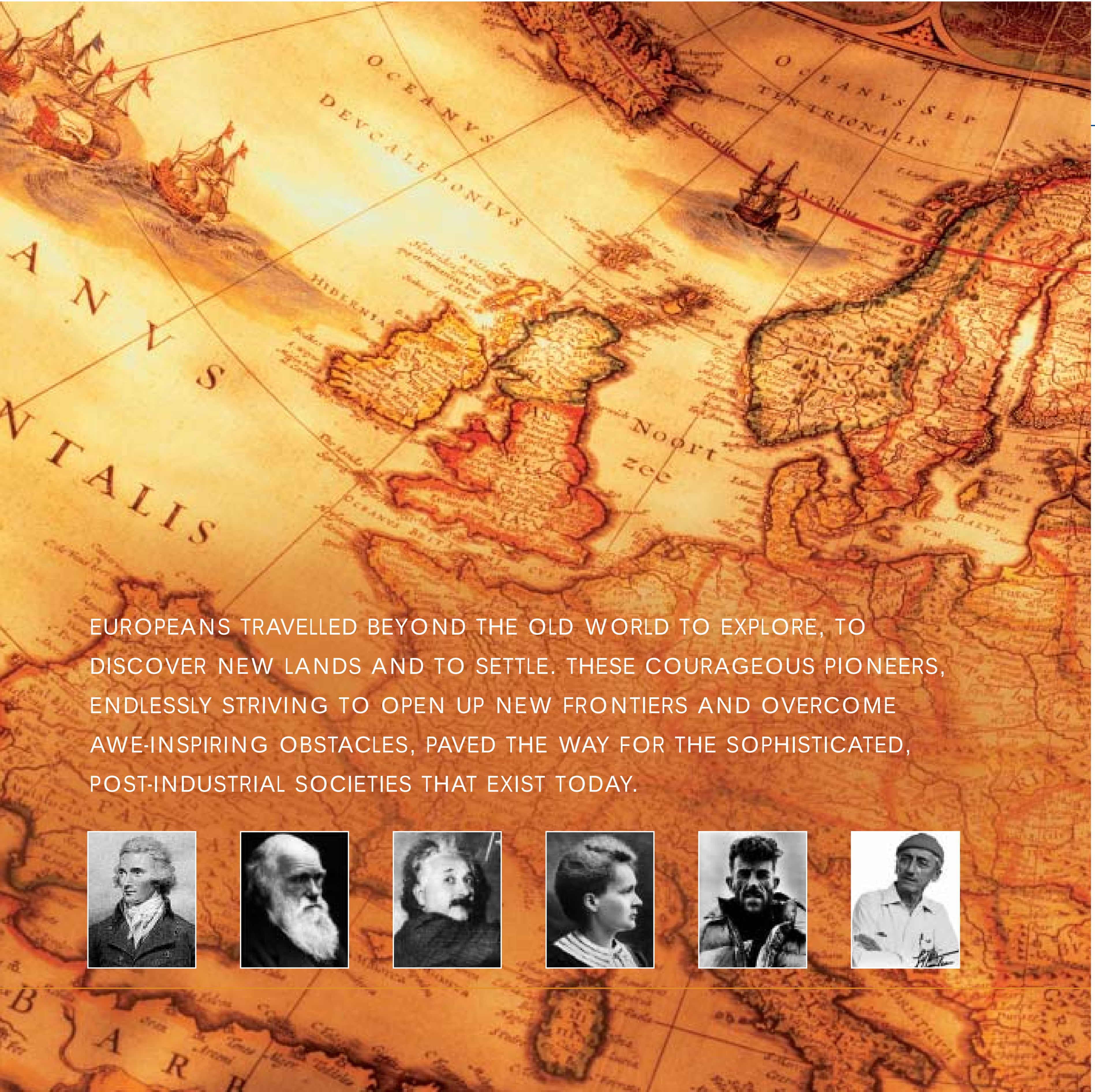
Many technological and medical spinoffs that would benefit humankind would be expected through utilisation and modification of technologies from the lunar programme. Furthermore, learning how to survive in a uniquely hostile environment (the Moon), will help us to understand more about life on 'spaceship Earth' and enable us to manage our own world in a more sustainable manner.

The impact of purely scientific discoveries must not be underestimated. Although the Moon has been visited by a dozen Apollo astronauts and various robotic craft, there are still many scientific questions that remain. By selecting this unique location, the Vision will also allow scientists to answer key questions about our broader cosmic environment - the birth of the Solar System and Earth, the genesis of life, the state of the Universe, and life's ability to adapt to hostile environments.

"EXPLORATORY SPACEFLIGHT PUTS SCIENTIFIC IDEAS, SCIENTIFIC THINKING, AND SCIENTIFIC VOCABULARY IN THE PUBLIC EYE. IT ELEVATES THE GENERAL LEVEL OF INTELLECTUAL INQUIRY." CARL SAGAN.

Improving the Ability to Manage Life in Hostile Environments

Apart from the obvious technological advances related to development of human spaceflight capabilities, the Vision would also be seen as a means of improving our ability to protect and manage extreme environments, unfavourable to life. Hence, the lunar base could be used as a test bed to learn how to deal with limited resources and environmental stress. New techniques to conserve food, water and energy could be allied to optimisation of waste management.



EUROPEANS TRAVELLED BEYOND THE OLD WORLD TO EXPLORE, TO DISCOVER NEW LANDS AND TO SETTLE. THESE COURAGEOUS PIONEERS, ENDLESSLY STRIVING TO OPEN UP NEW FRONTIERS AND OVERCOME AWE-INSPIRING OBSTACLES, PAVED THE WAY FOR THE SOPHISTICATED, POST-INDUSTRIAL SOCIETIES THAT EXIST TODAY.

Connecting to Europe's Culture

In this age of electronic communication and mass media, modern societies are subject to rapid change and enrichment through the exchange of ideas with other cultures. However, cultures stemming from many diverse civilisations do not always cohabit easily.

Space exploration may be seen as an extension of Europe's unique tradition of discovery, exploration, and settlement of new worlds – a tradition which links exploration, culture and humanism through such pioneers as Columbus, Magellan, Humboldt, Amundsen and Scott.

In the longer term, the creation of a permanently manned outpost on the Moon may be seen as the first stage in the spread of European values and culture across the Solar System as humanity visits and settle on other planets – Mars, in particular.

Europe, more than any other region of the world, is best placed to attempt this political and cultural experiment, and bring the Human Spaceflight Vision to fruition.

Human spaceflight is the most visible manifestation of space activity in the public perception, because it represents a novel cultural adventure with which most people can identify. Accordingly, the human element is a quintessential component in the continuing interest and support of the public for the space programme.

At the dawn of the twenty-first century, Europe's bold Human Spaceflight Vision will enable its citizens to reconnect to their traditions through pursuit of a peaceful, non-destructive adventure, as envisaged by the philosopher Bertrand Russell. **"If the world is ever to have peace, it must find ways of combining peace with the possibility of adventures that are not destructive."**[1]

This sense of adventure will come from the general public's identification with the 'heroic' human participants in the Moon programme – the European astronauts. At a later stage, it may also open the door to space tourism and human spaceflight opportunities for a broader cross-section of European citizens.

Furthermore, the opening up of new frontiers will meet a fundamental human social need. Indeed, R. Zubrin argued that, "without a frontier in which to grow, the entire global civilisation based upon Western enlightenment values of humanism, reason, science and progress will ultimately die"[2].

These values may be applied during wide-ranging international discussions to design and test new multi-cultural and international governance and organisational structures for the management and operations of the lunar base.

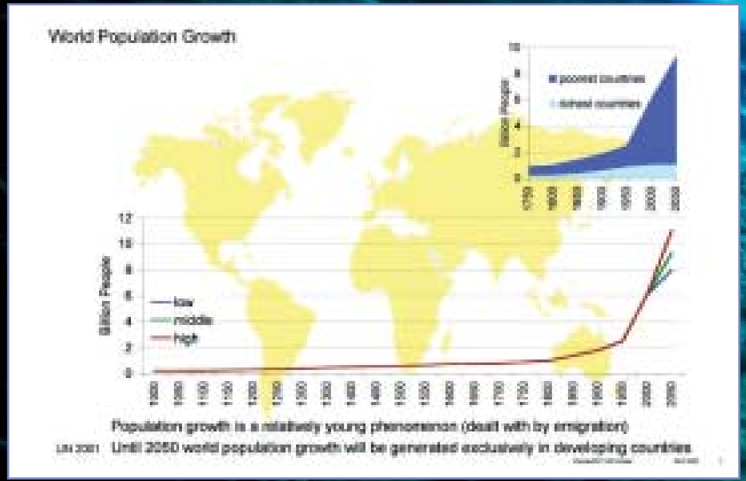
As the explosive Tunguska event of 1908 amply demonstrated, our Earth is located within a cosmic shooting gallery. Tunguska-like impacts that could destroy a large city may be expected to occur on average once every few centuries, while larger impact events that can cause destruction and loss of life on a regional scale typically occur every 600,000 years. However, such statistical analyses ignore the fact that Earth could be hit at any time.

The development of an advanced space transportation infrastructure, linked to the establishment of a human base and an observatory on the Moon, would ease the generation of countermeasures against an incoming asteroid or comet. In the worst case scenario of an impact that could wipe out global civilisation, a permanent Moon Base would operate as a sanctuary to ensure the survival of the human race, while providing a global archive of human knowledge.

"WHEN YOU SEE THE EARTH FROM SPACE, YOU DON'T SEE ANY DIVISIONS OF NATION-STATES THERE. THIS MAY BE THE SYMBOL OF THE NEW MYTHOLOGY TO COME; THIS IS THE COUNTRY WE WILL CELEBRATE, AND THESE ARE THE PEOPLE WE ARE ONE WITH." JOSEPH CAMPBELL.

[1] B. Russell: "Impact of Science on Society" (1952)

[2] R. Zubrin: "The Significance of the Martian Frontier".



OUR PLANET CAN BE COMPARED WITH A LARGE, SELF-SUPPORTING SPACESHIP THAT IS SURROUNDED BY THE HOSTILE ENVIRONMENT OF SPACE. HOWEVER, LIKE ANY SPACESHIP, ITS RESOURCES ARE LIMITED. MAJOR CHANGES IN POPULATION OR ENVIRONMENT MAY THREATEN THE STABILITY AND SURVIVAL OF OUR ISLAND HOME.

Spaceship Earth

The European Human Spaceflight Vision was developed in order to meet the needs of a broad range of stakeholders. One of its most important aspects is its long-term societal dimension, which provides strong links to the long-term strategic objectives of the European Union.

Thus, the Vision must be seen as one element in an ensemble of initiatives within an overall European societal project. In that view, it serves as its symbol and a comprehensive translation into an outstanding social and technological project.The long-term character of the Vision means that it is also necessary to assess it in light of the future challenges facing the Earth, which will set the background for Europe's broader policy decisions and its human spaceflight programme.

Spaceship Earth

Our planet can be compared with a large, self-supporting spaceship that is surrounded by the hostile environment of space – "a blue oasis" as astronaut Buzz Aldrin described it. However, like any spaceship, its resources are limited. Major changes in population or environment may threaten the stability and survival of our island home.

A multitude of challenges faces humankind during the first quarter of the 21st century. Although none of these can be completely resolved by the implementation of the European Human Spaceflight Vision, nevertheless the long-term development of a Moon Base would, by its very nature, necessarily offer some new ways to deal with many of the major global problems.

"THERE ARE NO PASSENGERS ON SPACESHIP EARTH. WE ARE ALL CREW." MARSHALL MCLUHAN.

