INVESTING IN SPACE
THE CHALLENGE FOR EUROPE

LONG-TERM SPACE POLICY COMMITTEE

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Why Must Europe Invest in Space?

Space has transformed daily life.

With just over forty years having elapsed since the first satellite launch, achievements in space have already led to a host of discoveries and have induced a massive expansion in associated activities and services throughout the World. Space has transformed daily life, thanks to the quality and efficiency of worldwide telecommunications, broadcasting, weather forecasting and navigation. Unprecedented discoveries in the Solar System and the Universe are fulfilling scientists' wildest aspirations. A new understanding of our planet and the complex interactions of its oceans, land masses and atmosphere is fostering a sense of responsibility for the Earth's ecosystem and also forms the basis for many space applications.

Today's space systems are the key to the understanding and management of the World, to the provision of goods and services in the global marketplace, and to regional and global security and peacekeeping. They are also the source of a large number of highly skilled jobs: space employs about 35 000 people directly in Europe, and estimates for the indirect employment that it creates approach 400 000.

The use of space is a continuing and ever-growing success story. It would be unthinkable for Europe not to play its part, and thereby fail to reap the rewards of its investments so far.

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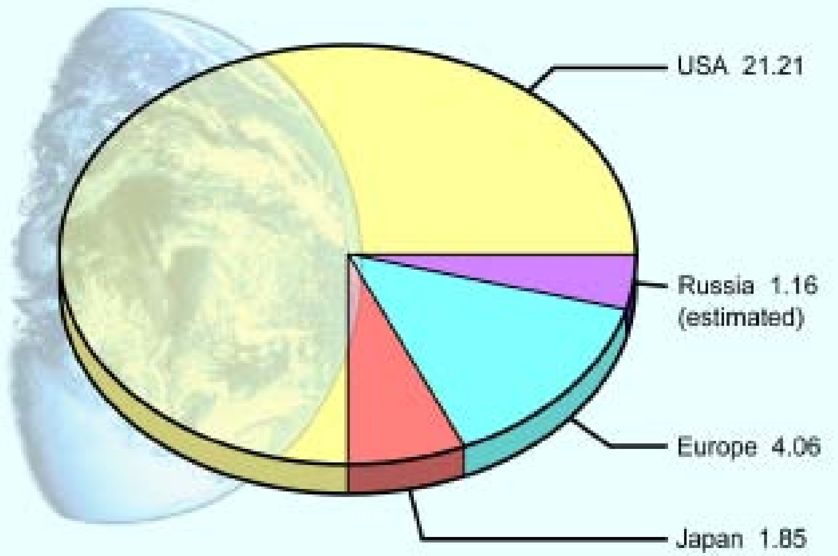
In order to fulfil this role, a full space capability is essential, including the industrial strength and talented work force necessary for mastering all areas of advanced technology and science.

A full space capability means the freedom to access space and to define, build and operate complete space systems in all strategic areas. As the American example shows, this capability is increasingly being used as an instrument and integral part of overall political, economic and military leadership.

Europe already possesses certain elements of this capability, but these need to be sustained and expanded as a basis for continued success. Tomorrow's successes will indeed be built on Europe's past and present accomplishments in space: science, access to space, applications, and innovation through advanced technology. These successes are to be treasured: they are proof of what a united Europe can achieve, and provide the confidence that if it goes on combining technical competence and political will, it will successfully master the challenges ahead.



Spending of main space powers in 1997 in B€

However, Europe is falling behind in crucial applications of space technology where lack of vision and leadership is becoming ever more apparent. Europe must acquire real strategic independence in these key areas.

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Europe must also continue to be a leading partner in global cooperation on space systems for research into and monitoring of the Earth's ecosystem. Europe's role in this planetary-management effort is essential for ensuring the planet's long-term sustainability as well as for Europe's own credibility and status.

Beyond that, Europe has to be able to lead in some areas of future commercial space applications. Success in the potentially huge space market requires forward-looking policies

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and investments that go beyond short-term commercial concerns. Europe must rise to this challenge. Airbus and Ariane are prime examples of worldwide commercial success built on such policies.

It would be neither wise nor worthy of Europe to rely exclusively on market-proven technology. A vigorous and forward-looking Europe must also invest in ideas that, although seemingly exotic in the short-term, will lay the foundations for as yet unforeseen applications, and contribute to its future as a leading force in World politics and commerce in the 21st Century.

If Europe wants to succeed, it must in the short-term explore as many future options as possible. Although nine out of ten of these may lead nowhere, one might just open up new fields. A climate of courage and imagination is needed as the breeding ground for future technologies, products and services.

The Three Challenges

The short-term challenge is clear. Europe has to consolidate and expand its overall space capability. 'The Challenge of Independence' (Chapter 1) is to avoid reliance on others in strategic areas of space. Immediate decisions are needed as the future will not wait for the slow.

A climate of courage and imagination is needed as the breeding ground for future technologies, products and services.

Threats to the planet's environment require an urgent response. 'The Challenge of Planetary Management' (Chapter 2) is for Europe to be a major and responsible player in the worldwide effort to ensure the sustainability of civilization on the planet.

Beyond the horizons of today, humankind will have to find ingenious ways of using the resources of space and of expanding into the Solar System. 'The Challenge Beyond' (Chapter 3) is for Europe to play a leading role in these areas.

1. The Challenge of Independence

Europe was the cradle of modern science and technology, and has shaped the modern World. Today, as in earlier times, it is scientifically and culturally powerful, and it has become the economic equal of the USA in terms of Gross National Product (GNP). Yet, total European Government spending on space is at least five times less.

Much more is at stake than just independence. It is Europe's sustained prosperity, enhanced quality of life and creative cultural identity.

The continuing massive public investments in space by the USA, together with the technological harvest from previous pioneering space feats, are responsible for Europe's absence today from key strategic areas. As a result, highly sophisticated services have been made available to Europe, in some cases at no cost for the space segment, especially in key strategic areas such as surveillance, intelligence, military and civil navigation. A comfortable but dangerous dependence has developed, inhibiting any initiative to even catch up, let alone take the lead.

Much more is at stake here than just independence. It is Europe's sustained prosperity, enhanced quality of life and creative cultural identity. This is the legacy that must be handed down to the young Europeans of the next century. Proud of their past and confident in their future, they must have the freedom to express their ideas, develop their talents and implement their convictions in all economic, political, strategic and cultural domains. The vitality of today is the heritage of tomorrow. The question "Has Space a Future?" is obsolete: without space there will be no future!

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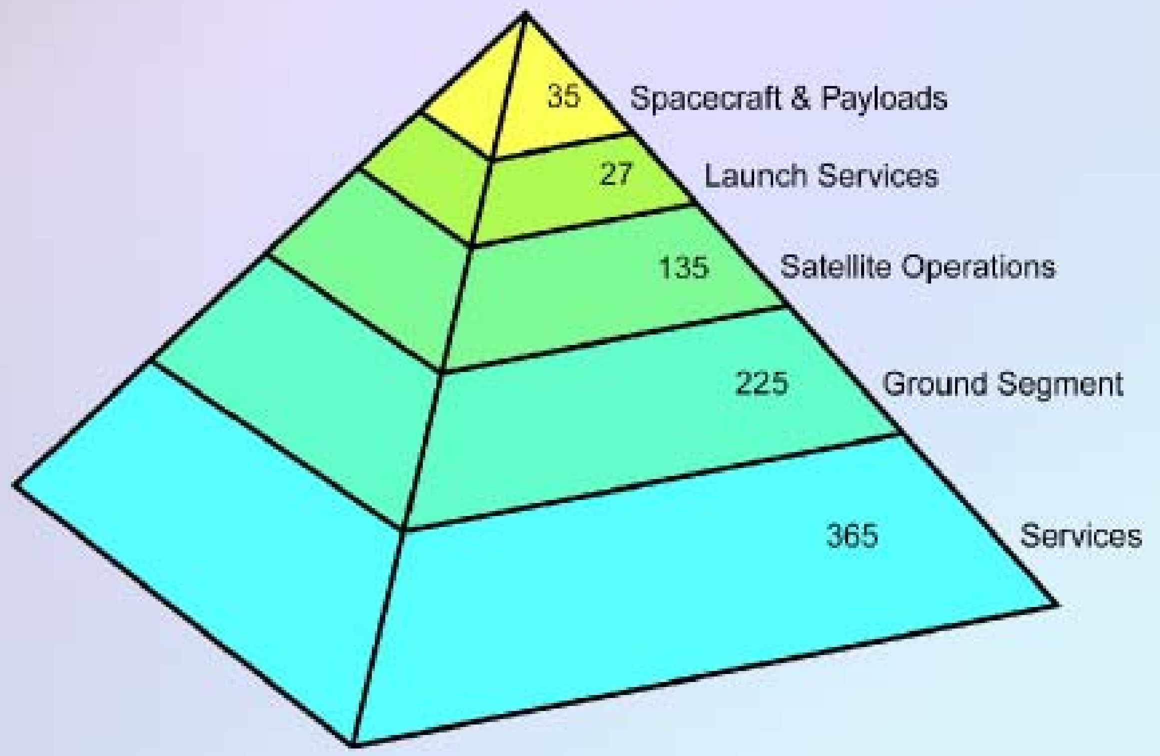
Europe is widely respected in a number of space fields and the acknowledged World leader in some areas, such as space science and launchers. In a number of key space technology and



Value-added chain for commercial satellite navigation and communications:
Cumulative figures 1998-2007 in B€ (Euroconsult)

applications areas, however, Europe's presence certainly does not reflect its current power and future potential. Urgent action in these areas, which include navigation, security and peacekeeping, and information services, is therefore needed to secure Europe's stake in World society in the 21st Century.

Science

The success of ESA's Scientific Programme is an excellent example of what an ambitious and organized Europe can achieve. This success relies on wise long-term planning, a multi-year funding commitment and mission selection based on scientific excellence. This success should not, however, be taken for granted and support to this Programme should be reinforced to enable the inclusion of new fields like fundamental physics, and to safeguard European scientific competence in new fields.

Science is at the root of technological progress as well as economic prosperity, and it carries strong cultural values for young Europeans.

The big issues of the coming century range from management of the Earth's ecosystem, to reaching out towards planets and asteroids. Science is at the root of technological progress as well as economic prosperity, and it carries strong cultural values for young Europeans. An increase in the basic European Space Science Programme and its extension to wider fields would be beneficial to the long-term competitiveness of most of the European space effort. Curtailment of its participation in Space Science programmes, on the other hand, would damage Europe's competitiveness and shift the focus of interest in fundamental knowledge elsewhere, with dire consequences for both its culture and technical capabilities. Space Science has revolutionised the understanding of planet Earth, the Solar System and the Universe; in the 21st Century it will unravel many remaining mysteries such as the long-term interaction between the Earth and the Sun, and it may provide the ultimate key to the most intriguing and far-reaching mystery of them all - the origin of life itself and its evolution in the Universe **(see Action 1).**

Action 1. Involve Europe in the search for Earth-like planets and the detection of extraterrestrial life forms.

Space Access and Infrastructure

The highly successful Ariane Programme and the Guiana Space Centre have secured independent access to space for Europe. However, Europe's presently strong position for launches to geostationary orbit is being vigorously attacked from many sides, using either the same ideas and technology as Europe - standardised and modular expendable rockets - or else radically new concepts and architectures that are fully or partly reusable. In order to safeguard

If Europe does not invest now in future launcher technology, it will lose this vitally important market, as well as strategic independence in all other areas of space.

its long-term strategic and economic interests, it is of crucial importance for Europe to maintain and enhance its position in the space-transportation market.

In the longer term, strong support should be given to research into materials and combustion processes, as the breakthroughs in launcher design may well come from there. Improvements in lightweight structures, engine efficiencies and hypersonic aerodynamic design will be the key to the development of a reusable system. Today, a dangerous disparity in effort is evident. In the USA, at least a dozen publicly or privately funded projects are underway – in Europe there are none. Most or all might fail, but one of them just might be the breakthrough that leads to the long sought after low-cost, routine access to space.

Action 2. Put Europe among the winners in the competition to achieve substantial launch-cost reduction.

In addition to the vigorous pursuit of cost reduction and improved performance, a new generation of low-cost smaller systems should complement the heavy launcher Ariane-5 and its growth versions **(see Action 2)**. Several options can be studied, including an air-launched, partially reusable system that would be particularly competitive for the satellite-constellation launch market.

Cheap access to space is still the most essential step towards reaping the full potential of space. If Europe does not invest now in future launcher technology, it will lose this vitally important and expanding market, as well as the basic prerequisite for strategic independence in all other areas of space.

Action 3. Ensure that Europe participates fully in the utilisation of the International Space Station.

