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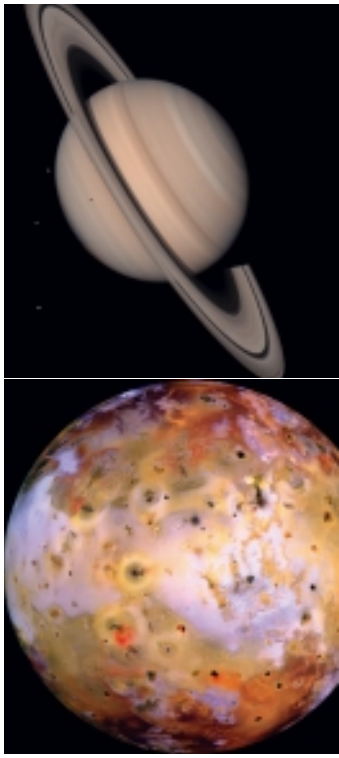

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Introduction

The German and European space endeavour can look back over 40 years of uninterrupted development and growing importance. For weather forecasting and communications, for TV transmission and navigation, space infrastructures have grown up whose benefits are now so all-pervading that it is hard to imagine daily life without them – and yet the connection with space is not always consciously realised. German space science and technology has world status and is one of the major factors shaping European missions.

The usefulness of space activity for the citizen and scientific excellence are the two main criteria guiding German space policy. In Germany the public authorities will this year be spending some 1.9 billion DM on space and space science. The bulk of that money – 1.7 billion DM – comes from BMBF.

To accommodate the size of the projects, space activity transcends national boundaries. The German space sector is thus tied in to the European space activities managed by the European Space Agency (ESA). Within the framework of European co-operation, German space research will increasingly be focusing its efforts in specific areas in order to improve the performance of industry and science. Further co-operative ventures can also be expected, primarily with the USA but also with Russia.

Space technologies create scope for action in various areas of government provision and commercial activity. Examples include disaster warning and management in broad or remote areas or assessment of ground erosion or crop yield projections. It may not be long before provision of some quite extraordinary services by private industry is taken for granted; these could include worldwide mobile communications systems capable of performing reliably in the remotest areas and offered at a reasonable price, telemedicine (remote treatment on trips to distant places, for example), or even tips on the optimum use or fertilisation of arable land anywhere on the planet.

Establishing clear priorities is one way of ensuring that Germany and Europe take a substantial share of growth in these new markets and of the resulting jobs. But space applications will not only be playing a more prominent role in supporting 'new services' such as these. Space technologies will also come to play an increasingly important role in preserving the competitiveness of existing key areas of German and European industry. Permanent availability and high data quality are essential criteria for a number of critical navigation applications, air and rail transport being prime examples. This is why the transport sector has particularly high expectations of Galileo, the European satellite navigation project. It is hard to imagine an intelligent traffic management system that did not rely on the latest information, communication and routing technologies to organise traffic of all kinds more safely, more effectively and with greater regard for the environment. Indeed, space-based navigation and positioning systems are increasingly being seen as a key element in the networking of different transport media to form an integrated traffic system and in the optimisation of logistical arrangements at national and European levels. The combined operation of terrestrial and space infrastructures opens up the prospect of high-value, user-oriented applications and value-added services, in connection for example with digital geodata. The commercial and economic potential of these opportunities can only be guessed at today.

Satellite navigation is growing in importance in other economic and societal areas too, for instance in geodesy, agriculture and leisure activities, quite apart from the significance of an absolutely precise time signal for globalised trade and financial markets. Given the many commercial openings for space developments the Federal Government expects a growing proportion of space utilisation to eventually manage without public-sector aid.

Modern observation systems operating from Earth orbit are a source of invaluable knowledge for the Earth

sciences, environmental research and many other areas of activity. This knowledge can for example help limit the drain on the world's natural resources or develop reliable projections concerning atmospheric pollution. When the environmental satellite ENVISAT is launched in mid-2001 a new dimension will be opened up for research in this area.

Data gathered by scientific satellites have also, in recent years, greatly added to our understanding of the solar system and its planets and of how the Universe has developed. Top-quality science and research will continue in the future to be major applications of space technology.

Many of these potential space applications can only materialise if Europe acts together. This is no longer just about joint research but about developing infrastructures in European co-operation. Construction and operation of the International Space Station as a multidisciplinary facility for fundamental and applied research and commercial utilisation or again continued development of the European launcher Ariane to secure guaranteed autonomous access to space are particularly good examples of this.