From a European perspective the following issues are particularly important:

Demographics

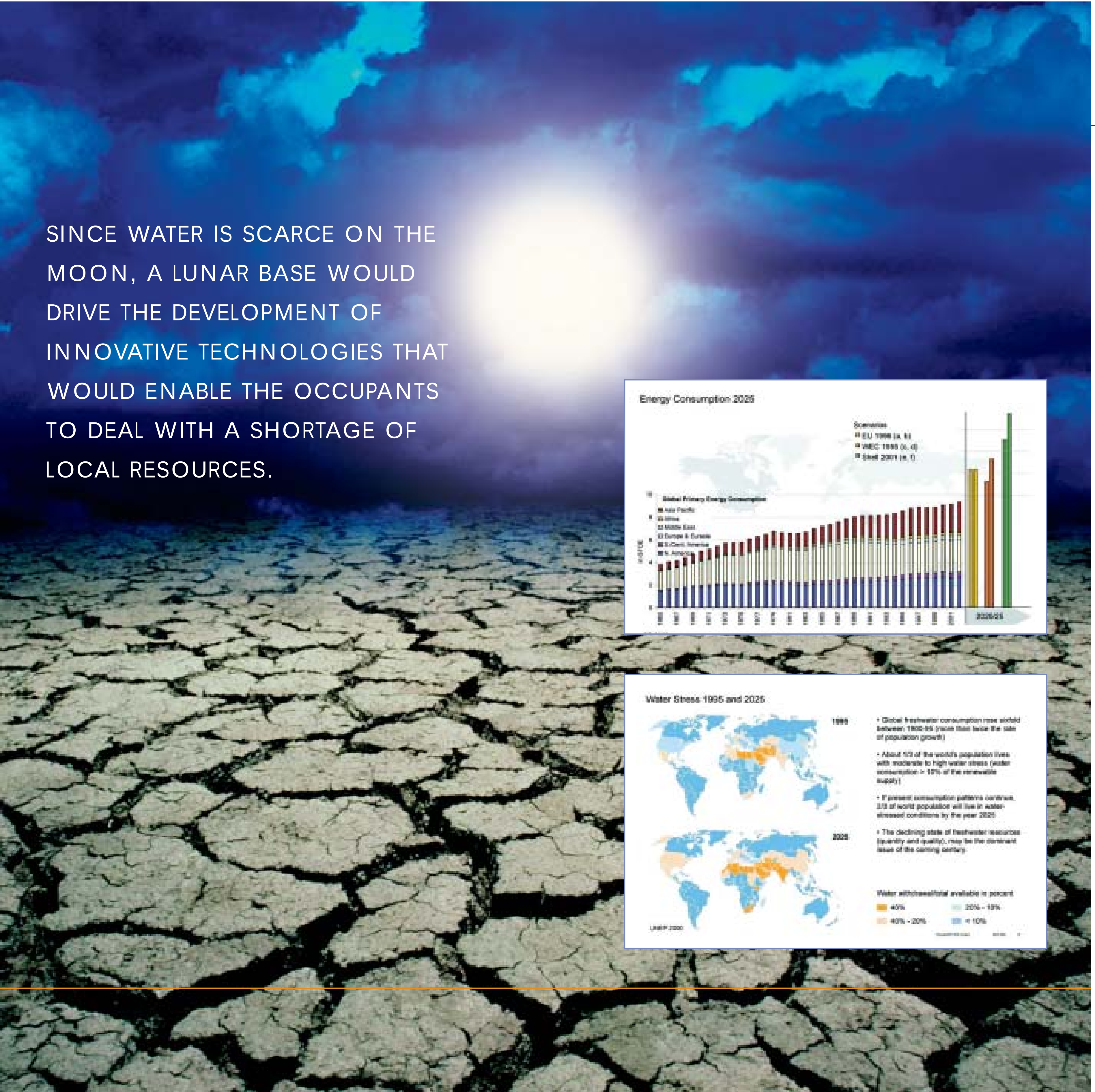
Over the next two decades, the population of Europe (including Russia), relative to the world population, is expected to shrink dramatically, in contrast to the rapid growth that will take place in developing countries. Although the overall age of the world population will increase as birth rates begin to fall and life expectancy increases, this effect will be most drastic in Europe, where the average age is predicted to rise to 46 years (30% > 60 years) by 2025. By then, the majority of the world's population will live in Asia – particularly India and China.

This polarisation sets the geopolitical stage on which the younger societies of Asia and the Arabian region will compete on many different levels with the aged societies of the western industrial countries – not only in terms of economic and industrial development, but also with respect to new ideas on societal development and desired futures.

The structural shifts in European societies call for a sustained drive towards social and technological innovation, linked to the expansion of a knowledge-based economy. The development of a Moon Base would help to establish, test and implement these innovations by inspiring young people to take up science and technology, and by enabling people of many nations to live and work together in a restricted environment.

Understanding Climate Change

The continued and increasing dependence on fossil fuels will ensure that environment-related issues pose a serious threat to humankind. Global carbon dioxide (CO_2) emissions will further increase until 2025, although different scenarios on the emission levels vary, dependent on ambiguities in driving forces, such as population size, consumption levels, availability



of cleaner alternative energy sources, technological progress and environmental regulations.

Many scientists believe that the average global temperature, which increased about 0.8˚C over the last 200 years, will further rise between 1.5˚ and 5.8˚C during the 21st century. However, opinions on the significance of this development vary, and there is much to be done to develop models that can accurately predict the likely environmental impact.

There is widespread concern about the possible effects of global warming on ocean currents, climate patterns etc., and a desire to safeguard the planet for future generations. The pressure for western societies to develop new concepts of securing their resource base and / or to change their resource consumption structures will rise dramatically in this context.

In order to assist our understanding of the interaction between Earth's atmosphere and its solar / galactic environment, a permanent research base on the near side of the Moon would provide an excellent location for long-term monitoring of our changing planet. Since it always remains visible in the sky, continuous observations could be made of the entire Earth as it rotates.

Resource Management Technology

Another upcoming critical resource challenge is water supply. Water stress may turn out to be the main challenge of the coming century in many parts of the world. If present consumption patterns continue, two thirds of the world's population will live in water-stressed conditions by 2025 and competition over access to water is likely to be one of the major causes of social conflict.

Since water is scarce on the Moon, a lunar base would drive the development of innovative technologies that would enable the occupants to deal with a shortage of local resources, e.g. through the development of closed biospheres and closed loop environmental life support systems which would provide food and water, as well as recycling waste and gases such as carbon dioxide.

Exploring Alternative Energy

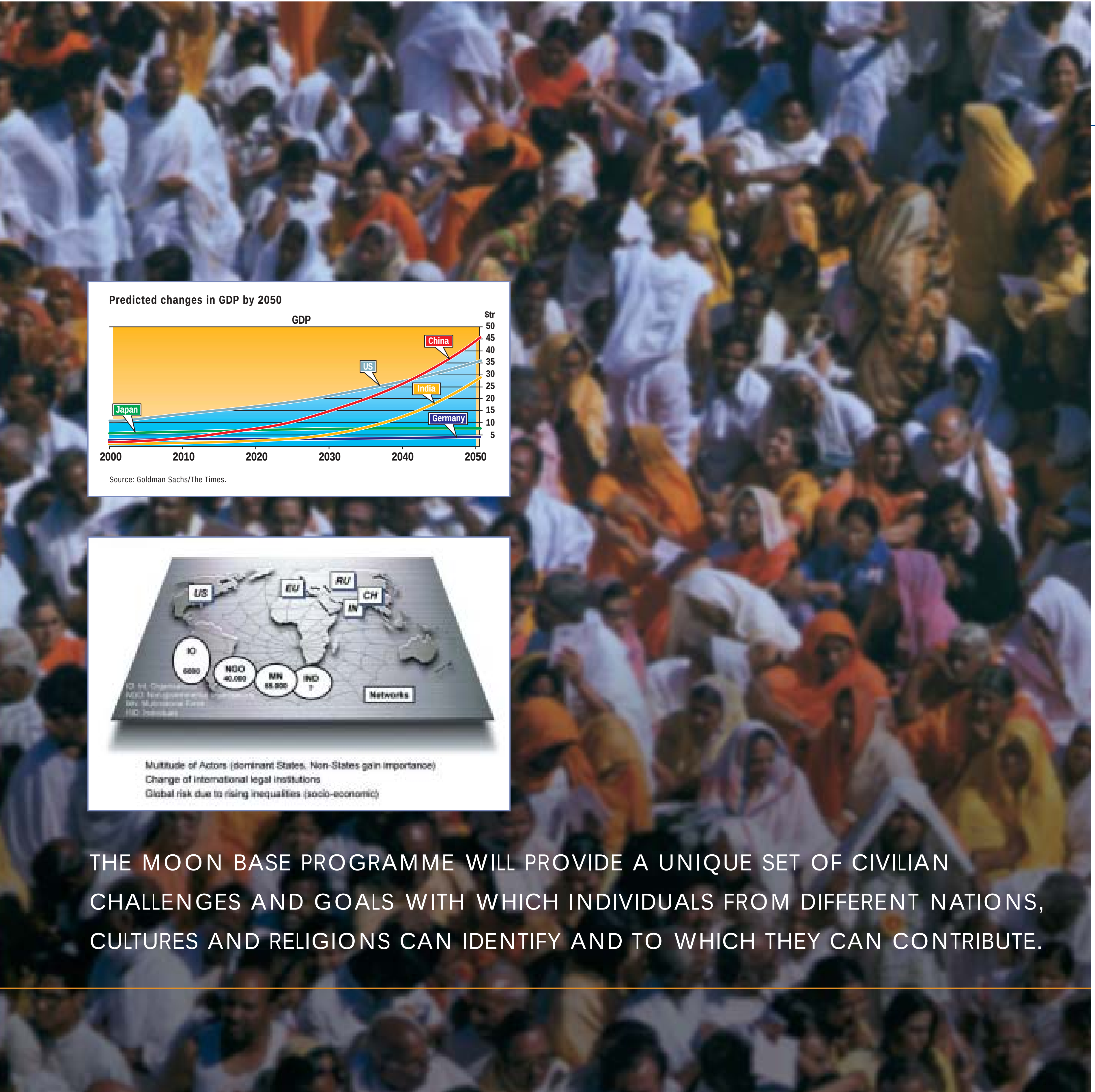
Fossil energy sources will still be the major cornerstone for the global energy supply up to 2025. Whereas the known reserves seem to be sufficient in the mid-term, especially in the industrialised countries, the situation is highly volatile and difficult to predict. However, it seems likely that the energy market will be characterised by an even higher import dependency than today.

By 2020, Europe will have to import more than 90% of its fossil energy resources. A high import dependency on the countries of the Middle East and the former Soviet Union, where 70% of the world's oil and gas reserves are located, poses a high strategic threat for Europe if these Countries remain unstable.

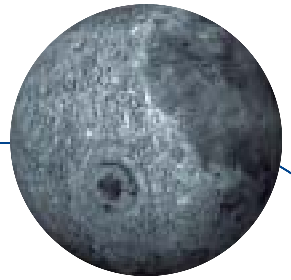
In the long term, the exploitation of helium-3 trapped in the lunar surface could provide a virtually limitless supply of clean energy through its use as a fuel in nuclear fusion reactors. Current analysis indicates that there is at least one million tonnes of helium-3 embedded in the lunar surface. If this unique resource could be exploited and utilised, its economic value would far exceed that of any other natural resource. While it is currently unclear how this resource could be made economically available to mankind, exploring its potential should be an imperative.

"WITH THIS NEW PERSPECTIVE OF THE EARTH .... WE MUST THINK OF BOLD AND VISIONARY IDEAS TO PRESERVE OUR SO LIMITED FRAGILE ENVIRONMENT. TEMPORARY SOLUTIONS TO THE PROBLEMS OF OUR TIMES MUST BE REPLACED BY PERMANENT SOLUTIONS FOR FUTURE GENERATIONS."

DAVID R. SCOTT (COMMANDER OF APOLLO 15).



THE MOON BASE PROGRAMME WILL PROVIDE A UNIQUE SET OF CIVILIAN CHALLENGES AND GOALS WITH WHICH INDIVIDUALS FROM DIFFERENT NATIONS, CULTURES AND RELIGIONS CAN IDENTIFY AND TO WHICH THEY CAN CONTRIBUTE.



Economy

In the period up to 2025, the U.S. will continue to be the pre-eminent global economy, but the economies of China and India will probably grow faster than those of most western countries.

Within the highly developed industrial countries, the shift towards knowledge-intensive economic structures will continue. Major technological advances in the fields of genetic research, laser technology, energy technology, material sciences, miniaturisation and computer technology are anticipated and it will be essential that Europe establishes itself at the forefront of this research. In the light of its aged population, this will call for major changes in education and production, as well as social welfare systems.

A Moon Base could support this evolution and restructuring through its impact on education (e.g. by inspiring young people to take up science and engineering), technological innovation, research and development. Miniaturisation of components and development of new materials, more efficient energy systems, advanced communications and computer technologies would arise from such a wide-ranging programme.

Multilateralism

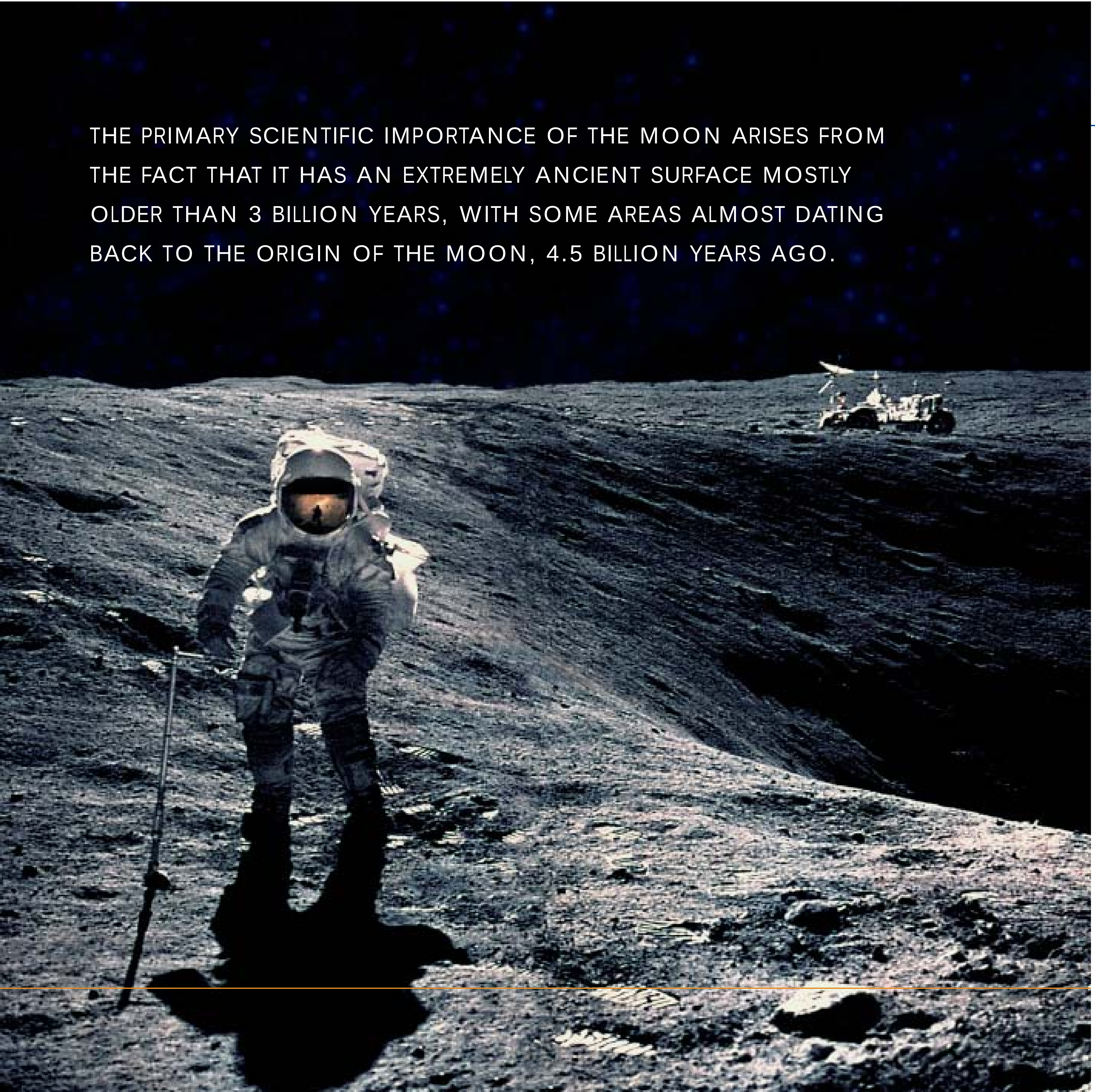
During the last few decades, the international political and economic system as a whole has achieved an unprecedented degree of largely peaceful convergence and development. Nation states, co-operating on a wide spectrum of issues, as in the European Union, is a reality today. International institutions, Non-Governmental Organisations, transnational business activities and networks of individuals are having a noticeable impact. Systemic interdependence seems to be continuously on the rise.