The Columbus laboratory and the Automated Transfer Vehicle are Europe's contribution to the International Space Station and its entry ticket to human space flight in the 21st Century. More than ten years of operation for the first permanent international outpost and scientific complex in space will offer unprecedented opportunities. Europe should maximise its benefits from this development with a full and active utilisation programme **(see Action 3)**. Space Station operations will dramatically improve our understanding of the effects of long space flights on humans and of the logistic support required for any potential extension of man's activities beyond the Earth, such as travel to Mars or extended stays on the Moon.

Navigation

Europe is at present entirely dependent for its navigation and positioning services on the Global Positioning System (GPS) built and operated by the US Department of Defense and, so far, made available free of charge to users worldwide. This ranks among the greatest threats to Europe's strategic independence, as well as to European industry. The provider of the space segment sets the standards, guides its use and secures for itself the lion's share of derived commercial benefits, which vastly surpass the initial investments. It is therefore a matter of urgency for Europe to promote a Global Navigation Satellite System and to prepare for the development of the associated future services **(see Action 4)**. Europe will have to choose very shortly between participation in a globally managed system, the development of a system in cooperation with international partners, or the development of its own system. Whichever option it eventually selects, Europe must play a full role in the development, operation and control of the future system. Europe has to acquire its own technological and operational capability as a prerequisite for true partnership.

Action 4. Secure Europe's position in the field of satellite navigation and prepare for future space navigation services.

Security and Peacekeeping

Unfortunately, the 21st Century is unlikely to see an end to human conflict. Ethnic differences, tensions arising from the denial of fundamental human rights, unsettled aspirations for territory and resources, population increases and rising demands in per capita consumption, as well as competition between political and religious ideologies, will continue to fuel the multi-dimensional confrontations of tomorrow. Security and peacekeeping forces depend on surveillance, communications and command systems. Hence, space systems for defence requirements are essential components of a European security architecture and its contribution to global peacekeeping efforts. Despite present political and institutional barriers, Europe urgently needs to face up to its responsibilities in this field **(see Action 5)**.

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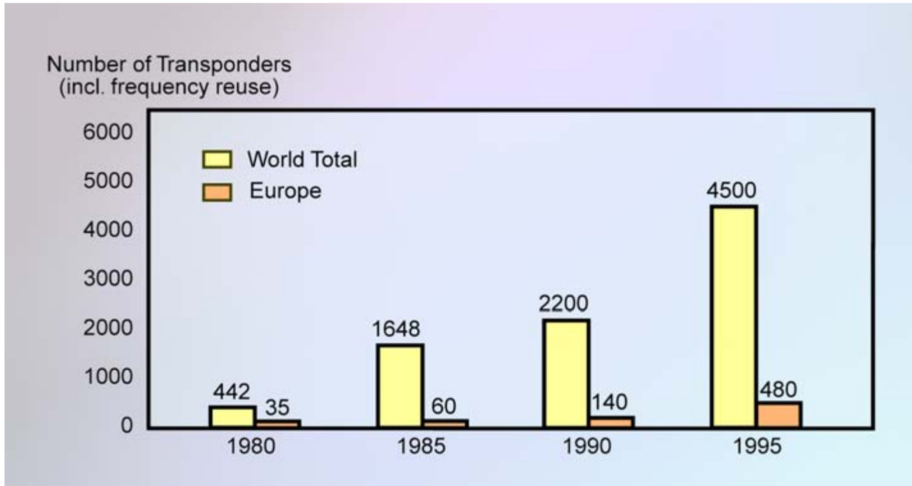
Action 5. Ensure that Europe has those space systems that are essential to meet its security and peacekeeping needs.

Information Services

Telecommunications is the largest and most rapidly expanding market for space products, be they in-orbit, ground hardware and software, or derived services. This rapid growth is providing substantial opportunities for service providers, operators and infrastructure suppliers in the more classical market areas of mobile communications and broadcasting, as well as in the new and fast-growing areas of information services such as interactive multimedia. The inherent commercial potential of the space-derived information technology is such that new products and services are being conceived, developed and marketed at an ever more rapid pace. Despite strong capabilities in these areas, it is difficult for European companies to remain competitive vis-à-vis American companies, who benefit from a much larger home market, a huge baseload of defence and other public investments, as well as a decisive influence in regulatory matters.

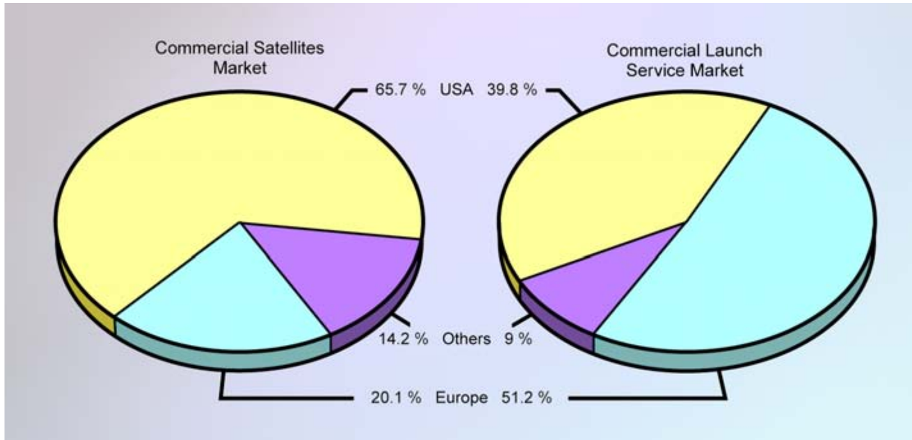


Growth in satellite telecommunications (Euroconsult)

If European industry is to succeed in this field, an improvement in regulatory mechanisms and the establishment of international standards are essential prerequisites. As individual nations will be unable to create an equitable regulatory environment, a European Union authority should be created to take responsibility for such regulatory aspects as frequency allocation and related matters **(see Action 6)**.

Action 6. Create a European body to negotiate orbits and frequencies for satellite communications services and strengthen Europe's negotiating power at international level.

The wave of mergers and acquisitions in the USA is creating overpowering conglomerates offering the complete range of products and services with an unprecedented competitive advantage. It is therefore essential that initiatives taken in response by European industry in the field of telecommunications and multimedia satellite systems be fully supported.



Satellite and launch-service market shares (Euroconsult)

European space industry is itself being transformed in response to the challenges of the new and fast-expanding markets. Besides a vigorous and healthy space industry, Europe also needs a strong institutional focus for public interests in space. Industry must further consolidate and change from a laboratory-type approach to a more production oriented approach. This is an area where the European Union has an important role to play, through its programmes and policies, in supporting the competitiveness of European industry. But industry also has a major responsibility which ESA should support: it is to ensure that today's space systems benefit from technological progress being made in other areas, and to exploit this synergy in order to achieve productivity gains, thereby improving the cost / efficiency ratios of space systems.

Finally, in all fields - whether science, launchers, information services, or other domains - the emergence of new ideas must be stimulated, particularly within small businesses, research laboratories and university groups **(see Action 7)**. Full advantage needs to be taken of commercial technologies, which are often as advanced and as reliable as space technologies. Developments in small satellite technology and micro-miniaturisation are beginning to provide quick, low-cost access to space for a range of research and business purposes, and Europe must not be absent from this important technological field **(see Action 8)**.

Action 7. Stimulate and encourage small businesses as a source of innovation in order to promote the potential multi-utilisation of technologies developed within space programmes.

Action 8. Improve the European micro-miniaturisation capability and promote its space application.

2. The Challenge of Planetary Management

The threat to Earth's ecosystem makes it vital that Europe be a leading force in the worldwide effort to ensure sustainability of our civilisation on the planet.

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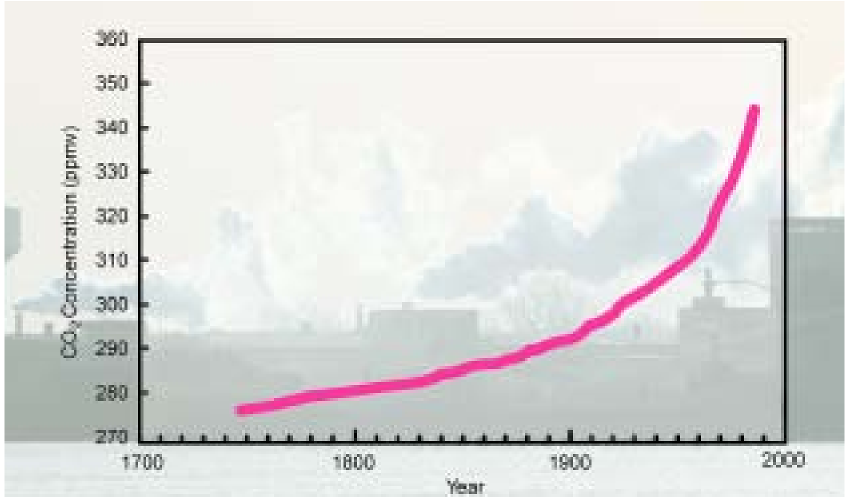
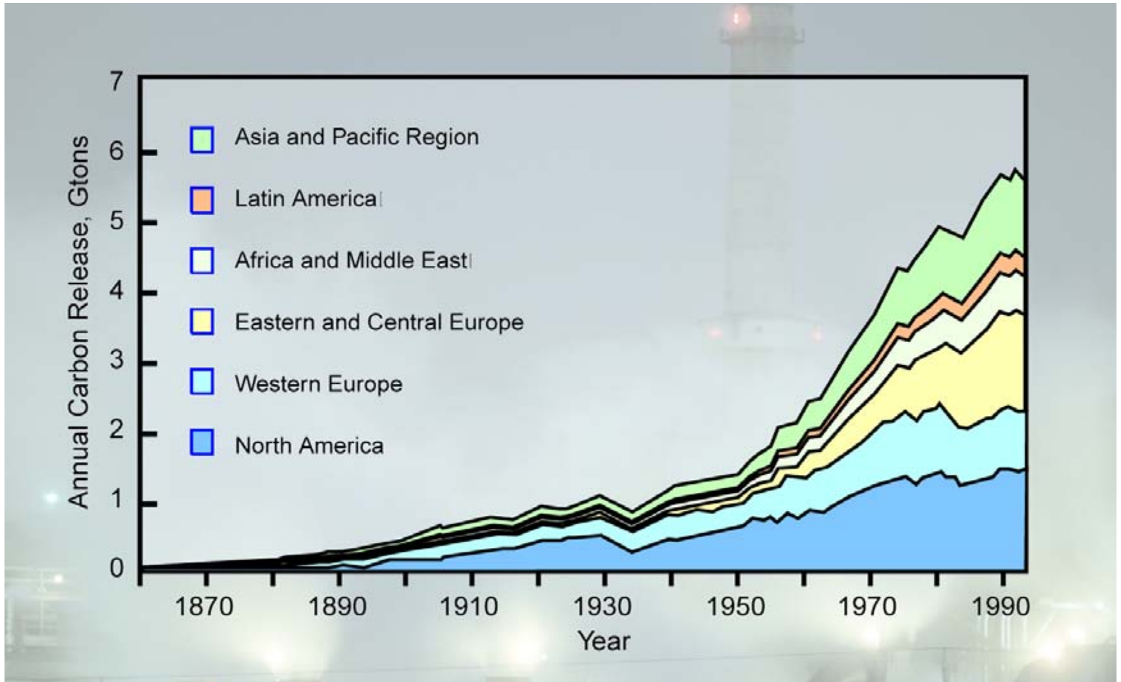
Europe's prime responsibility is to ensure a benign atmospheric and climatic environment for its people, and indeed humankind, as a basis for sustained economic, social and cultural advancement. Despite rapid progress, notably through space techniques, understanding of the complex machinery of the planet is far from satisfactory. The multiple interactions between its components, continents, oceans and atmosphere, and human activities, are not yet fully understood and modelled. There are multiple threats to the ecosystem's delicate balance: natural and man-made disasters, degradation of the environment, depletion of the ozone layer, climate change, solar flares and even cosmic collisions. The nature of most of these threats is such as to require global solutions.



Atmospheric CO_2 concentration over the last 250 years

Climate Change and Environmental Monitoring

Global warming, melting of the continental ice sheet, sea-level rises and desertification are causing alarming changes in living conditions, which may even endanger large populations. Failure to understand the causes of climate change, both natural and man-made, could have fatal consequences. Present analyses indicate that modifications to the current way of life are needed to avoid disastrous changes in the 21st Century. International regulations approved, trusted and adhered to by all nations are obviously needed, founded on a massive increase in our the understanding of solar-terrestrial relationships as well as of the natural processes controlling the functioning of planet Earth.



Global energy-related emissions of CO_2

Multi-scale monitoring of the environment is urgently required, using space-based, airborne and ground-based means. The role of space in planetary management will continue to grow, from data collection for modelling aimed at a better understanding, to global monitoring and fair observance of internationally agreed regulations **(see Action 9)**.

Action 9. Determine the potential contribution of space systems to the enforcement of international regulations on environment and climate, in particular the release of greenhouse gases.

The issue is all the more urgent as the time constants associated with the thermal inertia of the oceans and the decay of greenhouse gases in the atmosphere are so long that any countermeasure will only start to have an effect after a substantial number of years. Only from space can a transparent and coherent picture of environmental change be provided to convince nations and individuals of this urgency. Europe must continue to develop its own programme, coordinated internationally, to study climate change and its environmental impact. This should not be done in isolation, but exclusive reliance on data provided by others would lead to yet another form of apparently convenient but dangerous dependence. The main goal is to ensure that Governments take informed decisions based upon scientific fact. The costs of failure to act in time or of acting wrongly will far outweigh the necessary investments in the required global monitoring system.

Human fatalities due to major earthquakes this century

Year	Location	Magnitude	Fatalities
1906	Valparaiso	8.6	22 000
1908	Messina	7.5	83 000
1915	Avezzano	7.5	30 000
1920	Gansu	8.6	180 000
1923	Yokohama	8.3	143 000
1927	Nan Shan	8.3	200 000
1932	Gansu	7.6	70 000
1935	Quetta	7.5	60 000
1939	Chillan	8.3	28 000
1939	Erzincan	7.9	30 000
1970	Northern Peru	7.7	66 794
1976	Guatemala	7.5	22 778
1976	Tangshan	8.2	650 000
1978	Tabas	7.7	25 000
1988	Northwest Armenia	6.8	55 000
1990	Northern Iran	7.7	35 000

Natural Disasters

Pressure from continued population growth leads to the ever-increasing settlement of vulnerable areas. The human and economic impact of natural disasters on the planet has thus increased dramatically; in the last three decades, the costs associated with major natural disasters have risen by a factor of 5. This is partly due to current agricultural practices and growing urban pressure, but is also made worse by climatic phenomena such as El Niño.

Space data are already playing an essential role in disaster prevention, through their integration into Geographical Information Systems, which can thereby be frequently and inexpensively updated. They are also being used in combination with ground and airborne data to provide risk-vulnerability maps. Space-based communications are crucial during a natural disaster when the local ground infrastructure has been destroyed, and observation and navigation services are required for the optimal management of rescue activities. Space systems are not yet being used to their full potential for disaster management, as they are for rescue at sea for example.

Research into the provision of early warnings by detecting the precursors of natural disasters has progressed during the last decade. Some methods which rely on space data, such as radar interferometry, can detect the first minute displacements that precede a volcanic eruption, and tectonic shifts that may lead to earthquakes. Further development is needed to improve the reliability and sensitivity of these systems, as well as the analysis and prediction methods **(see Action 10)**. Combined with other detection methods, this could lead to the development of early-warning systems for a fraction of the costs incurred due to major disasters. This is yet another example of an increase in basic scientific knowledge leading to applications with enormous potential.

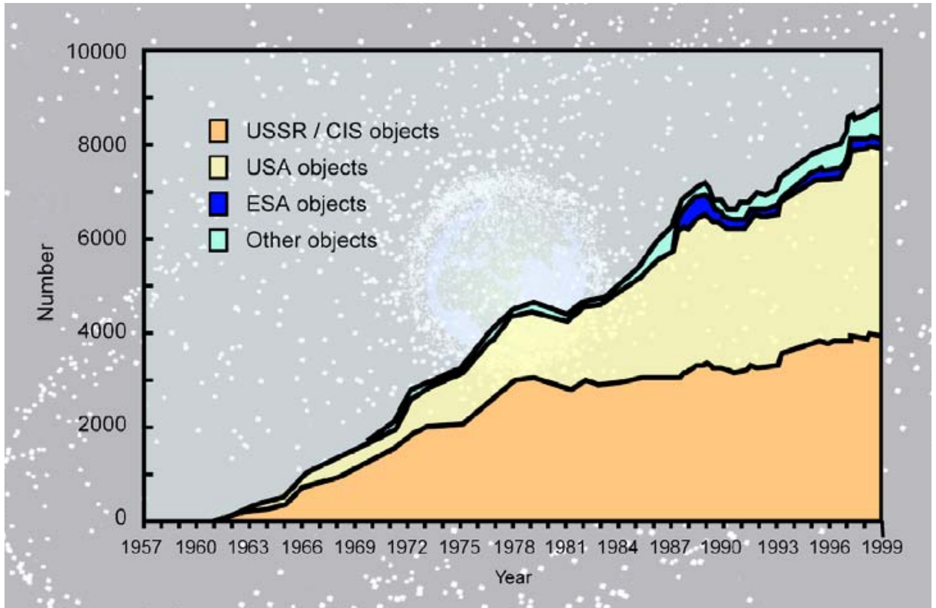
Action 10. Evaluate the feasibility of spaceborne early-warning systems, especially for earthquakes and volcanic eruptions.

Space Weather

Space weather is a recently coined term for a multitude of interactions between the Sun, the interplanetary environment and Earth. Solar eruptions damage space systems and endanger astronauts. Large solar eruptions also cause strong perturbations on Earth, in communications, radar operations and navigation systems, and have led to massive power failures as well as damage to pipelines at high latitudes. Basic scientific understanding of all of these space-weather factors affecting the planet must be consolidated, and operational space systems providing the necessary warnings established on an international basis **(see Action 11)**. Very little is known as yet about the terrestrial effects of long-term changes in solar activity. Studies of solar-terrestrial coupling mechanisms should therefore receive greater emphasis.

Action 11. Improve the understanding of space weather and the early warning of hazardous conditions.

Long-term growth of space activities cannot be envisaged if the debris problem is not tackled.



Catalogued debris objects in orbit, per end-1998 (Data ESOC)

Space Debris

The growth in space activities, coupled with the use of today's technologies based on disposable launchers, is resulting in a considerable amount of residual hardware in orbit. The problem is exacerbated by collisions between the debris items themselves. The long-term growth of space activities cannot be envisaged if the debris problem is not tackled. International regulations will have to be implemented, and Europe should be associated with their control. Techniques for destroying debris will also have to be assessed, as a key issue in the mid- and longer term **(see Action 12)**.

Action 12. Improve Europe's knowledge of space debris, its forecasting, modelling and removal.

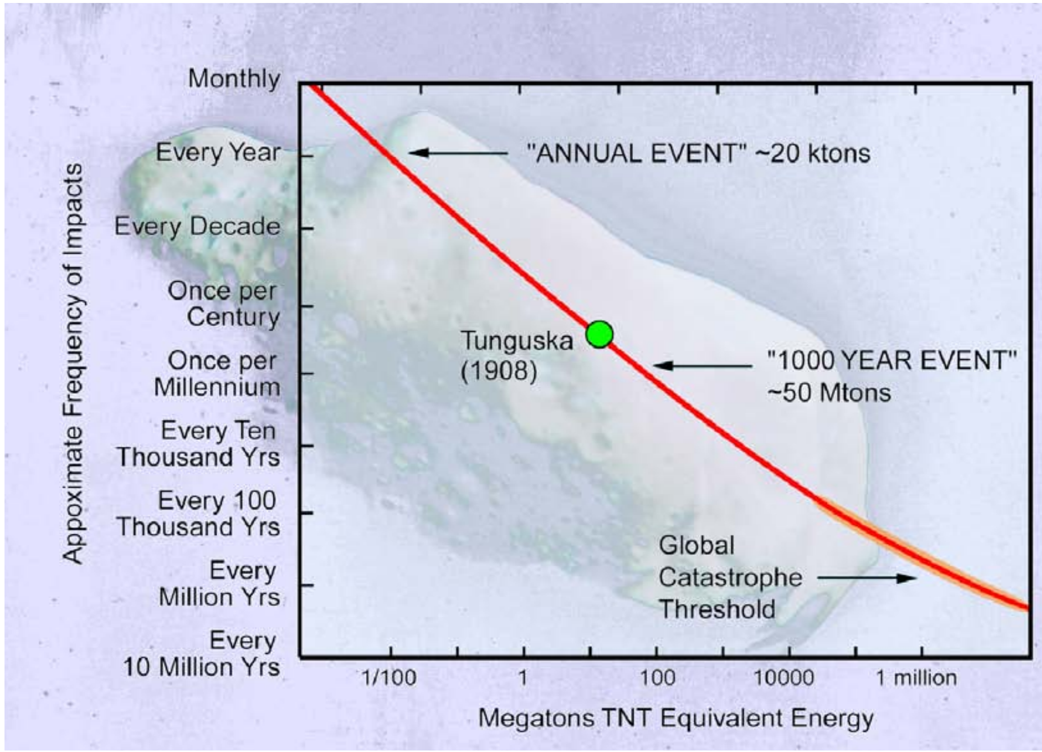
Avoidance of space debris should also become a major motivation for the development of fully reusable space transportation systems, in order to avoid leaving inert and potentially dangerous objects, such as upper stages, in orbit with each payload.

Impact of a Large Asteroid on Earth

The cosmic threat to life on Earth from asteroid collision is real and cannot be ignored.

Understanding the threat posed to Earth by incoming objects from space is of more than academic interest. Evolution has been periodically punctuated with massive extinctions due to the impacts of cosmic bodies comparable in size to Comet Shoemaker-Levy, which hit Jupiter in 1994. The Tungunska impact in 1908 could have destroyed any metropolis, and impacts of this kind statistically occur once every 100 to 300 years. This cosmic threat to life on Earth is real and cannot be ignored. Europe owes it to future generations to make an assessment of the specific risks and probabilities, as well as of potential countermeasures. As a pre-requisite, a detailed and regularly updated catalogue of objects that pose a threat must be compiled. Europe should also get actively involved in risk evaluation, detection and intervention, leading up to a public debate about a future response to this cosmic threat **(see Action 13)**.

Action 13. Assess the risk of collision with near-Earth objects and possible countermeasures.



Estimated intervals between asteroid collisions with Earth, and the related destruction potentials. The impact eliminating the dinosaurs occurred 65 million years ago. Impacts like the one in Tunguska are estimated to occur once every 300 years

3. The Challenge Beyond

The next millennium may show whether our technical and global civilisation becomes a stable form of human evolution, mastering the problems on its home planet and eventually spreading out into the Solar System.

Beyond the challenge of strategic autonomy and the contribution to the protection of humankind and its activities, the challenge is for our civilisation to find ingenious ways of using the resources of space and to expand further into the Solar System.

Besides the timeless thirst for exploration and discovery, the challenge is also to provide a growing World population with increased and justly distributed wealth and well-being, through a process of sustained development, to avoid ecological collapse, to secure an abundance of resources, and to foster democracy, peace and security.

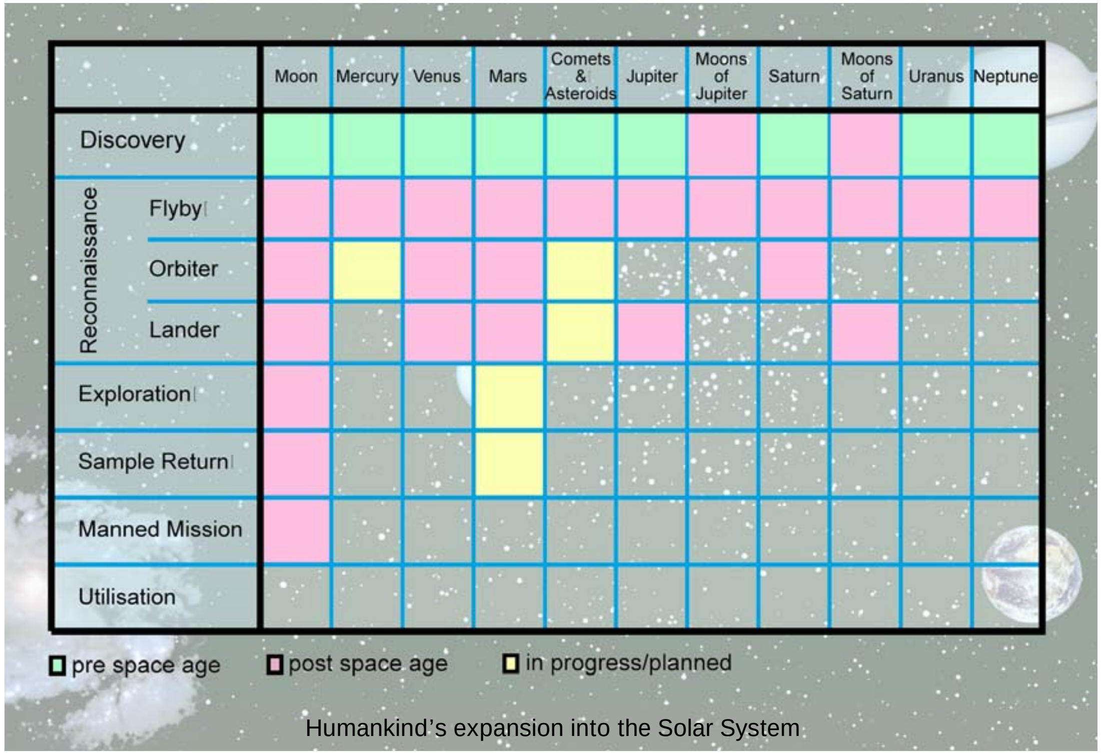
Over the last 10 000 years, numerous civilisations have come and gone on planet Earth. Ours is the first truly global one, multi-dimensionally intertwined, full of promise yet threatened in many ways. The next millennium may show whether this technical and global civilisation is also comparatively short-lived or becomes a stable form of human evolution, mastering the problems on its home planet and eventually spreading out into the Solar System. If we fail to meet this challenge, our technological civilisation may turn out to be the shortest lived of all of the great civilisations that have shaped human history.