This world offers enormous opportunities for realising shared interests and reaching out together to new frontiers. At the same time, it is a highly vulnerable world, threatened by violent rejection through global terrorism and a possible revival of nationalism and interstate war.

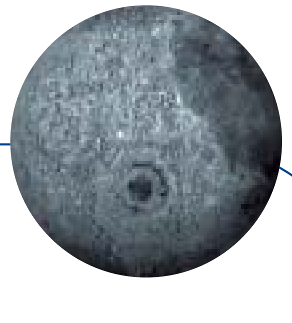
By developing a Moon Base, Europe will be able to lead the way by demonstrating how nations may overcome their differences by integrating and working together for the common good and the service of mankind. It will provide a unique set of civilian challenges and goals with which individuals from different nations, cultures and religions can identify and to which they can contribute.

This approach has been supported in a recent White Paper produced by the European Commission, which stated that: “Existing areas of co-operation, such as human spaceflight, solar system exploration, space and Earth sciences could be extended into new fields of applications for improving infrastructures, social development and security in their broadest sense.” [1]

[1] “Space: A New Frontier for an Expanding Union”, European Commission, Brussels, 2003.



The Scientific Case



While science is only one of several drivers for human space exploration, there is little doubt that a return to the Moon would vastly enhance our knowledge of the Universe and our place within it.

The most compelling arguments supporting the scientific case for a return to the Moon are based on **geoscience** and **life sciences**, although other disciplines would also benefit, e.g. **astronomy and the observation of the Sun, Earth and space weather.**

The primary scientific importance of the Moon arises from the fact that it has an extremely ancient surface (mostly older than 3 billion years, with some areas almost dating back to the origin of the Moon 4.5 billion years ago). It, therefore, preserves an invaluable record of early impacts and geological evolution which has been lost on Earth, Venus and Mars.

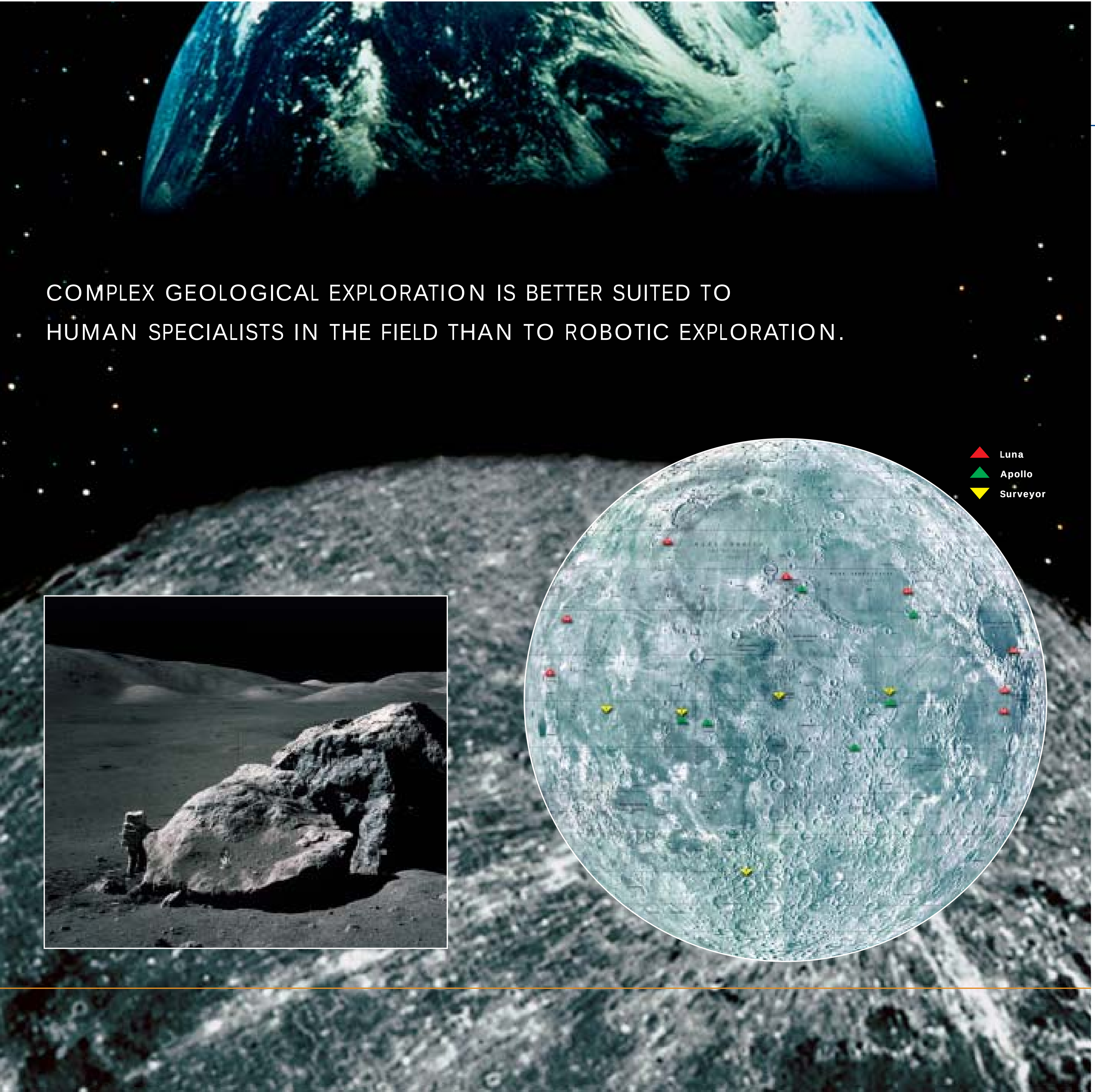
Moreover, the Moon's outer layers also preserve a record of the environment in the inner Solar System billions of years ago (e.g. meteorite flux, interplanetary dust density, solar wind flux and composition, galactic cosmic ray flux). With the possible exception of Mercury, which is much less accessible, this record has probably not been preserved anywhere else.

Accessing this potentially huge scientific archive is unlikely to be possible by robotic exploration alone. Instead, studies of lunar geology and evolution would benefit greatly from extended human activities on the lunar surface, since random collection of samples for dating and geochemical analysis is seldom adequate. A human presence may be seen as essential for some activities, such as the identification and characterisation of palaeoregolith layers and the drilling of kilometre-deep boreholes. Even relatively simple tasks, such as sample collection and the deployment of seismometers and magnetometers, would probably be performed more effectively by humans.

Another factor is the sheer quantity of material which may need collecting from scores, perhaps hundreds, of different sites. Working out the geology of an area as complicated as the South Pole - Aitken basin, with its many superimposed craters, basins, and small maria, will require many individual sample collection sites. While, in principle, it may be possible to conduct numerous robotic sample return missions, human specialists can collect a larger variety of samples and are more likely to make serendipitous discoveries not anticipated in advance (such as the famous 'orange soil' found at the Apollo 17 landing site in 1972).

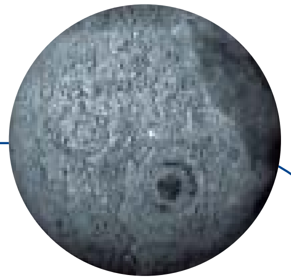
Although an international lunar base is unlikely to be justified by lunar science alone, it is clear that science would be a major beneficiary, and that such a base would facilitate scientific studies of the Moon that would not otherwise occur.

Once the infrastructural support provided by a lunar base is in place, opportunities for the wide-ranging collection of rock samples would arise naturally, as would opportunities for the deployment of scientific instruments (seismometers, magnetometers, gravimeters….) that may not occur otherwise. Given the presence of qualified personnel and their equipment (microscopes, ion probes, mass spectrometers, etc) actually on the Moon, only a fraction of the intrinsically heavy rock samples may need to be transported to Earth for analysis.



COMPLEX GEOLOGICAL EXPLORATION IS BETTER SUITED TO HUMAN SPECIALISTS IN THE FIELD THAN TO ROBOTIC EXPLORATION.

Geology



The main scientific areas that would benefit from a return to the Moon, and especially the establishment of a permanently occupied scientific outpost are as follows:

Identification and Sampling of Palaeoregoliths

Samples of ancient solar wind, cosmic ray particles, and interplanetary dust are likely to be trapped in **palaeoregolith** – ancient layers of loose surface material - sandwiched between mare basalt flows of different ages. It is also possible that the Moon has collected meteorites blasted off other terrestrial planets (including the early-Earth and the pre-greenhouse Venus). If such material has been preserved on the Moon, it is more likely to be preserved in the palaeorogolith than exposed on the surface.

Identifying palaeoregoliths, which may only rarely, if at all, be exposed on the surface, will require considerable geological fieldwork. This may require local seismic profiling and the ability to extract core samples from depths of hundreds of metres. Such complex geological exploration is better suited to human specialists in the field than to robotic exploration, and may be wholly impractical otherwise. It would be ideally suited to geologists operating from a permanently occupied lunar base, without the strict time constraints which so curtailed the possibilities of geological field exploration during the Apollo project.

Sampling a Representative Range of Lunar Deposits and Rock Formations

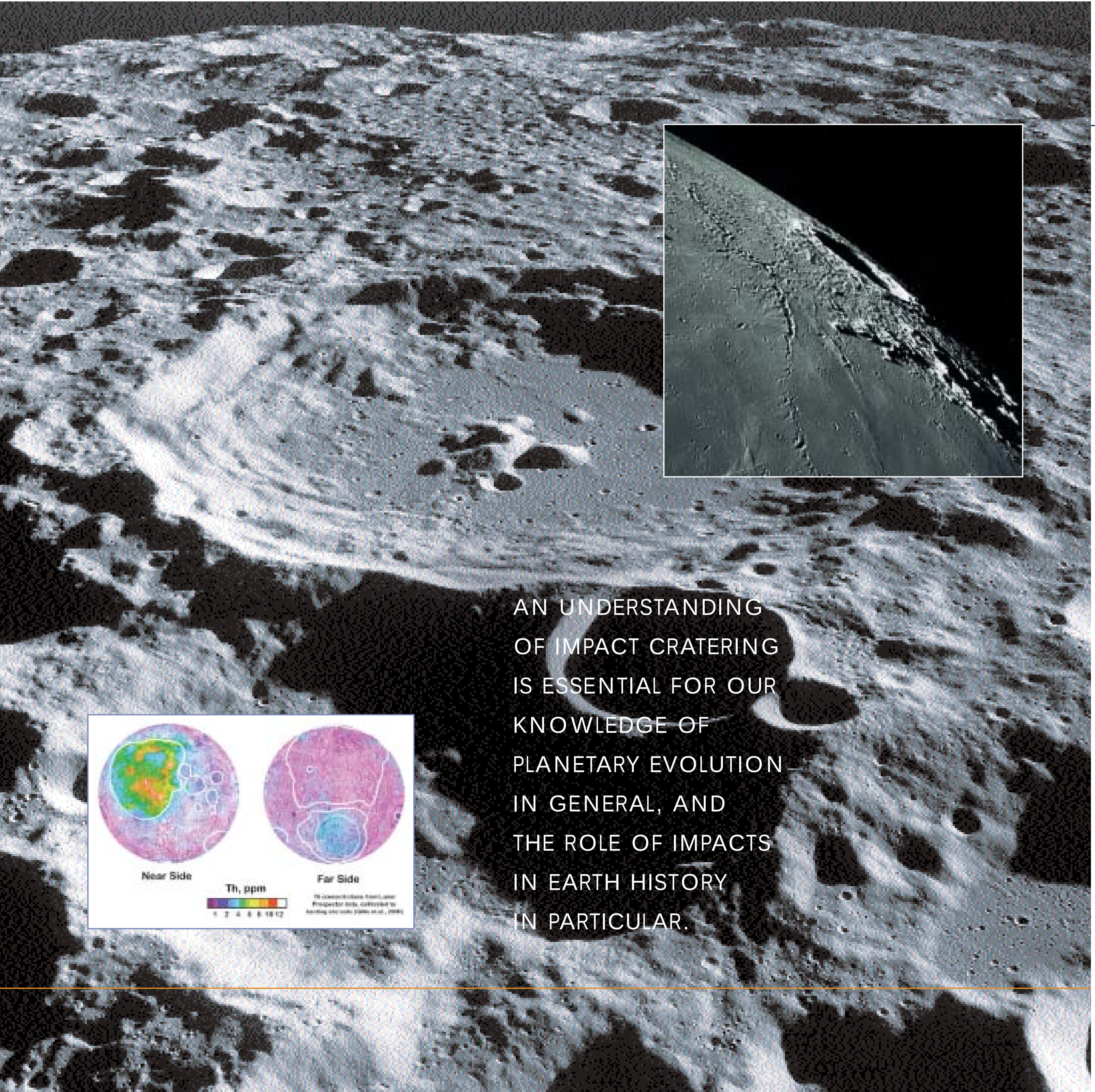
Essentially our whole knowledge of the origin and evolution of the lunar crust, has come from examination of the Apollo samples. However, it is now recognised that these samples are not representative of the lunar crust as a whole, being heavily biased by the peculiar rock layers and deposits that surround the Imbrium Basin. Studies of lunar meteorites and remote sensing data tell us that Apollo did not sample anything like the full range of lunar rock types.

Samples from undisturbed lunar bedrock are urgently required from the polar regions (especially the floor of the giant South Pole - Aitken basin, which may have penetrated the lunar mantle), and from the unsampled lunar far side. Only then will it be possible to arrive at a consistent model of the evolution of the lunar crust, which can then form models for the early evolution of other, more complex, terrestrial planets.

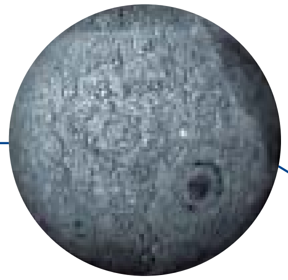
Establishing a Comprehensive Lunar Seismic Network

The Apollo seismometers remained active for up to eight years, providing information on the structure of the lunar crust and upper mantle. However, their limited numbers and relatively nearby locations on the lunar nearside meant that little information was gained about the deep interior of the Moon. As a result, we know very little about the physical state and composition of a lunar core – and there is even some uncertainty about whether one exists at all.

There is clearly a need for a much more widely spaced network of lunar seismic stations, including some at high latitudes and on the far side. There is also a case for humans to carry out more active seismology by detonating artificial explosions that can probe the deep interior.



AN UNDERSTANDING OF IMPACT CRATERING IS ESSENTIAL FOR OUR KNOWLEDGE OF PLANETARY EVOLUTION IN GENERAL, AND THE ROLE OF IMPACTS IN EARTH HISTORY IN PARTICULAR.



Calibration of the Lunar Cratering Rate

The vast majority of lunar terrains have never been sampled, and their ages are based on the observed density of impact craters. The current calibration of the cratering rate, used to convert crater densities to absolute ages, is based on the Apollo sample collection, and is neither as complete or reliable as it is often made out to be. The radiometric dating of a much greater range of samples, taken from areas with a wide range of crater densities, will be required to arrive at a truly reliable lunar impact cratering rate. Moreover, there is still uncertainty over whether the lunar cratering rate has declined steadily since the formation of the Moon, or whether there was a bombardment ‘cataclysm’ between about 3.8 and 4.0 billion years ago, characterised by an unusually high rate of impacts.

Better calibration of the cratering rate would require a considerable amount of geological fieldwork from many different sites, which would be best supported by a permanently occupied lunar base. This would be of great value for planetary science because:

- It would provide better estimates for the ages of unsampled regions of the lunar surface;
- It would provide us with a more reliable estimate of the impact history of the inner Solar System, especially that of the Earth at a time when life was evolving on our planet;
- The lunar impact rate is used, with various other assumptions, to date the surfaces of other planets for which samples have not been obtained. To the extent that the lunar rate remains unreliable, so do the age estimates of surfaces on the other terrestrial planets.

Enhanced understanding of impact cratering mechanics

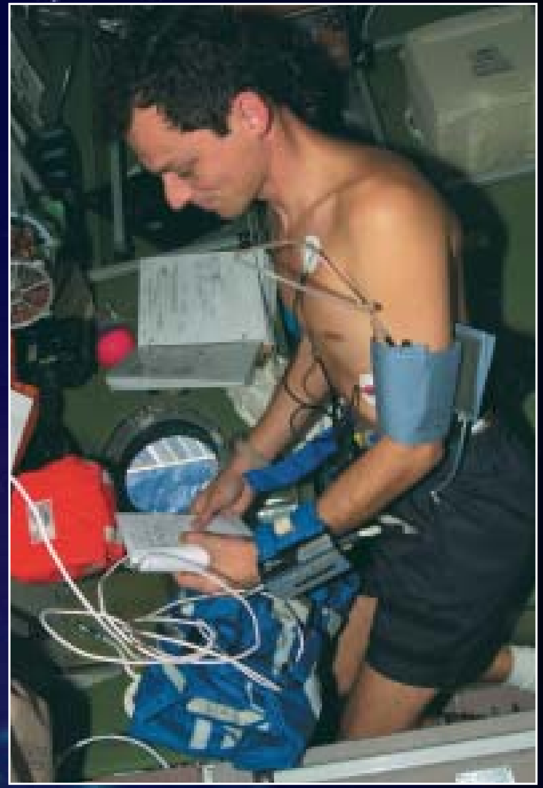
An understanding of impact cratering is essential for our knowledge of planetary evolution in general, and the role of impacts in Earth history in particular. Yet our knowledge of impact processes is based on a combination of theoretical modelling, small-scale laboratory hyper-velocity impact experiments, and field geological studies of generally poorly preserved terrestrial impact craters. The Moon provides a unique record of essentially pristine impact craters of all sizes (from micron-sized pits up to the 900 km diameter Orientale Basin). Field studies, combining sample collection (including drill coring) and in situ geophysical studies (e.g. active seismic profiling), of the ejecta blankets and sub-floor structures of pristine lunar craters of a range of sizes would greatly aid in our understanding of the impact cratering process. Infrastructural support for such, necessarily time-intensive, fieldwork could be provided by a permanently occupied scientific outpost.

Other Geophysical Investigations

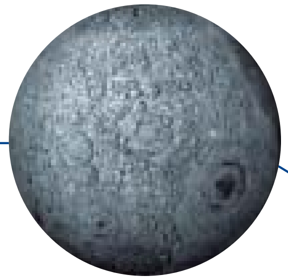
Many other geological and geophysical investigations undertaken by human field geologists would aid in the characterisation of lunar structure and evolution. They include:

- Accurate determination of the lunar heat flow.
- Local seismic profiling and gravity measurements.
- Drilling of deep boreholes into the lunar crust.
- Geomagnetic studies of lunar rocks to understand remanent magnetisation.
- In situ geophysical investigations of the mysterious lunar magnetic anomalies.

LIFE SCIENCES RESEARCH INTO THE PSYCHOLOGICAL AND PHYSIOLOGICAL EFFECTS OF LONG-DURATION HUMAN SPACEFLIGHT IS UNDERTAKEN ON BOARD THE ISS – A LUNAR BASE OFFERS THE OPPORTUNITY TO STUDY ADAPTATION IN A REDUCED GRAVITY ENVIRONMENT.



Life Sciences: Beyond the ISS



A wide range of life sciences research, from molecular biology to whole-body physiology, would benefit from the establishment of a permanently occupied scientific outpost on the Moon.

Fundamental Biological Research

It is now realised that many of the physiological responses of organisms to the space environment are modulated at the cellular and sub-cellular levels. Gravity, in particular, appears able to affect cellular function at a molecular level. While there is a growing body of knowledge of these processes in microgravity, **the biological effects of reduced, but non-zero, gravity are largely unknown.** For example, it is not known whether reduced gravity causes the same biological changes as zero gravity, only more slowly, or whether some, or all, such processes have gravity thresholds which must be passed before they kick in.

Long-term studies in a reduced gravitational environment are required to quantify these effects, and a permanently occupied lunar base would be ideally suited to this task. Moreover, the unique radiation environment of the Moon would also provide many opportunities for fundamental research in the field of radiation biology.

Human Physiology and Medicine

There is particular interest in the long-term effects of reduced gravity on the human body. Of special importance is the need to establish potential gravity thresholds for different body functions, in particular with regard to loss of muscle and bone mass, reduced cardiovascular capacity, functioning of the central nervous system, and immune system deficiencies.

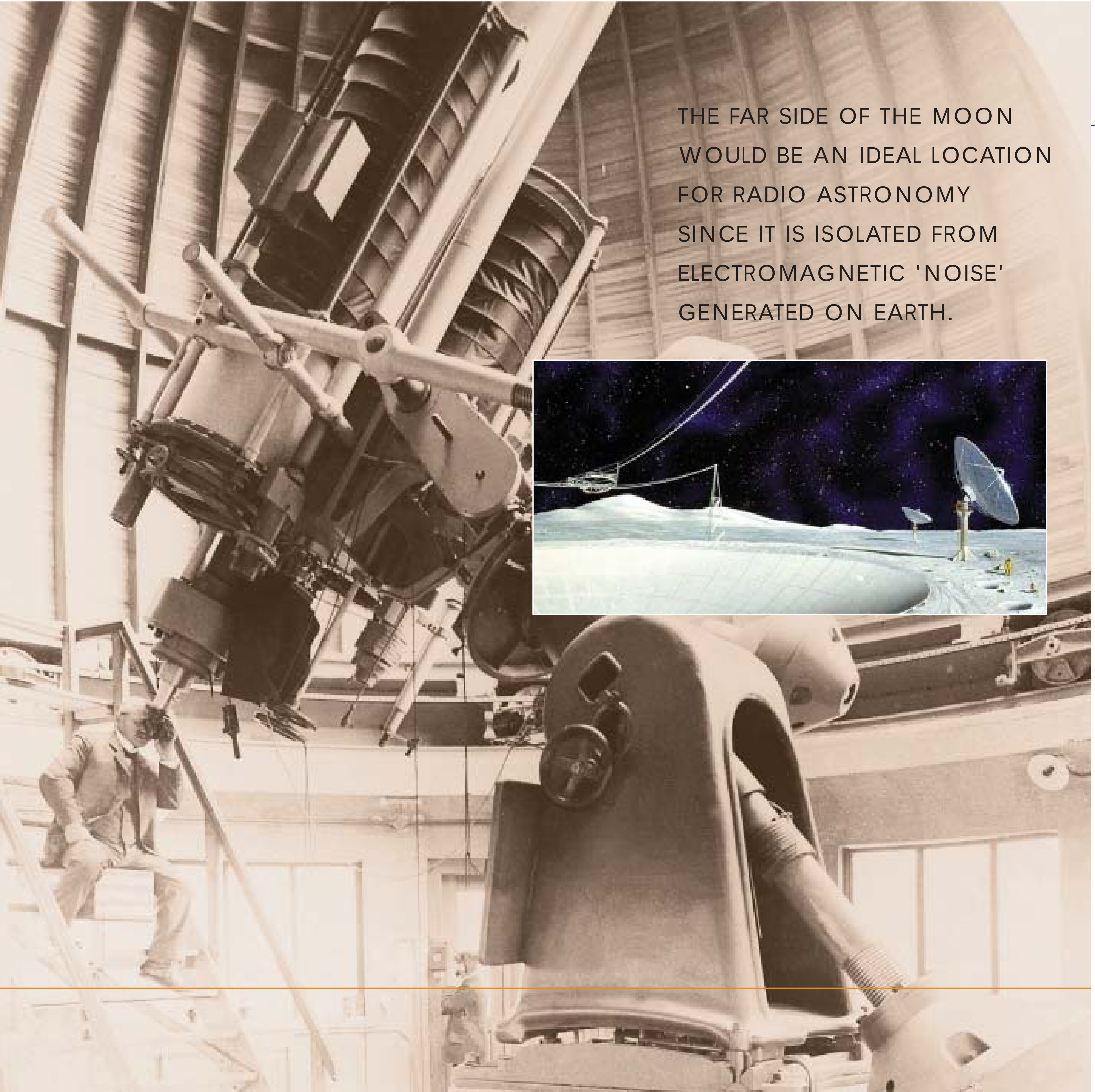
This research is needed partly to enhance our understanding of fundamental biological processes, with potential feedback into the design of medical therapies for use on Earth, but also partly in support of future human space operations. A lunar base, perhaps in combination with microgravity research on the ISS, is probably the only location where such research could be safely conducted.

Artificial Ecosystems

Long-term future human space operations will require increased reliance on ecologically closed life support systems. They will be particularly important for long-duration spaceflights (e.g. to Mars) and as a means of reducing reliance of orbital, lunar and martian outposts on supplies from Earth. Moreover, construction and operation of such closed ecosystems will enhance our understanding of the operation of the terrestrial biosphere. It will be important to have the opportunity to gradually reduce the reliance of the ecosystem on external supply, and to have the capacity to intervene safely if and when necessary. Although much preparatory work can be done on Earth and on the ISS, the Moon would be the most appropriate location to test fully closed ecosystem designs in a non-terrestrial environment.