Exploring the Solar System

The quest for knowledge and exploration of the unknown is a basic trait of human nature. By building on the lessons learnt and technologies developed in the context of the International Space Station, truly cooperative international programmes for exploration will continue. Likely targets for such programmes are the Moon and Mars, the moons of other planets, and near-

Earth asteroids. These fundamentally different future destinations deserve, even in the near-term, greater assessment of their value to science and their economic potential.

The first imperative for Europe is therefore to invest in forward-looking technologies. Space exploration programmes provide a powerful motivation as well as the right framework for such advanced technological developments **(see Action 14)**.



Humankind's expansion into the Solar System

Action 14. Establish a European robotic presence on the Moon, and prepare for a future extraterrestrial outpost.

The importance of a renewed Lunar Programme has already been analysed in detail: for science, for future applications as an inter-planetary staging base, as well as for energy production. This wealth of potential uses will make it increasingly difficult to regard the Moon as belonging to deep space. The Moon may well be Earth's biggest continent, torn from our planet in a cosmic collision more than 3.5 billion years ago. Yet even with classical propulsion it is only three travel days away, and its integration into Earth's economy, beyond its obvious role as a natural long-term station in space, is a real possibility with considerable social and political implications. Europe should therefore take the initiative in organising and coordinating an international worldwide effort to update the concept of a sustained Lunar Programme, integrating new scientific data, new technologies and new infrastructures **(see Action 15)**.

Action 15. Take the initiative and leadership in a worldwide effort for an updated international lunar programme.

A Mars Programme culminating with a human trip to the planet will renew public interest in space.

Mars is an entirely different target. It is not ‘part of Earth’, but another planet entirely, with a total surface larger than all of Earth’s continents, to be explored and perhaps eventually settled. Today’s space technology and infrastructure permit the systematic exploration of this planet at affordable cost. Europe, by initiating mission scenarios and technological developments, has to be part of this effort directed at this new world, whose gradual transformation into a habitable planet amenable to permanent human settlement is a breathtaking, but imaginable goal. A Mars Programme culminating with a human trip to the planet will renew public interest in space.

The moons of Saturn and Jupiter are faraway destinations that are completely different from the Moon and Mars. Titan, almost half the size of Earth, might be covered by oceans of organic molecules. Europa might be the only other body in the Solar System containing vast quantities of liquid water, whilst Io has the most violent volcanic activity known.

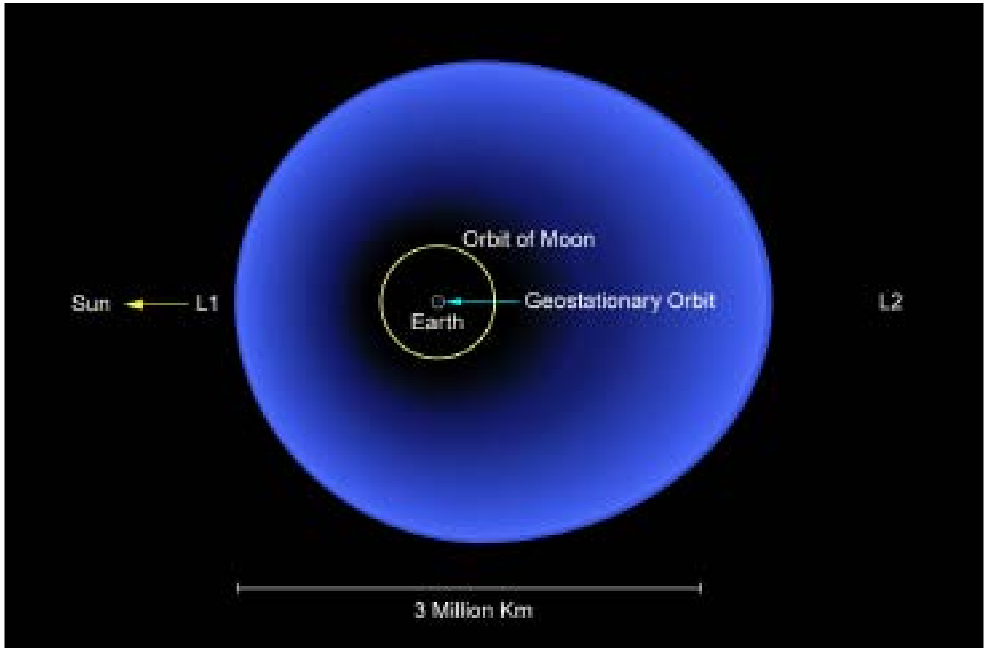
Exploiting the Solar System

Intelligent use of space resources might be the missing link between our basic drive for prosperity and wealth, and the imperative of protecting Earth from irreversible devastation.

The Club of Rome has warned of the threat of social and economic collapse as a consequence of overpopulation, excessive pollution and shortages of non-renewable resources. Even modest population growth rates over several decades rapidly overtax any system based on finite resources, and sustained growth will be required over at least the next hundred years to secure a decent standard of living for about 10 billion inhabitants of Earth. This probably means tapping resources outside our own planet’s limited ecosystem. Intelligent use of space resources might be the missing link between our basic drive for prosperity and wealth, and the imperative of protecting the crown jewel of the Solar System, Earth, with its splendid beauty and richness of life forms, from irreversible devastation.

Space resources that are already increasingly in demand today comprise vacuum, microgravity and orbital positions. In the 21st Century, space energy and materials, and possibly space tourism and climate control, will be of real interest for the Earth’s economy.

In this context, the classical notion of Earth's extent may have to be revised. Its true dimensions may be defined by the spherical volume about 3 million kilometres in diameter, within which Earth's gravity dominates over that of the Sun. This volume receives at least 30 000 times the amount of solar energy collectible on Earth and is wholly accessible from geostationary orbit with little additional energy. 'Greater Earth' - this volume within which objects remain permanently related to Earth - is therefore a domain that can serve the planet in producing energy, relaying signals and monitoring the environment.



The concept of "Greater Earth"

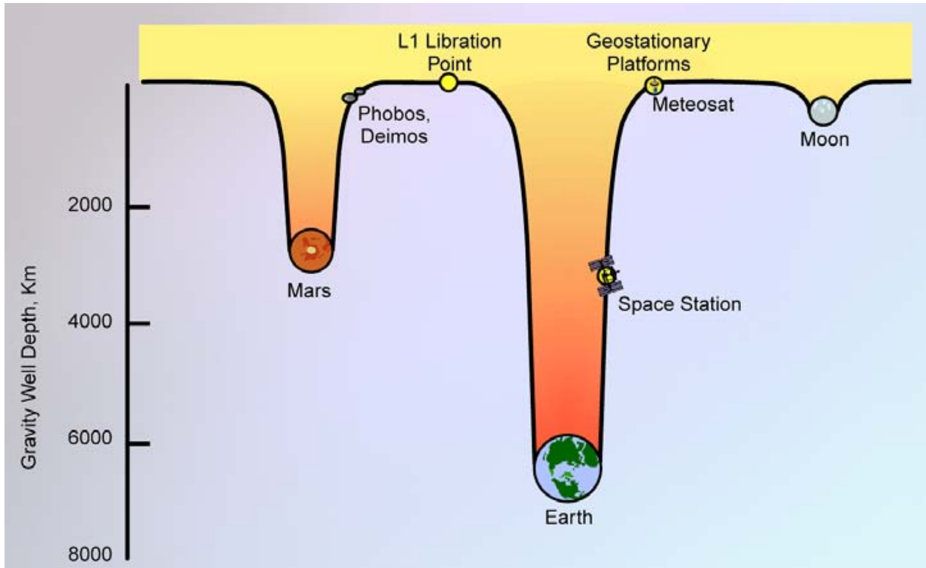
Exploration and scientific programmes will show what resources could be exploited in the Solar System. A first vital resource, abundant and freely available in space, is of course energy. As energy consumption on Earth rises, the increasing use of non-renewable fuels, with their associated pollution, must be reversed. The Sun is the prime non-polluting energy source, and assessments and demonstrations of collecting and converting this energy are therefore of growing interest. A thorough evaluation of the Earth's needs for energy and other resources in the 21st Century, and a realistic assessment of the planet's own reserves, might lead to space-based systems which would provide large amounts of clean and cheap energy. A fresh look should compare the different options and their economic viability: solar energy collected on Earth, in orbit, or on the Moon **(see Action 16)**. Demonstration projects for related technologies could be conducted as part of the exploration programmes.

The Sun is the prime non-polluting energy source.

Action 16. Assess the economic viability of collecting solar energy on Earth, in space and on the Moon, as well as of asteroid mining.

- A similar evaluation should be made for resources other than energy, together with an assessment of the long-term resource potential of the Moon and near-Earth asteroids. The first task is to establish the composition of these asteroids. It is much easier to rendezvous with and land on an asteroid than on the Moon because of the asteroid's very much weaker gravity. For the same reason, it is relatively easy to return to Earth from an asteroid. If resources from asteroids could be used in space, for instance liquid oxygen and hydrogen used as fuel, then a substantial reduction could be achieved in the cost of space transportation for future exploitation of the Solar System. Once the technology for such a space-based transportation infrastructure existed, a practically unlimited amount of physical resources, from volatiles to rare metals, would be within reach of a space-based economy.

If resources from asteroids could be used in space, a substantial reduction could be achieved in the cost of space transportation for future exploitation of the Solar System.



Well depths represent the escape energies needed

Space tourism may well develop in the 21st Century. It could start with virtual exploration based on data relayed from spacecraft, extend to sub-orbital flights allowing passengers to experience weightlessness, and ultimately expand to include longer stays in orbital hotels or on the Moon. The extent and speed of development of space tourism is intimately linked to the progress in space-transportation technology, just as tourism on Earth exploded with the development of jet aircraft. The reality of the potential market - millions of customers ready to pay tens of thousands of Euros for a trip into space - cannot be denied. Considering the growth of traditional tourism, from the first recorded flight in 1906 to an average of two million travellers in the air at any given moment in 1998, it would seem fair to postulate that by 2050 space tourism and sub-orbital travel will have become one of the largest and most rapidly expanding commercial applications of space.

By 2050 space tourism and sub-orbital travel will have become one of the largest and most rapidly expanding commercial applications of space.

Finally, space resources may, in the long-term, be used for the modification of local weather conditions or even the mitigation of climate change from space. Large reflecting structures in orbit might offset greenhouse effects, and there may be ways of restoring appropriate ozone concentrations in the stratosphere by space-based means. Furthermore, there is a considerable security interest, for example for improving local weather conditions to allow optical observation. The awareness of such applications should be increased and their feasibility and potential consequences assessed **(see Action 17)**.

Action 17. Increase European awareness of space-based weather-modification concepts in order to be prepared and able to avoid dangerous dependencies and consequences.

How Must Europe Invest in Space?

New ideas in terms of technologies and systems are vital to progress and success. Europe must bolster its innovative potential.

Europe is becoming increasingly aware of the necessity of using space for the benefit of its citizens and humankind. With its large economy and the necessary political will, it is able to take decisive action towards securing its cultural heritage and future prosperity.

Europe faces important and time-critical challenges relating to its independence, to the management of the Earth's ecosystem, and to the expansion of humankind beyond present boundaries. The Long-term Space Policy Committee is confident that Europe can have the vision and capability to find innovative solutions to these specific challenges, provided the political will exists. Modest funding is required, as well as investment in terms of ambition, talent and energy.

In addition to addressing these specific challenges, more general measures have to be taken to allow Europe to take its rightful place into the worldwide scientific and economic competition of tomorrow, and to reach out to the youth and to the general public.

Foster Innovation and Vision

Education is a key to tomorrow's successes in the space field, as well as in many other areas.

New ideas in terms of technologies and systems are vital to progress and success. Europe must bolster its innovative potential. Innovation is bred by the courage to look beyond today's agenda and to lead and succeed in uncharted territory. Vision is a prerequisite to give meaningful direction to all efforts in science, infrastructure, technology and industry. Only foresight will provide valid long-term solutions to the major issues that lie ahead. This requires educated leaders, as well as a constant supply of skilled young scientists and engineers. Education is a key to tomorrow's successes in the space field, as well as in many other areas **(see Action 18)**.

Action 18. Contribute to the creation of a European focus for space education.

Involve the General Public

The public also needs to be more aware of the huge potential of space and of what is being done on its behalf in this field, and to be fully engaged in the discussion to decide on priorities. This requires a specific effort from major space players, in particular the European Space Agency, aimed at wider and more efficient communication of the benefits of space **(see Action 19)**.

Action 19. Increase the public's awareness of Europe's space institutions, policies and programmes.

Think European!

Finally, Europe as a whole must agree on its role in space and define its specific needs and long-term objectives. Its ideas and reflections on space policy should be fostered in a European Space Policy Institute, and a long-term vision of Europe's role and place in space developed **(see Action 20)**.

Action 20. Create a focal point for the analysis of European needs, capabilities and long-term prospects in space.

Twenty Actions for Year 2001

The following Action Plan proposes twenty initiatives aimed at providing a first response to the Three Challenges, elaborated in this Report, that Europe will have to face in the 21st Century. These Twenty Actions are modest first steps, which can be implemented immediately, directed towards a more space-minded Europe, proud of its past achievements and confident in its future. They will send a clear signal that Europe is on the move, they will stimulate interest, and attract new talents. Each Action is a building block in a strategically important field and their cost is so affordable that inaction cannot be justified on financial grounds. It is up to decision-makers to decide whether they want to be among those who helped open new and promising areas of space applications worthy of Europe's destiny.

The Committee is pleased to recognise that in a number of areas, major new initiatives are already starting - in navigation, Space Station utilisation, education and public awareness - and stresses the need to bring them to fruition, as the proposed actions do not in any way replace, but complement, these initiatives. The Committee also emphasises that many of these new initiatives rely on solid programmes in basic science. Both the consolidation of traditional fields and support to the new ones are required to provide Europe with a leading position in the face of fierce international competition.

Finally, the Committee requests that ESA organise an assessment Conference in 2001, to analyse the results of the implementation of the 'first steps' as well as general progress on the Action Plan. The Committee therefore recommends that the Executive prepare an Implementation Plan enabling these first steps to start quickly and efficiently, and report regularly on their progress.

Annex: Action Plan

The Challenge of Independence

1. Search for Earth-like Planets
2. Cheaper Access to Space
3. Innovative Space Station Utilisation
4. Future Navigation Services
5. European Space Systems for Security and Peacekeeping
6. Creation of a European Telecommunications Regulatory Body
7. Small Business Innovation Initiative
8. Micro-miniaturisation Technology Initiative

The Challenge of Planetary Management

9. Space Monitoring of Compliance with Environmental Regulations
10. Disaster Warning from Space
11. Space Weather
12. Space Debris
13. Threat of Cosmic Collision

The Challenge Beyond

14. Telepresence Demonstration Project
15. European Lunar Initiative
16. Space Energy and Resources
17. Weather Modification from Space

Reaching Out

18. European Space Education Programme
19. Public-Awareness Initiative
20. European Space Policy Institute

ACTION 1
Search for Earth-like Planets

Purpose:

Involve Europe in the search for Earth-like planets and the detection of extraterrestrial life forms.

Enormous progress has been made in assessing the fundamental question of whether Earth and life are exceptions in an otherwise lifeless Universe. The existence of star-orbiting planets has been demonstrated and the basic ingredients of life – water and organic molecules – are almost ubiquitous in the Universe. Present observation techniques do not yet permit the detection of Earth-sized or Earth-like planets, but there is growing evidence that basic conditions for the evolution of life elsewhere are fulfilled much more frequently than previously assumed. This area of scientific research has enormous public appeal and far-reaching implications for everyone. Europe must take part in this fundamentally interdisciplinary endeavour by contributing innovative concepts and appropriate scientific tools.

Strategy:

1. Assessment of current knowledge about Earth-like planets and the probability of extraterrestrial life.

2. Identification of areas for innovative European contributions, with a particular emphasis on synergies between different disciplines.

3. Study of a European or European-led space mission, with breakthrough potential, to substantially advance basic knowledge, including the search for the origin of life.

First Step:

ESA to convene an interdisciplinary Symposium on the subject and on state-of-the-art detection techniques.
Funding needed: 0.2 ME.

ACTION 2
Cheaper Access to Space

Purpose:

Put Europe among the winners in the competition to achieve substantial launch-cost reduction.

This action is complementary to ESA's proposed Future Launcher Technology Programme (FLTP), aiming at strengthening European competitiveness and massive cost reductions for large payloads. This action is focussed on low- to medium-mass payloads, particularly for the constellation market, and is based upon using proven technologies in new and innovative ways. The emphasis is on minimising both cost and time to first launch.

Strategy:

1. **Detailed study of current American, Russian and Ukrainian plans for achieving drastic cost reductions for launching 1 tonne-class payloads to Low Earth Orbit (LEO).**

2. **Identification of the most promising fully and partly reusable launcher technologies.**

3. **Detailed study of an air-launch system, in which the first stage is aircraft-based, the third stage is expendable, and the second stage is reusable, demonstrating technologies and operations applicable to future reusable launch systems for large payloads.**

First Step:

Take an initiative towards a joint venture with international partners for an air-launch space-transportation system.
Funding needed: 2 ME.

ACTION 3
Innovative Space Station Utilisation

Purpose:

Ensure that Europe participates fully in the utilisation of the International Space Station.

Europe is taking part in the International Space Station, but this project will only succeed fully if an adequate level of utilisation is assured. This utilisation should not be limited to microgravity research, but should also include technology development, disciplines benefiting from the remote sensing of terrestrial and celestial targets, and the preparation of long-duration manned space flights.

Strategy:

1. **Identification of the technologies needed for future large-scale space applications, such as energy transfer in space, and for long-duration space flights to the Moon or Mars, which could be tested and qualified on the Space Station.**

2. **Promotion of the utilisation of the Space Station by other scientific disciplines, such as physics.**

3. **Use of the Space Station for other operations, such as the assembly of large structures in space, the servicing of free-flyers, and as a launching base for missions beyond Low Earth Orbit (LEO).**

First Step:

Hold a Workshop on 'Unusual Potential Uses of the International Space Station'.
Organise a contest on innovative uses of the Space Station, with the results to be presented at the Workshop.
Funding needed: 0.2 ME.

ACTION 4
Future Navigation Services

Purpose:

Secure Europe's position in the field of satellite navigation and prepare for future space navigation services, thereby strengthening Europe's position when negotiating with potential partners for the development of an international system, and its technology and system-engineering capability for an autonomous system.

Strategy:

1. **Endorsement of the decisions taken on GNSS-2 and rapid implementation of EGNOS (European Geostationary Navigation Overlay Service) as the first step towards an autonomous European development.**

2. **Support to the rapid setting-up of a European Navigation Satellite Organisation.**

3. **Identification of novel future space-navigation applications with large commercial potential.**

First Step:

Based on a Call for Ideas, initiate novel space-navigation applications via a partnership between the European Union and ESA, and possibly national agencies and industry.
Funding needed: 5 ME.

ACTION 5
European Space Systems for Security and Peacekeeping

Purpose:

Ensure that Europe has those space systems that are essential to meet its security and peacekeeping needs.

Space defence applications and technologies are not yet intensively developed in Europe. Europe's need for these systems is, however, of such growing importance, both for its own future defence and to be able to make an effective contribution to worldwide peacekeeping, that the reticence of many European nations to address this issue must be overcome.

Strategy:

1. **Catalogue European technologies suitable for dual use, and identify missing technologies that still need to be developed.**

2. **Promotion of security applications of future European observation and telecommunications systems.**

3. **Benefit from technological progress achieved in ESA programmes, in particular miniaturisation, for the development of dual-use constellations.**

First Step:

Identify and organise the proper interfaces between ESAand security-related bodies. In particular, ESA should make contact with the Western European Union and the OCCAR (European organisation for the procurement of armaments), and jointly define and fund technological developments for security applications as part of ESA's Technology Programme.
Funding needed: 5 ME.

ACTION 6
Creation of a European Telecommunications Regulatory Body

Purpose:

Create a European body that can negotiate the allocation of orbits and frequencies for satellite communications, licence satellite services and strengthen Europe's negotiating power at international level.

European regulatory authorities operate at national level and thus have an inferior negotiating position vis-à-vis the USA, whose FCC dominates the international allocation process. Pressure from ESA and its Member States should be exercised towards the European Union and national authorities to correct this situation. Immediate action is required in order to put arrangements in place before the target date of 2005.

Strategy:

1. **Drafting of a position paper on the importance and urgency of the problem.**

2. **Setting up of a permanent conference for European regulatory agencies.**

3. **Implementation of the necessary delegation.**

First Step:

Initiate negotiations between the European Commission and national regulatory authorities for the implementation of such delegation, by proposing and preparing a first Conference on European regulatory matters.
Funding needed: 0.2 ME.

ACTION 7
Small Business Innovation Initiative

Purpose:

Stimulate and encourage small businesses as a source of innovation for technologies, architectures, equipment, processes and services, in order to promote the potential multi-utilisation of technologies developed within space programmes.

Strategy:

Initiate at European level a system to encourage innovation via:

1. Regular issuing of requests for proposals on innovative-type subjects.
2. Establishment of an Evaluation Board to select the best proposals, for an initial funding of 60 kEuro.
3. Selection of the most promising ideas, for further funding to a maximum of 600 kEuro for 18 months, to demonstrate their feasibility and to establish an implementation plan.

First Step:

Implement this initiative in Europe together with the European Commission, industry and national agencies.
Organise Workshops and Seminars to encourage innovative ideas.
Funding needed: 15 ME per year, shared among the various players, with an ESA contribution of 3-5 ME per year.

ACTION 8
Micro-miniaturisation Technology Initiative

Purpose:

Improve the European micro-miniaturisation capability and promote its space application.

Micro-miniaturisation has huge application potential, as demonstrated by the current Information Society infrastructure, with powerful, portable but cheap personal products. Nano-satellites, with masses of just a few kilograms, are nearing production and are expected to grow in importance in the longer term. In the shorter term, micro-technologies are facilitating small scientific satellites with interesting applications for human exploration missions.

Strategy:

1. Identification of innovative micro-technology areas that can provide greater redundancy as well as increased performance, and study of missions that can profit from such technologies.

2. Evaluation of existing and required technological developments.

3. Initiation of relevant developments in close co-ordination with universities and industry.

First Step:

Assessment studies and a two-year demonstration programme, including technological pre-developments.
Funding needed: 7 ME.

ACTION 9
Space Monitoring of Compliance with Environmental Regulations

Purpose:

Determine the potential contribution of space systems to the enforcement of international regulations on environment and climate, in particular the release of greenhouse gases.

Definition of regulations for environment and climate monitoring is not yet sufficiently advanced. Once defined, these regulations must be monitored in a way that is both transparent and global, and agreed to by all participants. Only space means can provide such transparency and global coverage.

Strategy:

1. **Establishment of the feasibility of detection from space and the specifications for spaceborne sensors able to provide the necessary detection capability.**

2. **Study of the relationship between the distribution of greenhouse gases in the Earth's atmosphere and their origin, including their transport and loss mechanisms.**

3. **Definition of the architecture for a global system, including possibly ground-based, air-based and space-based elements, capable of performing adequate monitoring of compliance with international regulations.**

First Step:

ESA to initiate a two-year feasibility study involving the European Commission, the European Environment Agency, national agencies, the scientific community and industry.
Funding needed: 2 ME.

ACTION 10
Disaster Warning from Space

Purpose:

Evaluate the feasibility of spaceborne early-warning systems, especially for earthquakes and volcanic eruptions.

Earthquakes are among the most damaging natural events in terms of human devastation. An early-warning system would require the regular monitoring and detection of anomalies in geophysical parameters. Ground-based observation networks are only available in a few places, because their installation and maintenance is very costly, especially in remote environments. Many parameters may be obtained directly from space observation, such as ground motion, gas emission, thermal anomalies, gravity anomalies and electromagnetic signals. Early warning capabilities would benefit from space-based data-collection systems with their wide geographical coverage.

Strategy:

1. **Evaluation of the feasibility of space-based early-warning systems, particularly for volcanic eruptions and earthquakes.**

2. **Assessment of the technologies – existing or yet to be developed – required for such forecasting and early warning by space means.**

3. **Definition of the specifications for a dedicated disaster-warning mission and performance of a preliminary mission-definition phase.**

First Step:

Two-year feasibility study and preliminary definition of a disaster-warning mission.
Funding needed: 2 ME.

ACTION 11
Space Weather

Purpose:

Improve the understanding of space weather and the early warning of hazardous conditions.

'Space weather' refers to conditions on the Sun and in the solar wind, magnetosphere, ionosphere, and thermosphere that influence the performance and reliability of space-borne and ground-based technological systems, and can endanger human health or even life. Their ultimate effects include electronics upsets, immediate and long-term hazards to astronauts and air crews, radiation damage, electrostatic charges/discharges, and disruptions to communications, GPS and terrestrial power systems. A Space Weather Programme would lead both to an understanding of the physical processes involved and to an ability to predict and assess hazardous conditions.