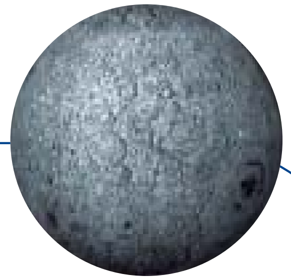
The Moon as a Test-Bed for Mars Exploration

Much will have to be learned about human adaptability to the space environment, and the long-term operation of human outposts on hostile planetary surfaces, before a human expedition is sent to Mars. Learning to construct and operate a Moon Base would help pioneer the technical and operational expertise that will be required for human operations on Mars. Long-term experience of human physiology in a reduced, but non-zero, gravitational environment will be particularly important.



THE FAR SIDE OF THE MOON WOULD BE AN IDEAL LOCATION FOR RADIO ASTRONOMY SINCE IT IS ISOLATED FROM ELECTROMAGNETIC 'NOISE' GENERATED ON EARTH.

The Moon as an Observational Platform



From the Moon, global observations of the Earth can be obtained in order to monitor weather, climate and surface changes over a long period of time. One can also study the Earth's large-scale magnetospheric and geocoronal environment using particle, optical and radio detectors.

For **optical astronomy**, the Sun-Earth L2 Lagrange point – located about 4 times the Moon's distance from Earth on the night side of our planet - offers a better location than the Moon itself. However, the lunar surface is still a potentially valuable site for astronomical observation - certainly better than the Earth's surface and low Earth orbit (LEO). Moreover, while L2 may, indeed, be required for very large, specialised facilities, other astronomical instruments (e.g. simple transit telescopes) could function well on the lunar surface and make valuable contributions.

The lunar far side, in particular, is probably the best site in the inner Solar System for **radio astronomy**, since it is completely isolated from interference by artificial transmissions from Earth.

The lunar surface also lends itself well to **cosmic ray astronomy**, since it is largely outside the Earth's magnetosphere and incoming charged particles will not be deflected en route from the Sun or distant supernovae.

The lunar surface might also be suitable for the construction of **X-ray and gamma ray** facilities that require stable structures and large, bulky detectors. Gamma ray detectors could be shielded by lunar soil against stray energetic particles and radiation.

Optical and infrared telescopes could be advantageously located in the cold, permanently shaded craters near the lunar poles. Such instruments could make extremely long exposures of the sky, enabling them to detect very faint, cold objects. The instruments could be powered by solar arrays located on a nearby crater rim which could utilise almost continuous sunlight.

Continuous solar observations could monitor solar output and enable helioseismological observations to probe the Sun's interior. X-ray and gamma ray observatories could also monitor violent solar eruptions and contribute to **space weather** early warning systems that would assist astronauts on the Moon.

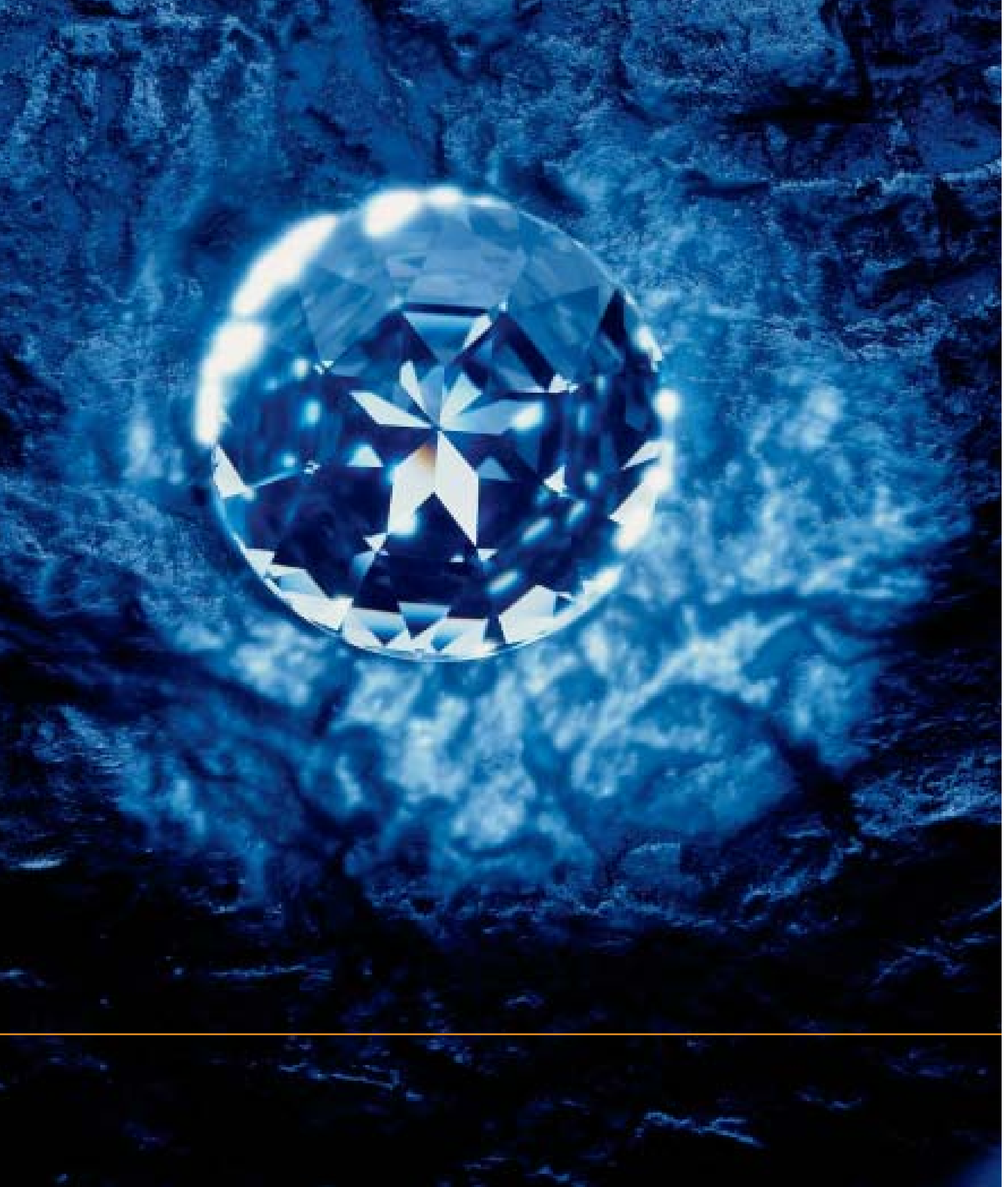
A large-diameter (16 m) telescope operating at infrared, optical and ultraviolet wavelengths would have the potential to discover Earth-like planets around nearby stars and, perhaps, detect oxygen in their atmospheres.

Thus, while the scientific case for a return to the Moon should be based primarily on the geoscience, and life science objectives (which must be done on the Moon), we may expect radio, optical and infrared astronomy to also benefit. This has been the experience with the ISS – although many astronomers opposed construction of the ISS, now that it exists as a piece of infrastructure they are beginning to suggest astronomical uses for it.

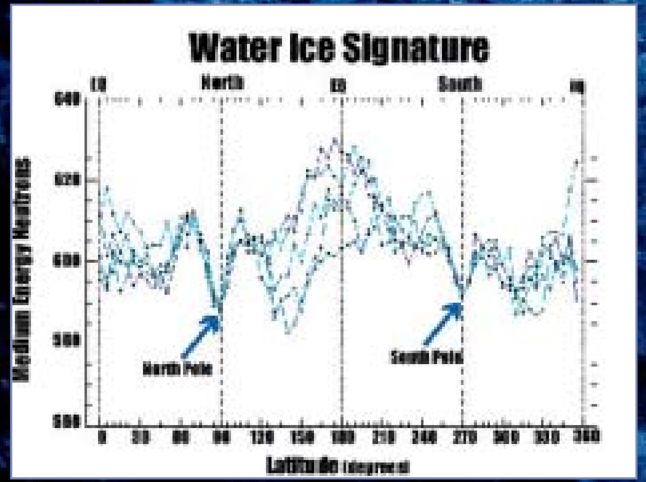
Once a human base exists, the Moon may actually become a more attractive astronomical location than LEO or L2 precisely because a human-tended infrastructure already exists to transport, service, and upgrade the instruments. The scientific value of such human intervention was, after all, one of the major lessons of the Hubble Space Telescope experience.

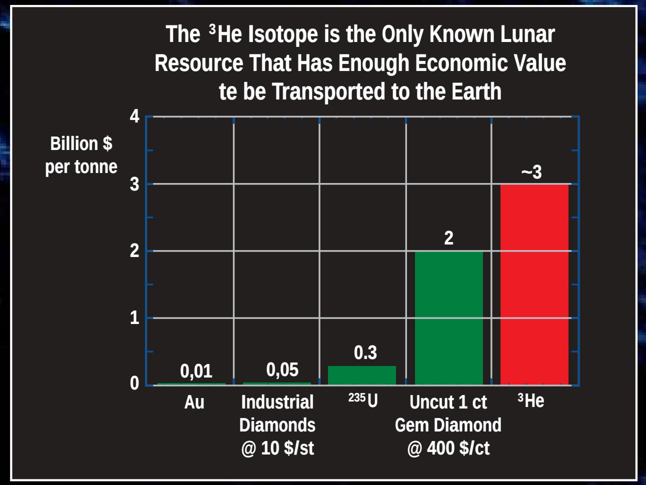
"BASED ON ASTRONOMICAL GOALS AND TELESCOPE ENGINEERING CONSTRAINTS, THE LUNAR POLE DESERVES TO BE TAKEN SERIOUSLY AS AN OBSERVATORY SITE FOR LARGE, CRYOGENIC TELESCOPES..."

ROGER ANGEL, TESTIMONY TO U.S. SENATE HEARINGS ON LUNAR EXPLORATION (6 NOVEMBER 2003)



A PERMANENT LUNAR OUTPOST WILL BE REQUIRED TO CONDUCT THE KIND OF DETAILED GEOLOGICAL FIELDWORK NEEDED TO ASCERTAIN WHETHER THE MOON HAS ANY ECONOMICALLY EXPLOITABLE RESOURCE.





Economic Elements of a Moon Base

There are many different economic aspects in the Human Spaceflight Vision. Clearly, the Vision of a lunar base will not become a reality without the investment of substantial public and private funds. However, this investment will be spread over a period of at least 20 years, and the benefits in terms of job creation, development of new skills and knowledge, medical and industrial spin-offs, and feedback of tax revenues into the economy may be expected to offset much of this investment in space infrastructure.

For comparison, employment in the 11-year Apollo programme peaked at over 400,000, of which just 30,000 worked for NASA. Thus **the Moon effort provided a tremendous economic stimulus** for both regional and local economies within the United States and beyond.

Already, a number of companies and universities in various countries have begun to study construction techniques and designs for lunar hotels. Other companies are investigating the commercial prospects of using the Moon for entertainment and leisure activities. The first small step towards this commercial exploitation of the Moon should get under way in 2004 when a small satellite named TrailBlazer will orbit the Moon and send back high-resolution video images of the surface. The craft will eventually crash into the Moon, broadcasting its descent to observers on Earth. A hardened capsule will protect its cargo of jewellery, cremated remains, messages and other personal items.

Meanwhile a company known as LunaCorp is currently seeking sponsorship and television funding to develop a series of broadband communications spacecraft. These will provide live digital video from the Moon and eventually enable the public to drive a lunar rover via telepresence portals at participating science centres or theme parks.

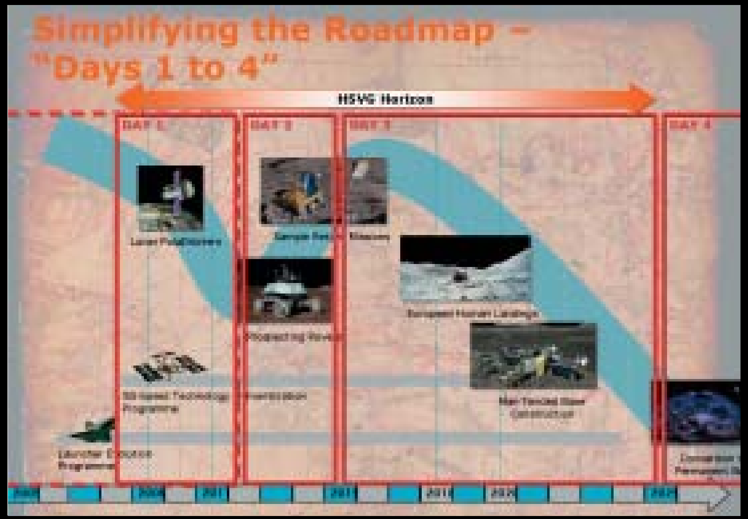
At this early stage, it is still premature to predict how successful the long-term economic exploitation of the Moon might be. One of the principal economic arguments centres on using helium-3 from the lunar regolith as a potential fuel for future nuclear fusion reactors. One kilogram of helium-3 in a fusion reactor would produce the same amount of energy as 10,000,000 kilograms of fossil fuel, offering a clean, efficient method of meeting global energy needs in the second half of the 21st century. Current analyses indicate that there are at least one million tonnes of helium-3 embedded in the lunar surface, although significant exploitation of this resource is only likely in the very long term, if at all.

There have also been suggestions that solar power plants built on the Moon could provide a clean, reliable source of renewable energy for our planet. These lunar solar power plants could collect a small fraction of the Moon's dependable sunlight and convert it into microwave beams that will be sent to receivers on Earth.

The other valuable lunar resource that seems to be available for extraction and utilisation is water ice. Permanently shaded areas in craters near the Moon's poles are thought to contain at least 10 billion tonnes of hydrogen, most probably in the form of ice. This ice could be used to support human life on the Moon and to make rocket propellant (liquid oxygen). By learning how to use off-planet resources, spaceflight will eventually become easier and cheaper in the future.