Strategy:

1. **Assessment of the threat posed and damage caused by space-weather events in daily life.**

2. **Development and flight of co-ordinated instrumentation, and establishment of large databases on environmental variations over space and time using advanced modelling and simulation methods.**

3. **Evaluation of improvements in warning and protection, and elaboration of a proposal for an operational European Space Weather Service, as part of a worldwide Space Weather effort, but with an independent warning capability.**

First Step:

ESA to initiate a two-year effort involving national agencies and the scientific community, to prepare a programme proposal contributing to a potential worldwide Space Weather Watch effort.
Funding needed: 2 ME.

ACTION 12
Space Debris

Purpose:

Improve Europe's knowledge of space debris, its forecasting, modelling and removal.

The growth in space activities, with current technologies and aggravated by the use of disposable launchers, leads to a considerable amount of debris in orbit. The problem is made worse by collisions between the debris items themselves, and it represents a severe threat to the long-term growth of space activities. Most of the information on space debris is currently obtained from the US Space Surveillance Network. Its as yet incomplete catalogue comprises about 10 000 objects larger than 10 cm in orbit around the Earth, each with catastrophic destruction potential.

Strategy:

1. **Definition of the most suitable tools for providing Europe with an independent capability for the description, tracking and forecasting of space debris.**

2. **Review debris control, avoidance and destruction technologies.**

3. **Define a policy, including a suitable regulatory approach and long-term strategy, for Europe's role in a global effort for the preservation of the near-Earth environment.**

First Step:

ESA to initiate a two-year effort involving national agencies, the scientific community and university research groups.
Funding needed: 2 ME.

ACTION 13
Threat of Cosmic Collision

Purpose:

Assess the risk of collision with near-Earth objects and possible countermeasures.

There is a risk of collision between the Earth and asteroids or comets in near-Earth orbits. Collision with bodies 1 km in size or larger could have global catastrophic consequences. Smaller bodies could produce local or regional devastation. There are estimated to be about 2000 objects larger than 1 km, of which only about 12% are known today. Appropriate avoiding actions and countermeasures have yet to be devised.

Strategy:

1. **Characterisation of the population of near-Earth objects within the next 15 to 20 years, with the objective of a 90%-complete catalogue for objects larger than 100 m. Innovative approaches to systematic detection should be sought.**

2. **Risk assessment: analysis of atmospheric, oceanic and solid-Earth effects, depending on the composition of the objects.**

3. **Analysis and definition of mitigation and countermeasure actions such as deflection techniques.**

First Step:

ESA, together with the Spaceguard Foundation, to define a European observation programme for near-Earth objects. An annual contest for European astronomers for the detection of the largest and nearest object should be envisaged. ESA should also establish contact with international partners in order to coordinate efforts.
Funding needed: 2 ME.

ACTION 14
Telepresence Demonstration Project

Purpose:

Establish a European robotic presence on the Moon, and prepare for a future extraterrestrial outpost.

Much of the detailed exploration of the Moon and Mars can be done by robots, thereby reducing that to be done by humans. In addition, most of the Solar System is so inhospitable to man that its exploration can only be undertaken by robots. It is therefore important that Europe improve its robotics capability in preparation for future exploration missions.

Strategy:

1. Development of human-like exploratory capabilities for tele-operated robotics based on micro-miniaturisation, as key technologies for a very broad range of applications.

2. Demonstration of the application of these technologies on the Moon for exploration, construction and maintenance of facilities like telescopes and even manufacturing.

3. Establishment of a permanent presence on the Moon, in preparation for a future industrialisation phase.

First Step:

Establish an initial two-year technology programme for robotics and micro-miniaturisation, and define a demonstration programme, possibly via a European contest.
Funding needed: 5 ME.

ACTION 15
European Lunar Initiative

Purpose:

Take the initiative and leadership in a worldwide effort for an updated international lunar programme.

ESA has already defined a global programme aiming at exploration and utilisation of the Moon. This work culminated in the Beatenberg Symposium in 1994, where Europe proposed a stepped, four-phase programme leading to the establishment of a first outpost on the Moon. Since then, considerable progress has been made in lunar scientific knowledge, thanks to orbiting missions, as well as in the infrastructure and technologies required. This programme needs updating and Europe should take the initiative in a worldwide effort involving all space powers.

Strategy:

1. **Updating of the main characteristics of the programme in terms of phases, scientific goals, applications, human involvement, cost, and international work-sharing.**

2. **Definition of a mission rationale and an implementation plan for the end of 2001.**

3. **Initiation of negotiations with the international partners, in order to start the first phase of the programme.**

First Step:

Perform the necessary preparatory work within ESA leading to an International Workshop in 2000.
Funding needed: 0.2 ME.

ACTION 16
Space Energy and Resources

Purpose:

Assess the economic viability of collecting solar energy on Earth, in space and on the Moon, as well as of asteroid mining.

For the time being, terrestrial resources, especially energy, are available at lower cost than any space solution can offer. The balance might change as launch costs fall and Earth's resources become depleted. Space Solar Power (SSP) has the potential to provide an ecologically acceptable response to climate change, by greatly reducing reliance on fossil fuels and thereby reducing the pace of greenhouse-effect buildup. Another space resource with potentially enormous revenues is the exploitation and mining of near-Earth objects, for precious metals and semi-conductor materials, and materials for construction and propulsion in near-Earth space.

Strategy:

1. **Assessment study of SSP technology development and market perspectives in Europe, and comparison with terrestrial solutions.**
2. **Assessment study of the exploitation of the resources of near-Earth objects, including their benefit in the context of SSP in-orbit infrastructure build-up.**
3. **Study (at Phase-A/B level) of an SSP technology-demonstration mission.**

First Step:

Detailed assessment study of energy and resources from space.
Funding needed: 2 ME.

ACTION 17
Weather Modification from Space

Purpose:

Increase European awareness of space-based weather-modification concepts in order to be prepared and able to avoid dangerous dependencies and consequences.

It is conceivable that the weather can be influenced by space means. Options for geo-engineering from space mainly concern major environmental problem areas, i.e. severe weather, climate change, and stratospheric ozone depletion. Weather control from space also has considerable security implications.

Strategy:

1. **Study of options and potential for artificial manipulation of the weather by use of future space technology, and improvement of the understanding of weather and climate dynamics, in order to determine the effectiveness and potential risks of geo-engineering intervention.**

2. **Assessment of scientific, political, legal and financial problems associated with potential options for geo-engineering from space.**

3. **Proposal of a plan for further action in both scientific and technological R&D.**

First Step:

ESA to convene an International Workshop on space-based weather control.
Funding needed: 0.2 M! .

ACTION 18
European Space Education Programme

Purpose:

Contribute to the creation of the talented work force needed for the 21st Century by providing a European focus for education on space matters, and stimulating interest in science and technology.

There is a pressing need to increase the outreach of space to youth, and to motivate further learning in science and technology. Education must be improved in these fields and space provides a high-profile focus and is one of the few areas able to capture young people's imagination. Stimulating and sustaining such interest is vitally important, and utilising space to advance Europe's education in these important areas will bring wide and lasting benefits.

Strategy:

1. Consultation with educators to establish requirements for all age groups.

2. Production of innovative packages, events and competitions which can be readily accessed via the Internet and used and participated in by both educators and students.

3. Provision of on-line, real-time access to special space events, together with complementary packages for further study.

First Step:

Setting up a European Space Education Programme within ESA.
Funding needed: 5 ME.

ACTION 19
Public-Awareness Initiative

Purpose:

Increase the public's knowledge of Europe's space institutions, policies and programmes, as well as awareness in the political world of space activities.

Public awareness is in flagrant disproportion to the real potential of space. The current situation in Europe is particularly dramatic, with only a small minority of Europeans knowing about ESA and its activities. Ariane is the only European space programme that is relatively widely known. At Charles de Gaulle airport in Paris, nine out of ten taxi drivers know UNESCO, while only one in ten has heard of ESA.

Strategy:

1. Overhaul of ESA's public-relations activities, with classical public relations to be integrated into a much broader approach. Outreach to the public must be built into every programme.

2. Definition of a common European approach to the massive enhancement of the public's space awareness.

3. Integration of space awareness into European media networks.

First Step:

Elaboration of a public-awareness initiative concept and first moves towards reform of ESA's PR activities. Choice of one ESA mission (science or application) as a public-involvement prototype, via publicly funded experiment(s), or an open channel to the mission as well as other activities inducing public participation.
Funding needed: 0.5 M€.

ACTION 20
European Space Policy Institute

Purpose:

Create a European focal point for the analysis and academic discussion of European needs, capabilities and long-term prospects in space.

Strategy:

1. Support and stimulation of academic and research work on space economics, law, history, long-term scenarios regarding the value of space for energy, exploration, management of our planet, communication, security, peacekeeping, geo-politics, etc.

2. Stimulation of the emergence of a common vision for the long-term future of space in Europe.

3. Promotion of innovative ideas and reflections to support and stimulate European Space Policy decisions.

First Step:

Set up a small expert group to present a detailed project within 6 months. A Foundation could be set up as a legal basis for the Institute.
Funding needed: 6-8 ME per year, shared between ESA, the European Commission, national agencies and industry.

See.......

Regardez.......

Sehen Sie.......

.......what a united Europe can achieve in space!

.......ce qu'une Europe unie peut accomplir dans l'espace!

.......was ein einiges Europa im Weltraum leistert!

1

The world's most modern launcher: The Ariane-5 launch of October 1998, together with the successful recovery of the ARD capsule, was a complete success, paving the way for the start of commercial operations by Arianespace. Ariane-4 has secured more than half of the world's commercial launch market. Ariane-5, which can deliver about 6 tonnes into geostationary transfer orbit, should further Europe's lead well into the next century.

Le lanceur le plus moderne du monde: Le lancement d'Ariane-5 en octobre 1998, ainsi que la récupération de la capsule ARD, ont été une réussite totale, qui augure bien du démarrage des vols commerciaux dont Arianespace aura la responsabilité. Le lanceur Ariane-4 s'est assuré plus de la moitié du marché mondial des lancements commerciaux. Grâce à Ariane-5, qui peut placer environ 6 tonnes en orbite de transfert géostationnaire, l'Europe devrait renforcer son avantage au cours du siècle prochain.

(ESA/CNES/CSG)

Die modernste Trägerrakete der Welt: Der Start der Ariane-5 im Oktober 1998 und die anschließende Bergung der ARD-Kapsel waren ein voller Erfolg, der den Weg für den kommerziellen Einsatz des neuen Trägers durch die Gesellschaft Arianespace freigab. Die Vorgängerin Ariane-4 hat über die Hälfte des Weltmarktes für kommerzielle Startdienste erobert. Ariane-5 kann rund 6 t Nutzlast in die Übergangsbahn zum geostationären Orbit befördern und dürfte die führende Stellung Europas bis weit ins nächste Jahrhundert hinein aufrechterhalten.

2

Watching starbirths: Thanks to the Hubble Space Telescope, we can observe the birth of stars in real time. This picture shows columns of cool interstellar hydrogen and dust in the Eagle Nebula, 7000 light-years from Earth, which act as incubators for new stars. Embryonic stars inside the dense clouds are feeding on their surroundings, which are slowly being blown away by hot, new stars off the edge of the image. The image was recorded on 1 April 1995.

Naissances d'étoiles en direct: Grâce au Télescope spatial Hubble, nous pouvons observer en temps réel la formation des étoiles. Cette photo montre des colonnes d'hydrogène interstellaire à faible température et de poussière dans la Nébuleuse de l'Aigle, à 7000 années-lumière de la Terre, qui sont de véritables incubateurs d'étoiles. A l'intérieur de ces nuages denses, des embryons d'étoiles absorbent la matière environnante, et on peut voir au bord de l'image des étoiles nouvellement créées, à une température élevée.

Blick in den kosmischen Kreißsaal : Mit dem Hubble-Weltraumteleskop können wir die Geburt von Sternen in Echtzeit verfolgen. Diese Aufnahme zeigt Säulen aus kühlem interstellarem Wasserstoff und Staub in dem 7000 Lichtjahre von der Erde entfernten Adler-Nebel, die Brutstätten für neue Sterne sind. Die embryonischen Sterne innerhalb der dichten Wolken nähren sich von den umgebenden Materiehaufen, die durch heiße neue Sterne außerhalb des Bildes langsam fortgeblasen werden. Das Bild wurde am 1. April 1995 aufgezeichnet.

(Arizona State University/NASA)

3
A worldwide meteo system: Meteorological pictures have become part of our daily life. This picture

has been formed by combining images from Europe's Meteosat-3 and -4 weather satellites on 16 May 1993. At the time, Meteosat-4 was hovering over Europe's prime observing longitude of 0°, whilst Meteosat-3 was at 50°W, on loan to the US weather service. ESA developed the Meteosat series of satellites, which are now an integral and indispensable part of the world's network of weather satellites.

(ESA/Eumetsat)

Un système météorologique mondial: Les images de satellites météo font partie intégrante de notre vie quotidienne. Cette image a été réalisée en combinant des photos prises le 16 mai 1993 par les satellites météorologiques européens Météosat-3 et -4. A cette époque, Météosat-4 était situé à la verticale de l'Europe, à la longitude 0 degré, tandis que Météosat-3, alors prêté au service météorologique américain, était à 50 degrés de longitude ouest. L'ESA a développé la série des satellites Météosat, qui sont devenus des éléments indispensables du réseau mondial de satellites météorologiques.

Weltweite Wetterwacht: Wetterbilder sind Bestandteil unseres Alltags geworden. Dieses Bild entstand durch Überlagerung von Aufnahmen der europäischen Wettersatelliten Meteosat-3 und Meteosat-4 vom 16. Mai 1993. Damals befand sich Meteosat-4 auf der normalen Position der europäischen Wettersatelliten über dem Nullmeridian, während Meteosat-3 für den amerikanischen Wetterdienst bei 50°W positioniert war. Die ESA hat die Wettersatelliten der Meteosat-Baureihe entwickelt, die nun integraler und unentbehrlicher Bestandteil des weltweiten Wettersatellitennetzes sind.

4
Europe's research laboratory in orbit: With dimensions of 75 m x 110 m - larger than a football pitch - and a total mass of more than 400 tonnes, the International Space Station will be the largest space complex ever built. Its assembly began in November 1998 and should be completed in 2004, when it will be permanently inhabited by 6 or 7 astronauts. ESA's Columbus Laboratory (inset, top right; bottom centre in main picture) will be one of the principal units of the Station. In this pressurised general-purpose laboratory, astronauts will be able to work in a comfortable shirt-sleeve environment, performing experiments in life sciences, materials processes, technology development, fundamental physics and other disciplines.

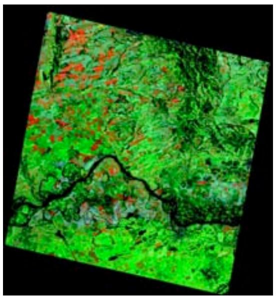
(ESA/D. Ducros)

Le laboratoire spatial de l'Europe: La Station spatiale internationale, qui mesurera 110 m par 75 m - soit plus qu'un terrain de football - pèsera plus de 400 tonnes, sera le plus grand complexe spatial jamais construit. Son assemblage a commencé en novembre 1998 et devrait être achevé en 2004; la Station sera alors habitée en permanence par 6 à 7 astronautes. Le laboratoire Columbus de l'ESA (encart en haut à droite; visible au centre de l'image principale) sera l'un des modules principaux de la Station. Dans ce laboratoire pressurisé multi-usages, les astronautes pourront travailler en bras de chemise, dans un environnement confortable, sur des expériences de sciences de la vie et des matériaux, de technologie, de physique fondamentale et d'autres disciplines.

Europas Forschungslabor im All: Bei Abmessungen von 75 x 110 m - größer als ein Fußballfeld - und einer Gesamtmasse von über 400 t wird die Internationale Raumstation der größte Weltraumkomplex sein, der je errichtet worden ist. Ihr Zusammenbau begann im November 1998 und dürfte im Jahr 2004 abgeschlossen sein, worauf sich 6 oder 7 Astronauten ständig in ihr aufhalten werden. Das Columbus-Labor der ESA (rechts oben im eingerückten Bild und Mitte unten im Hauptbild) ist einer der Hauptbausteine der Station. In diesem druckgeregelten Mehrzwecklaboratorium können die Astronauten ohne Raumanzug arbeiten und Experimente auf dem Gebiet der Lebenswissenschaften, Werkstofforschung, Technologieentwicklung, Grundlagenphysik und in anderen Disziplinen durchführen.

5
Resource management from space: Satellite data have become a very useful tool for resource and agricultural management. This Spot-4 satellite view shows the Gemence nature reserve and the small town of Baj 150 km south of Budapest, Hungary. The reserve is an old flooding zone criss-crossed by dykes and oxbow lakes created by the meandering River Danube. Early stages of crop growth (yellow, orange and pinkish-grey) can be seen in the fields. Vegetation in the small wood plantations (brown) at the bottom right is easily distinguished from that in the nature reserve (green). This short-wave infrared image allows one to see landscape features in detail, with important applications in agricultural planning.

La gestion des ressources depuis l'espace: Les données satellitaires sont devenues un outil indispensable à la gestion des ressources et la planification de l'agriculture. Cette vue prise par le satellite français SPOT-4 montre la réserve naturelle de Gemence et la petite ville de Baj, à 150 km au sud de Budapest, en Hongrie. La réserve est une ancienne zone inondable zébrée par des digues et des lacs créés par les méandres du Danube. On peut voir dans les champs, en jaune, orange et gris-rosé, des plantations en début de croissance. La végétation dans les petites plantations de bois en bas à droite (en marron) peut se différencier aisément de celle dans la réserve, en vert. La technique de l'infrarouge utilisée ici permet de bien distinguer les détails du paysage et trouve des applications importantes pour la planification de l'agriculture.



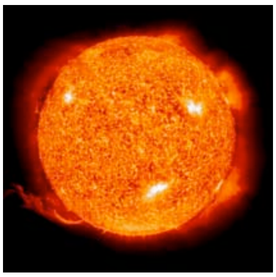
(CNES/Spot Image)

Satelliten helfen beim Ressourcenmanagement: Satellitendaten werden zunehmend für die Bewirtschaftung der Erdressourcen und in der Landwirtschaft eingesetzt. Diese Aufnahme des Satelliten Spot-4 zeigt das Naturschutzgebiet Gemence mit der Kleinstadt Baj 150 km südlich der ungarischen Hauptstadt Budapest. Das Naturschutzgebiet ist eine alte Überschwemmungszone der Donau, die von Deichen und durch die Flußschlingen geschaffenen Altwasserseen durchzogen ist. Anbauflächen in den ersten Wachstumsstadien sind gelb, orange und rosa-grau erkennbar. Die Vegetation in den kleinen Forstgebieten (braun) unten rechts unterscheidet sich deutlich von der im Naturschutzgebiet (grün). Die im kurz-welligen Infrarot gemachte Aufnahme vermittelt ein scharfes Bild der Landschaftskonturen, was für die landwirtschaftliche Planung von großem Nutzen ist.

6
Watching the Sun 24 hours a day: The ESA/NASA SOHO observatory allows us to permanently monitor the Sun and thereby gain a better understanding of its behaviour and interactions with our planet. This picture, taken on 14 September 1997 in extreme ultraviolet light, shows the complexity of the base of the hot solar atmosphere at about 60 000°C. The material in the solar prominence at the bottom left is at temperatures of 60 000 to 80 000°C, much cooler than the surrounding corona, which is typically hotter than 1 million °C.

Un observatoire permanent du Soleil: Grâce à l'observatoire SOHO, réalisé en coopération par l'ESA et la NASA, nous surveillons le Soleil 24 heures sur 24; nous comprenons ainsi mieux son comportement et ses interactions avec notre planète. Cette image, prise le 14 septembre 1997 dans le rayonnement UV, montre bien la complexité de la base de l'atmosphère solaire dont la température atteint 60 000 degrés Celsius. Les matériaux qui forment la proéminence éruptive, visible en bas à gauche, sont à une température de 60 000 à 80 000 degrés Celsius, bien inférieure à celle de la couronne solaire qui dépasse le million de degrés.

Die Sonne ständig im Visier: Das von der ESA und NASA gemeinsam betriebene Sonnen- und Heliosphären-Observatorium SOHO ermöglicht die Beobachtung unseres Tagesgestirns rund um die Uhr und verhilft uns zu einem besseren Verständnis seines Verhaltens und seiner Wechselwirkungen mit unserem Planeten. Diese am 14. September 1997 im äußersten Ultraviolettbereich gemachte Aufnahme zeigt die Komplexität der etwa 60 000°C heißen unteren Sonnenatmosphäre. Die Materie in der Protuberanz unten links ist mit Temperaturen zwischen 60 000 und 80 000°C sehr viel kühler als die umgebende Korona, die in der Regel über 1 Million°C heiß ist.



(ESA/NASA/EIT-Team)

7

(NASA)

Repair in orbit at 29 000 km/hour: 600 km over Australia's west coast, astronauts Story Musgrave and Jeffrey Hoffman complete the last of five space walks from the Space Shuttle to service the international Hubble Space Telescope. ESA contributed the Faint Object Camera and the solar wings to this major international observatory. The camera has provided unique close-up views of almost every type of astronomical object known - from the asteroids and planets of our Solar System to the remotest quasars and galaxies.

Réparation en orbite à 29 000 km/h: A 600 km au-dessus de la côte Ouest de l'Australie, les astronautes Story Musgrave et Jeffrey Hoffman terminent la dernière des cinq sorties extra-véhiculaires hors de la Navette spatiale requises pour la maintenance du Télescope spatial Hubble. L'ESA a participé au développement de ce grand observatoire international en fournissant notamment la caméra pour objets faiblement lumineux et les panneaux solaires. La caméra fournie par l'ESA a permis de prendre des vues rapprochées de presque tous les types connus d'objets astronomiques - depuis les astéroÏdes et planètes de notre Système solaire, jusqu'aux quasars et aux galaxies les plus lointaines.

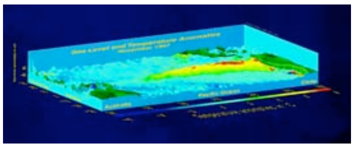
Reparatur im Orbit bei 29 000 km/h: 600 km über der Westküste Australiens absolvieren die Astronauten Story Musgrave und Jeffrey Hoffman den letzten von fünf Außenbordeinsätzen während einer Raumtransportermission zur Wartung des internationalen Hubble-Weltraumteleskops. Die ESA hat zu diesem Gemeinschaftsprojekt die Kamera für lichtschwache Objekte und die Sonnenzellenausleger beigetragen. Die Kamera hat einzigartige Nahaufnahmen von astronomischen Objekten fast jeder Art - von den Asteroiden und Planeten unseres Sonnensystems bis zu den fernsten Quasaren und Galaxien - geliefert.

8

Climate monitoring from space: El Niño is a disruption of the ocean and atmosphere in the tropical Pacific, with global consequences for our weather. The 1997-98 El Niño, observed here by ESA's ERS-2 satellite, is one of the strongest this century, with increased rainfall causing flooding in the USA and Peru, and drought in the western Pacific. The image shows the state of the Pacific in November 1997, in terms of deviations from the 'normal' ocean - namely, height changes between -40 cm and +40 cm, and temperature changes of -6°C (blue) to 8°C (red).

Le changement climatique vu de l'espace: El Niño est un phénomène de modification de l'océan et de l'atmosphère dans le Pacifique à hauteur des tropiques, qui a des conséquences globales sur le climat. Le phénomène El Niño de 1997-1998, que l'on peut observer ici grâce au satellite ERS-2 de l'ESA, est l'un des plus forts de ce siècle. Il a été à l'origine d'inondations aux USA et au Pérou, et de sécheresse dans l'Ouest du Pacifique. Cette image montre le Pacifique en novembre 1997, avec ses modifications par rapport à l'état ‹normal› de l'océan: changements de hauteur de l'océan de - 40 à + 40 cm, et changements de températures de -6 degrés C (en bleu) à + 8 degrés C (en rouge).

Klimaüberwachung aus dem Weltraum: El Niño ist eine Meeres- und atmosphärische Störung im tropischen Pazifik mit weltweiten Auswirkungen auf unser Wetter. Das El-Niño-Phänomen 1997/98, das hier mit dem ESA-Satelliten ERS-2 beobachtet wurde, war eine der ausgeprägtesten Erscheinungen in diesem Jahrhundert und hatte verstärkte Niederschläge mit Überschwemmungen in den USA und Peru und Dürre im westlichen Pazifik zur Folge. Die Aufnahme läßt den Zustand des Pazifik im November 1997 mit Abweichungen von der normalen Meereshöhe zwischen -40 cm und +40 cm und Temperaturunterschieden zwischen -6°C (blau) und +8°C (rot) erkennen.



(ESA/ESRIN/CCLRC/RAL/NERC/BNSC)

9

A European probe to land on Titan: Launched in 1997, ESA's Huygens is the first probe designed to descend through the thick atmosphere of Saturn's moon Titan, where it should arrive in November 2004. The mission allows us to travel back in time: conditions on Titan today resemble those of the primordial Earth when the chemical reactions required for the origin of life were taking place. This montage shows key phases in Huygens' descent sequence, from the probe's release (top left) by NASA's Cassini Saturn-orbiter into Titan's atmosphere, to the descent through the clouds under the stabiliser parachute (centre), and after surface contact (bottom right).