There is a very strong case for establishing a human presence on the Moon so that its economic potential can be properly assessed. The extent to which economically exploitable mineral deposits may exist is currently unknown, so a permanent lunar outpost will be required to conduct the detailed geological fieldwork needed to ascertain whether the Moon has economically exploitable resources which may be of value for either terrestrial consumption, or future space operations, or both.

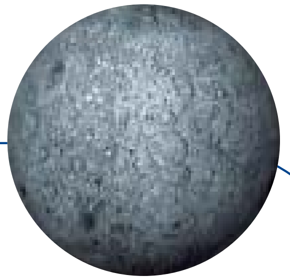
"IT IS THEREFORE POSSIBLE THAT LAYERED ORE DEPOSITS SIMILAR TO OR EVEN LARGER THAN THOSE ON EARTH MAY OCCUR ON THE MOON." PAPIKE ET AL. (1991)



THE VISION ROADMAP ENVISAGES THE FIRST EUROPEANS SETTING FOOT ON THE MOON AROUND 2018-19.

Lessons Learnt from the ISS Programme

The International Space Station Programme is in financial terms the largest co-operative civilian venture ever undertaken at international level. In the last decade important lessons have been learnt for Europe from this programme. First, autonomous capabilities strengthen international co-operation. External factors such as the current Shuttle grounding have led to significant cost increases of the European programme component. Thus to ensure programme and co-operation stability, international collaboration needs to be based on the back-up capabilities of the cooperating partners.
Secondly, international co-operation provides programme stability. For example, Russian logistics services currently enable the ISS to remain manned and operational while the Shuttle is grounded. Moreover, international partnership has stabilised the programme in periods of short-term fluctuation of political priorities and related budget discussions.
Thirdly, international cooperation creates opportunities for sharing the overall programme costs and for enhancing the overall cost effectiveness of the programme. For instance, barter arrangements allow for maximising value for money for all partners. However, in order to be successful international co-operation requires significant preparation. Defining the technical contributions and developing legal agreements have proven not to be enough. In fact, major internal and external risk factors need to be analysed beforehand and risk mitigation measures put in place. Furthermore, while bridging the gap between different cultures is a key benefit of international co-operation, the implications of their differences on the programme implementation need to be understood and controlled.



Technology Roadmap

Although the Human Spaceflight Vision Group did not look in detail at the technologies required to turn the Vision of a human-tended Moon Base into reality, an outline roadmap and implementation plan were discussed.

Under this roadmap, the European path to the Moon would begin without waiting for new technologies. It would follow an **evolutionary approach, building on existing technologies and capabilities to achieve specific mission goals and in parallel develop new and strategic technologies to Europe.**

In the early stages, Europe would benefit from operational and scientific knowledge gained from its existing programmes, such as the Smart-1 lunar polar orbiter. This would be combined with utilisation of the International Space Station to test new technologies and increase experience of long duration human spaceflight in low gravity environments. Utilisation of existing launchers, such as Ariane 5 and Soyuz, would have the beneficial side effect of supporting the European launch industry.

Where the relevant expertise does not exist in Europe, the plan anticipates active co-operation with various partners, e.g. Russia and the Ukraine, which have particular expertise in launch vehicles, roving vehicles and long-endurance human missions. This would enable Europe to avoid wasteful duplication of effort and resources, while taking advantage of the lessons learned by others.

Capabilities, which due to the role Europe envisages to play in the Moon base programme, or whose terrestrial application potential is deemed to be strategic, would be identified from the start of the programme and resources focused on their development.

Once the ability of automated rovers to conduct wide-ranging studies of the lunar surface has been demonstrated, and a sample return mission has demonstrated the ability to land a spacecraft on the Moon and return it to Earth, the next step will be to send humans to our cosmic neighbour.

The Vision roadmap envisages the first Europeans setting foot on the Moon around 2018-19, in time to celebrate the 50th anniversary of Apollo 11. This would also have the advantage of coinciding with a period of low solar activity.

Although the details have not yet been studied, it may well be possible to adopt an evolutionary approach through the gradual build-up of a lunar infrastructure. In its early stages, the programme would probably be implemented with upgraded versions of existing launch vehicles, e.g. Ariane 5 and Soyuz. This would result in the construction of a small, man-tended base, which would eventually have the capacity for conversion to a permanent base around 2025.

In its simplified form, this sample roadmap may be divided into four different stages or 'days'[1]. Under this scenario, the key characteristics of each 'day' would be as follows:

Day 1 already begun

Polar orbiters (such as Smart-1) would map the entire lunar surface at high resolution and at different wavelengths. This would not only provide invaluable scientific knowledge but it would also enable suitable base locations to be determined.

Day 2 2012 onwards

Automated rovers and sample missions would study the lunar surface and subsurface, further improving our knowledge of the Moon and leading to refinement of potential base sites. These robotic expeditions would demonstrate a wide range of lunar operational capabilities, including remote control, transport to and from the Moon, and soft landing / lift off / Earth re-entry.

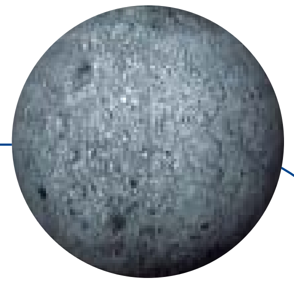
Day 3 2015 onwards

After the first short-duration human visits to the Moon, the introduction of increasingly sophisticated technologies would lead fairly rapidly to the establishment of a man-tended base. This would require delivery or construction of a permanent habitat, complete with life support systems and advanced communications.

Day 4 2025 onwards

The successful demonstration that humans can live and work in the hostile lunar environment would culminate in the

[1] This phased approach is similar to that one recommended by the International Lunar Exploration Working Group.



establishment of a permanently occupied base in which Europeans would conduct scientific, educational and technological programmes for the benefit of humanity back on Earth.

The roadmap presented above is the first iteration of how a Moon programme could evolve. Clearly, it will be essential to involve other nations in this Vision, not only to reduce the costs and time required, but also to advance the geopolitical and societal goals envisaged by the Human Spaceflight Vision Group.

At present, most of the human spaceflight capabilities reside with the two traditional space powers, the United States and Russia. Some of these capabilities, are unlikely to be replicated by other spacefaring nations for the foreseeable future.

However, despite its small programme size in comparison to NASA, **Europe has been able to develop some key technologies that will enable it to play a leading role in a future Moon programme.**

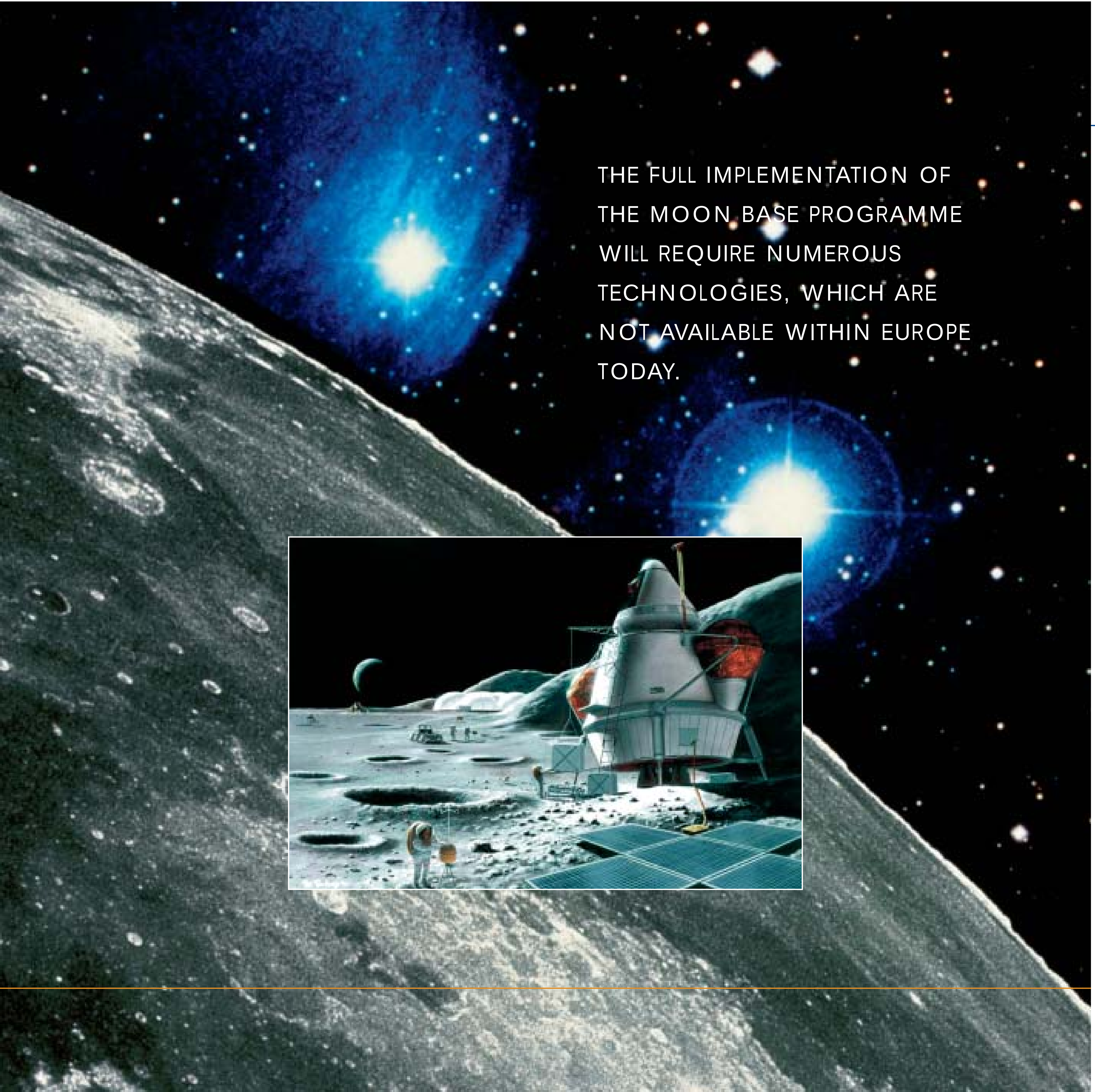
In the field of launchers, the Ariane 5 vehicle has been operational since 1998. Although the vehicle is not currently man-rated, it is possible to envisage a time when an Ariane 5 can carry a 20 tonne crew capsule into geostationary transfer orbit. Meanwhile, the construction of a Soyuz launch pad at the Kourou spaceport could enable Europe to launch a man-rated launch vehicle from French Guiana before 2010.

Russian involvement in the Vision would also be of particular value through utilisation of current human space and cargo transportation vehicles, notably the Soyuz and Progress. Cargo transfer, rendezvous and docking will also be available in the near future through Europe's Automated Transfer Vehicle (ATV). The ATV may subsequently evolve from an unmanned cargo ship to a mini-habitable crew vehicle with download capability. Atmospheric re-entry systems are already available in Russia, and various re-entry technologies have been developed and tested under Europe's Human Spaceflight and Science programmes.

Deep space operations, including guidance, navigation and control, have been successfully undertaken in Europe for many years. ESA's first lunar orbiter, Smart-1, is currently testing a number of new technologies, including ion propulsion and laser communications, as well as promising to provide high resolution global maps of lunar resources.

European experience in constructing Spacelab, the Columbus module and the ISS Nodes - complete with advanced data management systems, life support systems, power and communications - could pave the way for development of lunar habitat modules. Other advances, such as the creation of the Galileo satellite navigation constellation and the European Robotic Arm, would also be of benefit in the development of a Moon Base.

Clearly, many of the building blocks upon which the Vision will depend already exist, although, at this early stage, it is not possible – or desirable - to refine all of the technological details for such an ambitious programme. **However, the proposed European Moon programme is much more than a space engineering project driven by technical considerations. Instead, the focus will be on the achievement of the overall Vision and the ways in which technologies can be adapted and developed in order to meet the European objectives.**



Human Spaceflight Capabilities

Demonstrated Key Capabilities	US	Russia	Europe by 2005	Japan by 2006	Canada	China
Cargo Upload to ISS	•	•	•	•		
Cargo Return from ISS	•	Limited				
Human Transportation	•	•				•
Human Space Transfer to Moon	In the past					
Habitation in Space	•	•	•	•		
Robotics	•	•	•	•	•	
Extra Vehicular Activities	•	•				
Rendezvous and Docking	•	•	•	•		
Astronauts Capability	150	30-40	16	8	6	12

Missing European Technologies

Human Transportation

- **Launcher safety**
- **Ascent safety/ abort**
- **Rendez-vous**
- **Docking / Berthing**
- **Separation**
- **Re-entry***
- **Landing***
- **Recovery***
- **Propulsion (beyond LEO)**

Habitation Aspects

- **Ergonomics**
- **Closed loop food systems**
- **Closed loop life support systems**
- **Crew personal hygiene/ waste management**
- **Crew exercise/ medicine/ health / psychology**
- **Crew Leisure**
- **Spacecraft health management**
- **Large volume structures living areas**

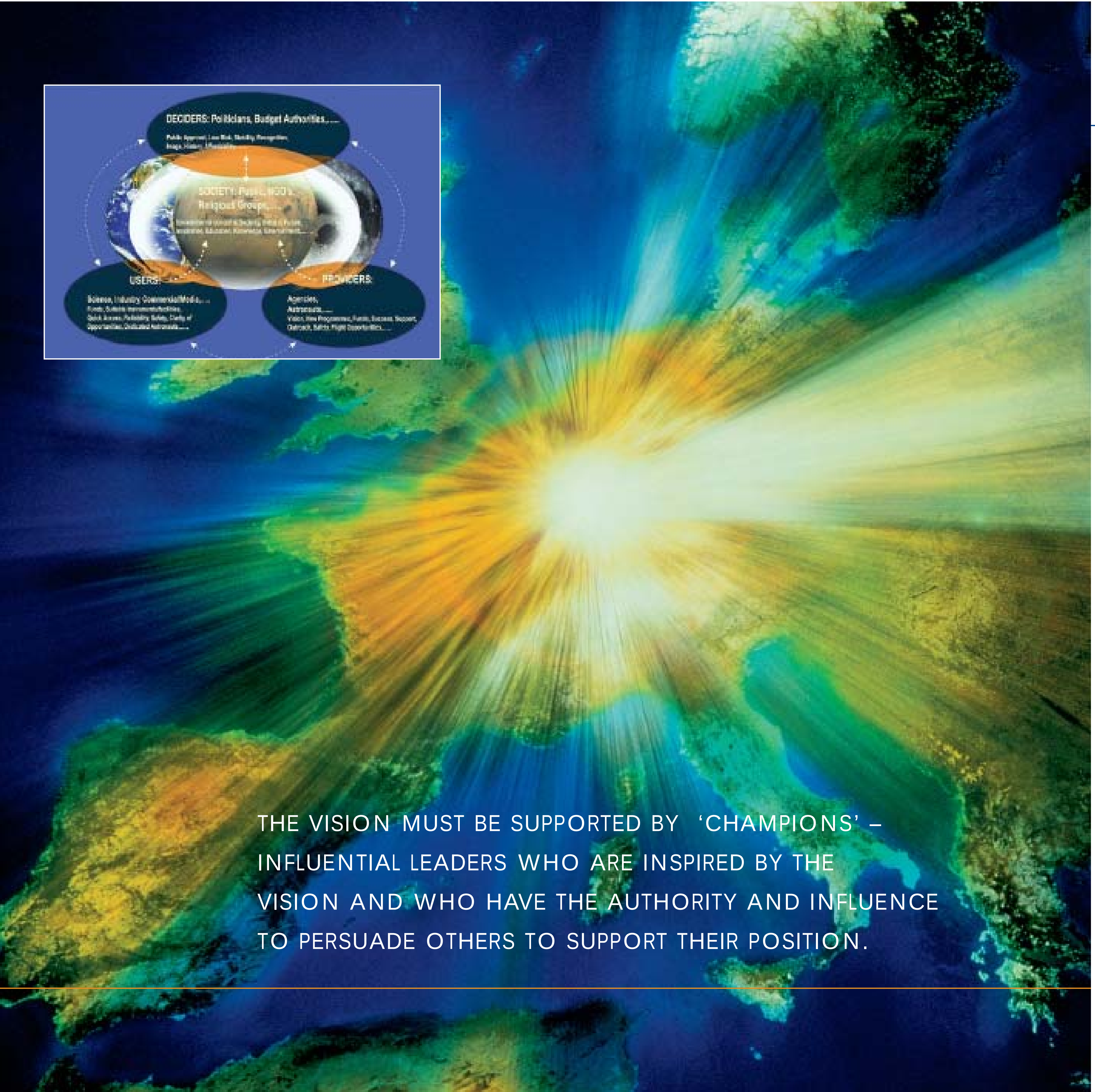
Extra Vehicular Servicing

- **EVA suits (space, surface)**
- **EVA mobility units**
- **Inspection**
- **Repair**
- **General robotics**
- **Spacecraft retrieval/ repositioning**
- **Large scale construction**

The full implementation of the Moon Base programme will require numerous technologies, which are not available within Europe today. A technology roadmap for the development of key technologies needs to be developed taking into account:

- The role Europe intends to play in the Moon Base programme (e.g. transportation capabilities are key for leading or being an equal partner of an international effort);
- The economic value of the technologies (e.g. closed loop food and life support systems may find numerous applications on Earth);
- The technological capabilities of other space-faring nations.

* Also missing capabilities for cargo transportation.



Reaching the Stakeholders

The Human Spaceflight Vision will only succeed if it receives substantial funding and widespread support from politicians and the general public. In order to obtain this funding and support, it will be essential to gain the attention and backing of key stakeholders and decision-makers.

In particular, the Vision must be supported by 'champions' – influential leaders who are inspired by the Vision and who have the authority and influence to persuade others to support their position. This will only be achieved by stressing the less tangible benefits of Europe's manifest destiny and international prestige alongside the traditional, concrete benefits offered by advances in science and engineering.

Who Are The Stakeholders?

In order to achieve the Vision, it will be essential to identify the Human Spaceflight stakeholders, together with their particular needs and interests. One key group will be leaders and decision makers. These include politicians and those who determine the ESA Human Spaceflight budget. This group may be influenced by three groups of stakeholders:

- Users – science, industry, and commercial/media.
- Providers – space agencies and astronauts.
- Society – the general public, non-government organisations, religious groups etc.

How Can the Vision Become A Reality?

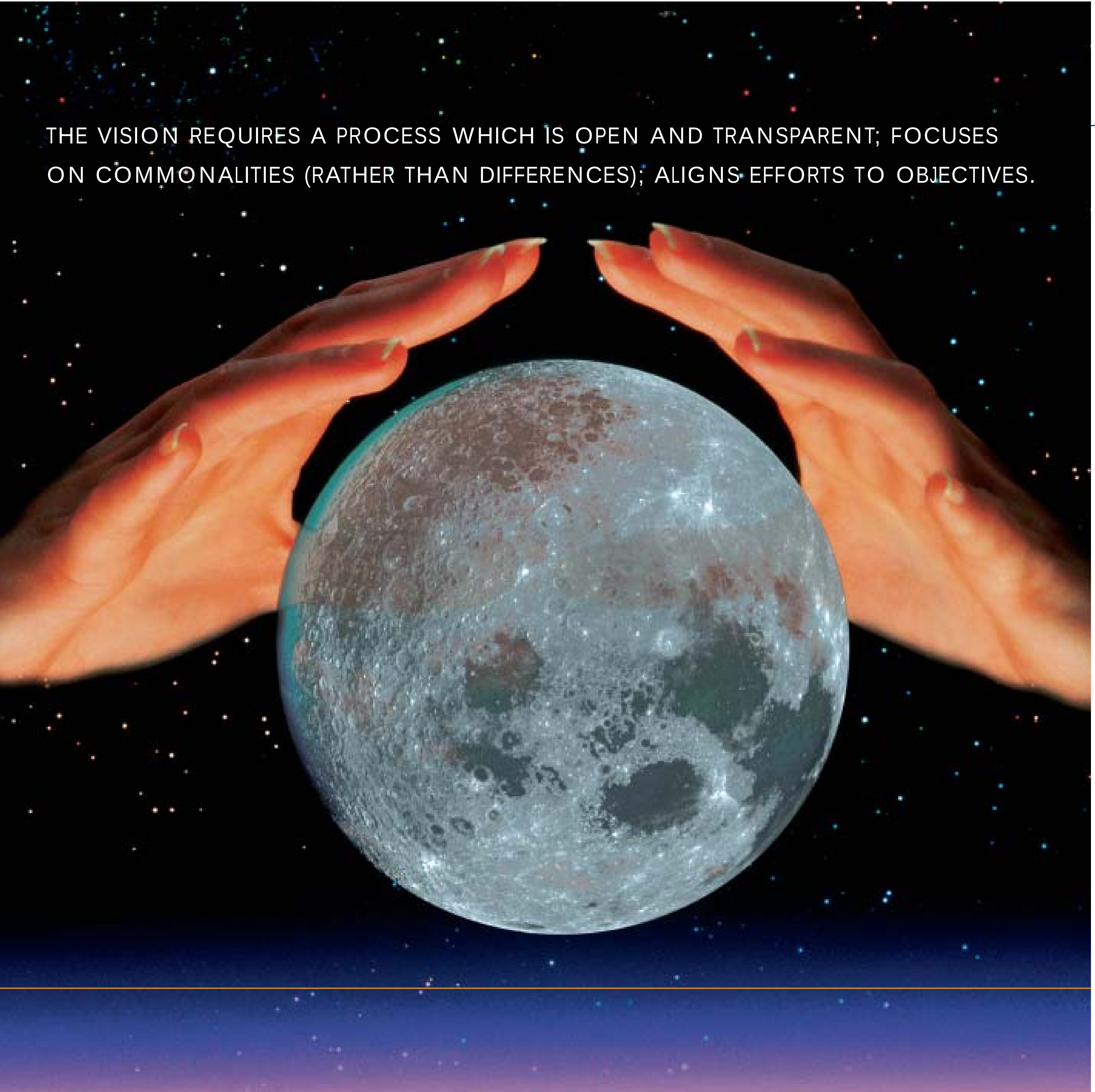
In view of the current economic climate, marked by a greater emphasis on space applications, human spaceflight will be increasingly evaluated by applying other investment opportunities in the space sector as a benchmark. If the European human spaceflight enterprise is to advance and evolve, it is essential to present a clear vision that excites decision makers and is supported by all stakeholders.

The key leaders and decision makers are most likely to give their support and use their influence if they are aware of a groundswell of public engagement, encouraged by the media, for the Vision. Their active support may also be encouraged by the long-term promise of a lasting legacy to humanity – as was the case with those who envisaged a European Union some 50 years ago.

The Moon Base programme must earn political and public support by presenting an inspiring vision, similar to that provided by the early stages of the Apollo programme, culminating with the landing of Apollo 11 on the Moon. In order to achieve such a resounding impact, it will be essential to promote the numerous benefits and spinoffs for the whole of European society that will result from the creation of a permanent Moon Base.

This **mega-impact scenario** would have a broad appeal on many levels, not only involving the development of new space technologies, but also the advancement of Europe in the fields of science, education, culture and geopolitics. One of the most important aspects of this appeal would be the encouragement of European unity through collaboration and integration.

Furthermore, the Vision should not be afraid to appeal to stakeholders on an emotional level, for example, as a means of generating a sense of pride and an awareness of Europe's leading role in pioneering such a prestigious undertaking.



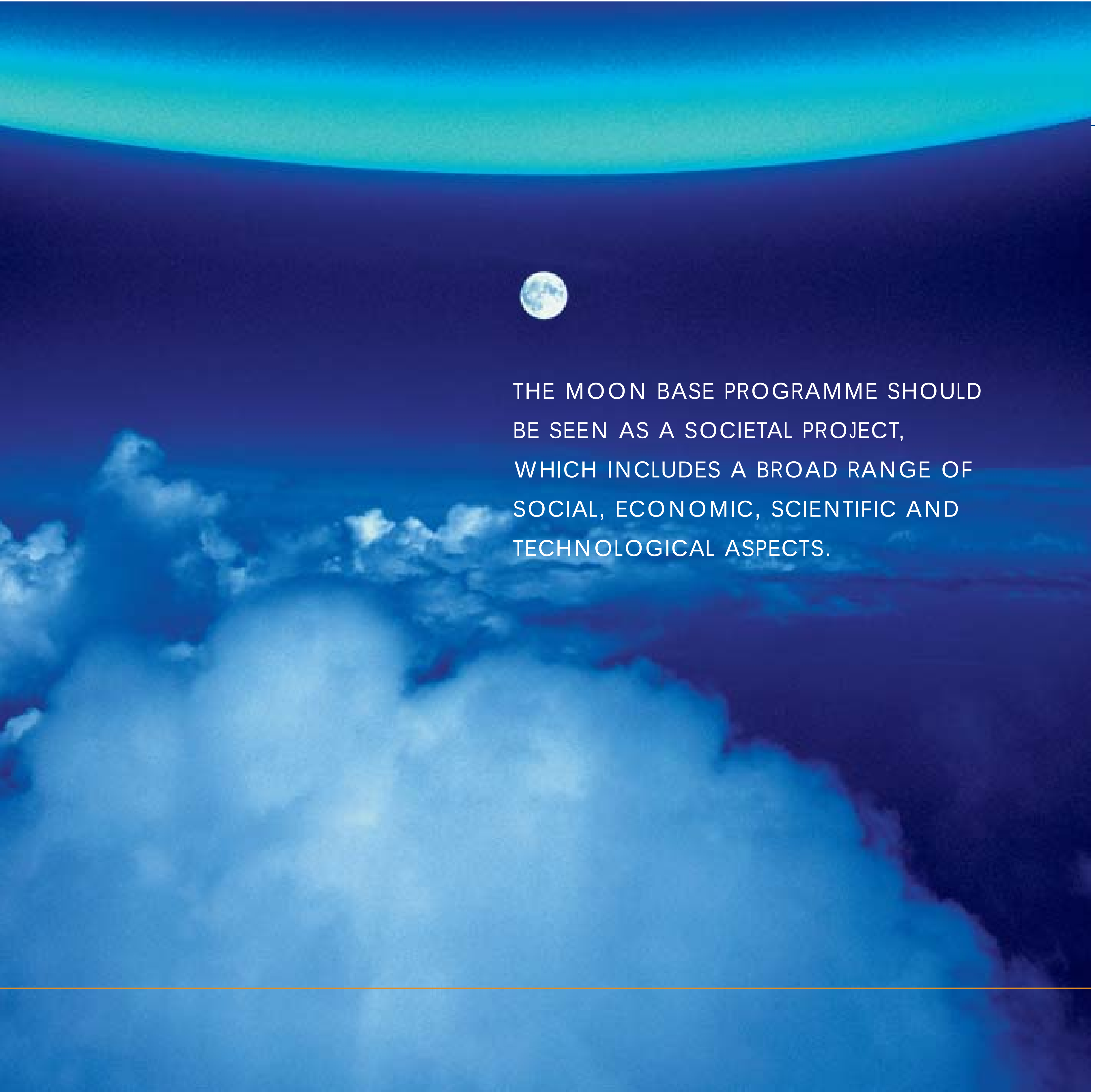
The First Steps

The Vision represents a bold, innovative European plan for the future of human space exploration.
In order to move forward, the Vision requires a process which:
- Is open and transparent;
- Focuses on commonalities (rather than differences);
- Aligns efforts to objectives.