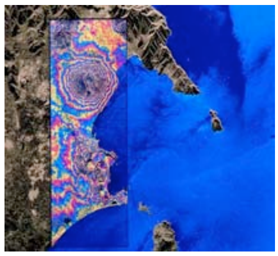
Une sonde européenne va atterrir sur Titan: Lancée en 1997, la sonde Huygens de l'ESA sera le premier engin à venir se poser sur Titan, la lune de Saturne, en novembre 2004, après avoir traversé son épaisse atmosphère. Cette mission va nous faire littéralement voyager dans le temps, dans la mesure où les conditions actuelles sur Titan ressemblent fortement à celles de la Terre peu après sa formation, alors que se déroulaient les premières réactions chimiques nécessaires à l'apparition de la vie. Ce montage montre les phases de la séquence de descente sur Titan: en haut à gauche, on voit la libération de la sonde par Cassini (réalisé par la NASA), en orbite autour de Saturne, puis au centre la descente de Huygens, sous son parachute de stabilisation, à travers les nuages de Titan, et en bas à droite la sonde après son atterrissage.

Europäische Landung auf Titan: Die von der ESA entwickelte Raumsonde Huygens soll erstmals durch die dichte Atmosphäre des Saturnmonds Titan absteigen. Sie wurde 1997 gestartet und dürfte im November 2004 ihren Bestimmungsort erreichen. Diese Mission ist eine Reise zurück zur Urzeit: Die heutigen Bedingungen auf Titan ähneln dem Zustand der Erde zu einer Zeit, als die für die Entstehung des Lebens notwendigen chemischen Reaktionen abliefen. Diese Fotomontage zeigt die Hauptphasen des Abstiegs der Huygens-Sonde, von ihrer Freisetzung durch die NASA-Saturnsonde Cassini (oben links) bis zur Durchquerung der Wolken an einem Stabilisierungsfallschirm (Mitte) und zum Niedergehen auf der Titan-Oberfläche (unten rechts).

10

A 3-D image of Vesuvius: Radar interferometry is a promising technique that allows three-dimensional mapping of the Earth's surface with a precision of a few metres, as in this view of the Bay of Naples and the Vesuvius volcano, in Italy. Interferometry is also very promising for the detection of early signs of major catastrophes such as earthquakes or volcanic eruptions. Volcanoes tend to swell before they erupt and these centimetric deformations could be measured from space by interferometry, thus possibly allowing early warnings to be given.

Le Vésuve en trois dimensions: L'interférométrie radar est une technique prometteuse qui permet de réaliser des cartes en 3 dimensions de la surface terrestre avec une précision de quelques mètres, comme cette vue de la Baie de Naples et du Vésuve, en Italie. L'interférométrie est également très prometteuse en ce qui concerne la détection des signes précurseurs de catastrophes naturelles telles que les tremblements de terre ou les éruptions volcaniques. Les volcans gonflent légèrement avant d'entrer en éruption et l'interférométrie permet de détecter ces déformations centimétriques, ce qui pourrait permettre de donner l'alerte de manière précoce.



Der Vesuv in drei Dimensionen: Die Radar-Interferometrie ist eine vielversprechende Technik, die eine dreidimensionale Kartierung der Erdoberfläche mit einer Präzision im Meterbereich ermöglicht, wie diese Aufnahme der Bucht von Neapel und der Umgebung des Vesuvs zeigt. Diese Technik wird auch zur Aufspürung der Vorläufererscheinungen großer Katastrophen wie Erdbeben und Vulkanausbrüche genutzt. Vulkankegel verdicken sich vor dem Ausbruch häufig um mehrere Zentimeter, und diese Verformung läßt sich aus dem Weltraum mittels Interferometrie messen, was künftig vielleicht eine Frühwarnung ermöglicht.

11

Working and living in space: ESA astronaut Thomas Reiter (spacesuit with blue stripe) and Russian cosmonaut Yuri Gidzenko (red stripe) making a space walk from the Mir space station on 8 February 1996. Reiter spent 177 days aboard Mir between September 1995 and February 1996. This Euromir-95 mission was highly representative of future International Space Station operations, especially the Station's on-going assembly.

Vivre et travailler dans l'espace: L'astronaute de l'ESA Thomas Reiter (scaphandre avec une rayure bleue) et le cosmonaute russe Yuri Gidzenko (rayure rouge) effectuent une sortie extra-véhiculaire hors de la station Mir, le 8 février 1996. Reiter a passé 177 jours à bord de Mir entre septembre 1995 et février 1996. Cette mission, Euromir-95, était particulièrement représentative des opérations de la future Station spatiale internationale, dont l'assemblage a commencé.

Leben und Arbeiten im All: Der ESA-Astronaut Thomas Reiter (Raumanzug mit blauem Streifen) und der russische Kosmonaut Juri Gidsenko (roter Streifen) bei einem Außenbordeinsatz an der Raumstation Mir am 8. Februar 1996. Reiter hielt sich zwischen September 1995 und Februar 1996 insgesamt 177 Tage lang an Bord der Mir auf. Diese Euromir-95 genannte Mission ähnelte weitgehend den künftigen Einsätzen auf der Internationalen Raumstation, deren Zusammenbau begonnen hat.

12

The damage of deforestation: This ESA ERS-1 radar image, acquired on 14 April 1992, shows the extent of deforestation in the Amazonian rain forest. Still-forested areas appear in green and deforested areas in red, while the Teles Pires River is shown in blue. The satellite's active radar (SAR) can penetrate cloud cover, operating in all weathers and even at night.

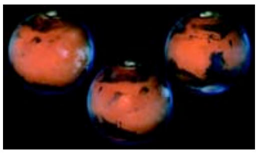
Les ravages de la déforestation: Cette image radar, acquise le 14 avril 1992 par le satellite ERS-1 de l'ESA, met en évidence l'étendue de la déforestation dans la forêt amazonienne. Les zones de forêt apparaissent en vert, tandis que les zones déboisées sont en rouge, et la rivière Teles Pires en bleu. La technique radar permet de voir à travers la couche nuageuse, par tout temps et même de nuit.

Raubrodung im Regenwald: Diese Radaraufnahme des ESA-Satelliten ERS-1 vom 14. April 1992 zeigt das Ausmaß der Rodungsflächen im Regenwald des Amazonasbeckens. Die noch bewaldeten Gebiete erscheinen in grün und die Rodungsflächen in rot, während der Fluß Teles Pires blau erkennbar ist. Das aktive Satellitenradar (SAR) kann die Wolkendecke durchdringen und arbeitet Tag und Nacht und bei jedem Wetter.

13
Ice on the Red Planet: The most detailed views of Mars ever seen from Earth were recorded by the Hubble Space Telescope in March 1997. Recorded about 6 hours apart, these images show most of the Red Planet as it made one of its closest approaches to the Earth - about 100 million km. They were taken on the last day of Martian spring in the northern hemisphere. The annual north polar dry ice cap is rapidly sublimating, revealing the much smaller permanent water ice cap.

De la glace sur la planète rouge: En mars 1997, le Télescope spatial Hubble a pris des vues extrêmement détaillées de Mars. Prises à 6 heures d'intervalle, elles nous permettent de voir l'ensemble de la planète rouge alors qu'elle passait à proximité de la Terre - à environ 100 millions de km. C'était le dernier jour du printemps martien de l'hémisphère Nord. On peut voir la glace sèche (neige carbonique) du pôle Nord, en train de se sublimer rapidement, révélant ainsi la calotte permanente d'eau sous forme de glace, beaucoup plus petite.

Eis auf dem Roten Planeten: Das Hubble-Weltraumteleskop brachte im März 1997 die bisher schärfsten Aufnahmen des Planeten Mars hervor. Diese im Abstand von etwa 6 Stunden aufgezeichneten Bilder zeigen den Großteil des Roten Planeten zu einer Zeit, als er der Erde bis auf etwa 100 Millionen km nahekam. Sie wurden am letzten Frühlingstag der Nordhalbkugel gemacht. Die sich jedes Jahr am Nordpol bildende Trockeneiskappe ist bereits weitgehend verdampft, so daß die sehr viel kleinere ständige Wassereiskappe sichtbar wird.

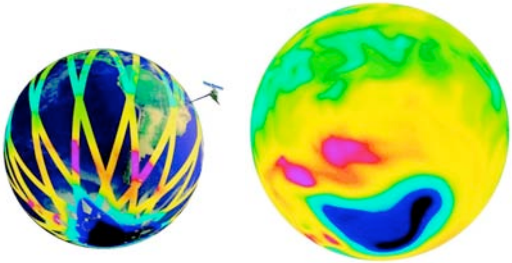


(David Crisp/WFPC2-Wissenschaftsteam/JPL)

14
Global problems require global solutions: Specialised instruments observing from space confirm the depletion of the Earth's protective ozone layer year by year. In particular, satellites can map the deepening seasonal ozone hole over the Antarctic. The Global Ozone Monitoring Experiment aboard ESA's ERS-2 satellite continues this important work. Blue/black highlights areas of ozone depletion, whilst red/yellow denotes higher concentrations.

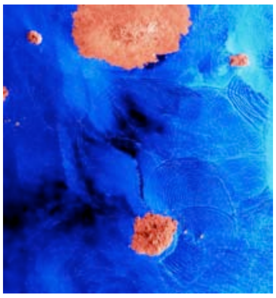
A problème global, solution globale: Des instruments spécialisés observant depuis l'espace permettent de confirmer l'appauvrissement, année après année, de la couche protectrice d'ozone de la Terre. En particulier, les satellites peuvent cartographier le trou dans la couche d'ozone au-dessus de l'Antarctique et suivre ses variations saisonnières. Cette image est réalisée grâce à l'expérience de surveillance globale de la couche d'ozone, embarquée à bord du satellite ERS-2 de l'ESA; les zones pauvres en ozone sont en bleu/noir, tandis que les zones plus riches en ozone sont en rouge/jaune.

Globale Probleme erfordern globale Lösungen: Beobachtungen mit satellitengestützten Instrumenten bestätigen den zunehmenden Abbau der die Erde schützenden Ozonschicht. Mit Satelliten läßt sich insbesondere das wachsende jahreszeitliche Ozonloch über der Antarktis vermessen. Das Experiment für weltweite Ozonüberwachung (GOME) an Bord des ESA-Satelliten ERS-2 setzt diese wichtigen Messungen fort. Zonen des Ozonschwunds treten blau-schwarz hervor, während rot-gelbe Farbtöne auf höhere Konzentrationen hindeuten.



(ESA/DLR/KNMI)

15



When a satellite sees underwater: In this ERS-1 image of the Galapagos Islands, undersea waves, produced by the interaction of strong ocean currents with the islands and the sea-bed, can be seen. These waves, which cannot be detected by optical sensors, reflect differences in water density and salinity. This is just one of the many phenomena associated with marine current, tidal and wind/ocean effects that can be observed from space with radar sensors.

Les satellites voient aussi sous l'eau: Sur cette image des Galapagos prise par le satellite ERS-1, on peut voir les vagues sous-marines produites par l'interaction entre les courants océaniques, les îles et le fond de l'océan. Ces vagues, qu'il est impossible de détecter par des capteurs optiques, mettent en évidence des différences de densité et de salinité de l'eau. C'est l'un des phénomènes liés aux courants marins, à la marée et aux effets des vents et de l'océan, qu'il est possible d'observer grâce au radar.

Satelliten sehen auch unter Wasser: In dieser mit ERS-1 gemachten Aufnahme der Galapagos-Inseln sind Unterwasserwellen erkennbar, die durch die Wechselwirkung starker Meeresströmungen mit den Inseln und dem Meeresboden entstehen. Diese mit optischen Sensoren nicht erfaßbaren Wellen deuten auf Veränderungen der Wasserdichte und des Salzgehalts hin, eines der zahlreichen Phänomene im Zusammenhang mit Meeresströmungen, Gezeiten- und Windeinwirkungen, die sich aus dem Weltraum mit Radarsensoren beobachten lassen.

16

Europe as seen from space: more than 2500 images from the Along-Track Scanning Radiometer aboard ESA's ERS-2 remote-sensing satellite have been merged into this composite in order to highlight vegetation coverage.

L'Europe vue de l'espace: cette vue est réalisée à partir de plus de 2500 photos prises par le radiomètre du satellite ERS-2 de l'ESA, qui ont été fusionnées dans cette image composite permettant de mettre en valeur la couverture végétale.

Europa aus dem Weltraum betrachtet: Über 2500 Aufnahmen des in Flugrichtung abtastenden Radiometers an Bord des ESA-Fernerkundungssatelliten ERS-2 wurden verarbeitet, um dieses zusammengesetzte Bild der Vegetationsdecke herzustellen.

(ESA/CCLRC/RAL/NERC/BNSC)