The Way Forward

The following steps for 2004 are recommended:
- Explore the opportunities for international co-operation, by inviting other space agencies to join a task force to define the programme options;
- Assess the technical feasibility of the implementation roadmap;
- Promote the Vision to European institutions and leaders to consolidate the political case;
- Ensure the Vision is shared by key stakeholders through a co-visioning process, in particular with the private sector and Europe's political leadership, but also including the education sector and research organisations;
- Develop an integrated strategic plan for automatic and human space exploration;
- Carry out an inventory of existing technologies that could be applied to the realisation of the Vision, whether developed by Europeans or willingly shared with Europe by partners;
- Develop an R&D roadmap for the development of strategic and currently unavailable technologies;
- Define the human and cargo transportation scenario;
- Consolidate the scientific case for human presence on the Moon;
- Analyse and promote the role of the International Space Station as a test bed and stepping stone for implementation of the Vision.

Publicity and media support will play a key role in persuading the key stakeholders, particularly political leaders and the general public, of the importance of delivering this Vision. In order to reach the wider audience, it will be essential to employ a communication strategy that will put the message across in clear, unambiguous and non-technical language.



Conclusions

The Moon Base programme should be seen as a societal project, which includes a broad range of social, economic, scientific and technological aspects.

It meets the core European objectives and strategies, by fostering European values and the creation of a knowledge-based society in the 21st century.

This ambitious programme will attract partners, provide new opportunities to deal with the future global economic and environmental challenges for humankind on Earth, and offer a platform that will enable us to advance our knowledge and expertise on behalf of spaceship Earth.

The Moon Base will provide an ideal stepping stone on another world that will open the door to future exploration of the Solar System.

The Visionaries

The Human Spaceflight Vision Group (HSVG) was established by Mr. J. Feustel-Büechl, ESA Director of Human Spaceflight, and comprised "visionaries" from eight European countries, supported by "experts" in the field of human spaceflight. The Visionaries were assembled from many different fields, including space- and non-space industry, communications, marketing, research, and academic institutes, and were supported by ESA.

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"I HAVE GREATLY ENJOYED CONTRIBUTING TO THIS INTERESTING AND IMPORTANT ACTIVITY, AND I THANK ESA FOR GIVING ME THE OPPORTUNITY TO DO SO".

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"WITHOUT VISIONS THERE IS NO FUTURE!"

Dr. Günther Seibert
Germany

Prof. Ernesto Vallerani
Italy
"THE FUTURE OF OUR GRANDSONS STARTS TODAY. LET US LEAD THEIR WAY INTO SPACE."

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"EUROPEANS HAVE BEEN EXPLORERS. TRAILBLAZERS. SETTLERS. LET'S RECONNECT TO THAT TRADITION. LET'S AGAIN OPEN A NEW WORLD. LET'S BLAZE THE TRAIL TO THE WORLDS BEYOND THE SKY. LET'S CLAIM AN OUTPOST IN A VIRGIN LAND AND LEARN TO LIVE OFF THE LAND. IT'S TIME FOR EUROPEANS TO MAKE THE MOON THEIR OWN. LET'S GO SETTLE THE NEW FRONTIER."

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Participants from Alenia Spazio Space Infrastructure Programmes
Participants from Alenia Spazio Business development
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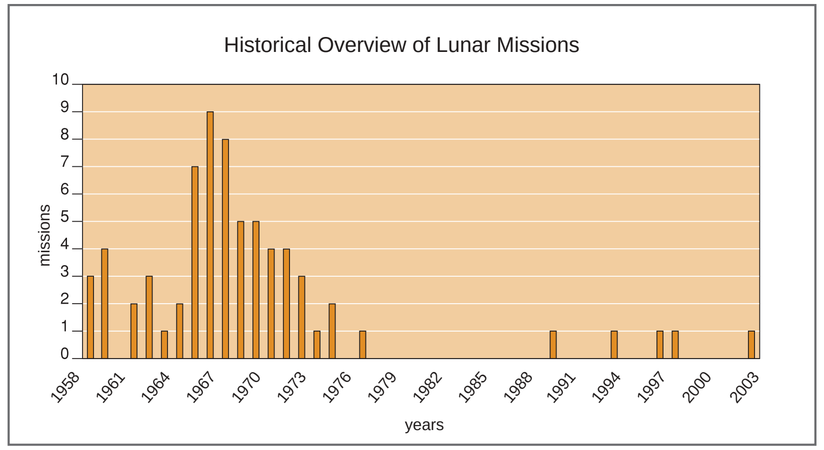
Characteristics of the Moon

- Creation: impact theory widely accepted
- Moon age: 4,6 billion years
- Distance from Earth: 356.400-406.700 km
- Composition of the tenuous lunar atmosphere is poorly known and variable. The most common constituents are thought to be: helium 4 (4He); neon 20 (20Ne); hydrogen (H); argon 40 (40Ar).
- Lunar Elementals: Aluminium, Calcium, Chromium, Iron, Magnesium, Manganese, Oxygen, Potassium, Silicon, Sodium, Titanium, Carbon, Hydrogen, Nitrogen, Sulphur, Pyroxene, Phosphorus, Helium, Neon. Water ice is probably present in permanently shadowed areas near the Moon's North and South poles.



Parameter	Moon	Earth	Ratio
Mass (10^{24} kg)	0.07349	5.9736	0.0123
Volume (10^{10} km^3)	2.1958	108.321	0.0203
Equatorial radius (km)	1738.1	6378.1	0.2725
Polar radius (km)	1736.0	6356.8	0.2731
Mean density (kg/m^3)	3350	5515	0.607
Surface gravity (m/s^2)	1.62 (0,17g)	9.80 (1g)	0.165
Escape velocity (km/s)	2.38	11.2	0.213
Length of Day	29.53 Earth days	23 h 56 min	
Atmospheric Pressure (night)	3 x 10^{-15} bar	1000 mbar	
Shielding	None above regolith	1000 gr/sq.cm	
Cosmic Ionising Radiation[1]	0.3 Sv/y	1-2 mSv/y	
Solar Particle Events	0.4-0.6 Sv/h	N/A	
Solar UV-Radiation	Unfiltered	All above 290 nm	
Diurnal Temperature Range [2]	-171 to + 111°C	10-20°C(std.atmosph.)	
Dust	Lunar Surf. Dust	Wind and dust	
Albedo	Average 0.067	0.5 variable	

Total mass of Moon rocks brought back to Earth: 382Kg

Lunar feature	Advantage	Disadvantage
No atmosphere	Access to all wavelengths No atmospheric distortion of images No wind loading of telescopes	No protection from cosmic rays No moderation of thermal effects Line of sight transmission
No ionosphere	No long-wave radio cut-off	
Seismic activity	Seismically quiet compared to the earth	
Solid surface	Radiation and thermal shielding Stable thermal environment at poles Raw construction materials	 Possible dust contamination
Lunar gravity	Lightweight structures possible	Telescopes require support
Slow, synchronous rotation	Two weeks of thermal stability Long integration times Far side isolated from terrestrial interference	300 K diurnal temperature change Very slow aperture synthesis No solar power at night
Distance from the earth	Long baseline for radio interferometry	Expensive transportation

Missions	No.	First	Latest	Planned
Successful				
Flybys	8	Luna 1 – Jan. 2, 1959	AsiaSat 3/HGS-1 – Dec 24,1997	
Probes	5	Luna 3 – Oct. 4, 1959	Zond 8 – Oct. 20, 1970	
Impacts	4	Luna 2 – Sep. 12, 1959	Luna 8 – Dec 3, 1965	
Landers	7	Luna 9 – Jan. 31, 1966	Luna 23 – Oct.28, 1974	
Orbiters	15	Luna 10 – Mar. 31, 1966	SMART 1 –Sep. 27, 2003	Lunar –A – Aug. 2004 Selene – Dec. 2005 Chang'e 2007 Chandrayan-1 2008
Sample return missions	3	Luna 16 – Sep. 12, 1970	Luna 24 – Aug. 14, 1976	South Pole Aitken Basin Sample Return 2009
Rovers	2	Luna 17 – Nov. 10, 1970	Luna 21 – Jan. 8, 1973	
Failed				
Robotic attempts	15	Pioneer 0 – Aug. 17, 1958	Luna 18 – Sep. 2, 1971	
Manned				
Missions (12 men, 0 women)	9	Apollo 8 – Dec. 21, 1968	Apollo 17 – Dec 7, 1972	

[1] In 1 m depth in lunar soil the cosmic radiation decreases to terrestrial levels.

[2] In 20 cm depth in lunar soil the temperature variation decreases to 10 °C and in 40 cm depth to 1°C, i.e. it is stable around -20°C, due to the very low thermal conductivity of lunar regolith.

HUMAN SPACEFLIGHT 2025

MOON: THE 8TH CONTINENT

Working at the Moon Base

A day in the lunar laboratory, the place where every student dreams of being

"Hi, welcome to Moon lab" says Laura showing me the way to her working space. Laura is a young Dutch scientist who works where every student dreams to be. We are in the amazing laboratory of the Moon base, which started being permanently inhabited a few days ago. "Well, the switch from missions lasting only a few days to long-term stays up here has been a major change indeed!" Laura's excitement shows very well that life at the Moon base is anything but routine!

Everything started in the first years of the 21st century when many people used to advocate the very strong case for going back to the Moon and staying. In particular, ESA promoted a vision, which was born to meet new geopolitical challenges and to advance a broad set of European aims and objectives. Support at EU level has been crucial and European politicians, like new Monnets, Adenauers and De Gasperis, devoted themselves to the project of a permanent base on the Moon. Their legacy will surely last forever. Laura continues: "The vision focused on how human spaceflight could extend our options to tackle some of the most important issues in a global context and the challenges likely to be faced on spaceship Earth." "For the first time scientists and engineers talked to people in simple terms and presented the new project as an engaging story whose characters are very human, i.e. people like me who work hard in order to achieve their goals. "In fact the possibility of one day being selected to go to the Moon has inspired hundreds of young students." Laura is right: statistics have shown that during the past 20 years a growing number of students have chosen technical and scientific university studies.

One of Laura's colleagues comes closer and introduces himself. "I'm John, an English engineer." John and Laura go on to explain to me how proud they are of their countries' contributions and of the fact that in 2005 Europe took the lead in what has become a truly international venture. Analysts agree on the fact that the Moon-base programme has strengthened Europe's position both internally (by enhancing integration and by creating a true European identity) and externally through renewed co-operation with the major players at a global level. "Nowadays Europe strives to keep up with countries like Japan, India and China," worries Laura". "What if we had not embarked on the Moon-base project which has boosted R&D and has brought Europe to the forefront of technological innovation?" They look down at Earth. They know how difficult life is now on their blue planet. "Environmental and water stress, aged populations, low growth rates, resource dependency... to mention just a few issues..." John intervenes: "Up here we pave the way for a time when everything will be recycled and used in the most efficient fashion."

"Ah, here is Luc!" calls out Laura. I turn towards the door and I see a clumsy shape fighting against a space suit. "Luc comes from a mission for exploring new perspectives for Moon resource utilization," explains Laura. Luc explains that the real exploitation of the Moon's resources is still in the preliminary stage of data collecting. "Work in the field allows us to investigate the geological evolution of the Moon, which contains a huge scientific record of past events during the evolution of the inner Solar System." "A more accurate analysis of the samples is obviously done here in the lab, and it is absolutely amazing to make new discoveries every day!" adds Laura. Her excitement is contagious. Luc starts talking about the potential development of the now permanently man-tended Moon base. "Cutting-edge astronomical instruments will be built soon while we are still assessing the feasibility of solar-panel installations here to produce energy for Earth. To sum up, at the moment all of our energies are devoted to assessing lunar resources, their value and efficient ways to mine them, in particular helium-3." Luc goes on saying: "The latest nuclear-fusion techniques, which already contribute significantly to clean energy production on Earth, lead to real perspectives of economic exploitation of helium-3 for terrestrial use". In the meantime, at the United Nations, diplomacy is working hard to reach an agreement on the proposed draft treaty that should establish a new international regime for the exploitation of the natural resources on the Moon and other celestial bodies.

I leave them discussing studies on radiation biology and the biological effects of reduced gravity on the human body. I look around thinking of just how difficult it has been to reach this point. Yet this is just the springboard for the future exploration of outer space, and Mars in particular. The construction of the Moon base has required an enormous effort by all of the international partners. Fortunately, Europe has from the outset adopted an evolutionary approach, building on the experience with the ISS and investing further in already existing capabilities. Co-operation has been sought from an early stage, and this has allowed ESA to make use of technologies available to other partners while concentrating its own R&D energies on truly new engineering challenges. In 2003, a little lunar polar orbiter paved the way for a series of automated rovers and sample return missions. These eventually led to the amazing reality that surrounds me now.

I look at the highly motivated young people in the laboratory and I ask myself: "Is this the same generation that will first set foot on Mars"?

Only time will tell...

Fabian Mundpol