The Federal Government is committed to ensuring that the European Union Commission, which has set itself the objective of developing European trans-national infrastructures, and the European Space Agency work together more closely in the future. A promising start was made on this front with their parallel resolutions on a European Strategy for Space. Specific objectives must now be formulated and pursued to bring substance to this framework.

A long-term goal is to arrive at a comprehensive European space programme. The policy of concentrating the German space effort on what our space industry and science do best should be viewed in this European context. A series of detailed core programmes will further develop the German Space Programme and hence pave the way for the future.

The German Space Programme creates the necessary basis and understanding for increasing use of space technology in a range of industrial and political contexts. It provides a road-map for strengthening the capabilities of European science and industry through the use of the space resource and space technologies, in co-operation with our European partners. This is essential if Europe is to remain competitive in relation to the world's other great industrial regions and if individual citizens are to enjoy in their daily lives the benefits of the growing opportunities offered by space.

Edelgard Bulmahn
Bundesministerin für Bildung und Forschung

Foreword

The German Space Programme incorporates:

- the German participation in the ESA and EUMETSAT programmes,
- the National Programme's projects, and
- the DLR's space R&D programme (HGF – Helmholtz research centres – sponsorship) in the framework of institutional support from the federal and Länder authorities.

Together they make up a co-ordinated, strategically focussed whole.

The primary contributors to the Space Programme are the Ministry of Education and Science, the Ministry of Transport, Building and Housing and the Ministry of Defence. This effort is complemented and accompanied by space research in the Max-Planck society, the Helmholtz centres, the Deutsche Forschungsgemeinschaft (German research community) and in university research units and institutes and also by contributions to the work of international user and operator organisations. In drawing up the German Space Programme general objectives and structural criteria have been developed with a view to giving direction and focus to Germany's space commitment in the longer term. It breaks down into eight core programmes.

The German Space Programme and its constituent core programmes have come through an extensive process of discussion and co-ordination with science, industry, ESA and the space organisations of European partners.

In the core programmes the global objectives set out in the general programme are translated into agreed action in the context of specific space projects. In the medium term these plans are consistent with federal financial planning. Beyond the existing planning horizon, the DLR provides longer-term planning guidance.

The German Space Programme gives the German space community a programmatic and financial framework in which to operate. For partners in industry and science the programme provides the transparency and planning stability they need to initiate decisions and pursue entrepreneurial objectives. Germany's status as a reliable and attractive partner or competitor for its European partners is enhanced by the programme.

This federal programme is implemented by the DLR as Germany's space agency in the framework of the Delegation of Space Activities Act (Raumfahrtaufgaben-Übertragungsgesetz).

A. Prospects

Space exploration is marked by a unique combination of inspiring vision and utility-oriented pragmatism. Space contributes to a wide array of human endeavours, enriching society, industry and scientific inquiry. Elements of a space-based service infrastructure have been engineered to support scientific research, industrial R&D, environmental monitoring, transportation support services, security, resource management and disaster response, with the space-based equipment and systems complementing the corresponding terrestrial infrastructure. Only co-ordinated use of the space and ground-based segments allows their full potential to be exploited. These are "global" infrastructures par excellence, requiring global co-operation and a global division of labour to reach scientific and political objectives. At the same time, they lead to intense international competition in projects that possess economic and strategic significance.

Forty years after the birth of spaceflight, its possibilities are only beginning to be explored. There is an enormous potential for innovation. Commercial exploitation of space infrastructure systems and the evolution of scientific insights for economic applications are creating new markets all over the world and providing the impetus for major new industries and higher employment. Space has become an indispensable prerequisite for Germany to maintain its economic and scientific position. Space is opening up new dimensions in the study of the earth and our universe and in applications involving transportation support services, communication and security. Public-sector activities are gaining added scope for protecting the environment, for the discovery and exploitation of natural resources, for disaster prediction and management, and for security.

The unique observation vantage offered by space and its global communication and navigation potential are a major input to the development and implementation of a policy of sustainable growth at world level. The Earth is a closed system, ecologically, economically and politically. We are gradually coming to understand the interaction of the various forces within the system and are able to take due account of the influences to which it is exposed. At political level this means for example the ability to detect the imminent outbreak of famine and react accordingly before large numbers of refugees start to flee. And as such developments can now be observed even in the most remote regions, authoritative governments are no longer in a position to hide the facts. Global knowledge does however add to global responsibility.

The aim of German space policy is to secure significant, worthwhile investment in the future of our community, thereby safeguarding the natural basis for the lives of present and future generations and improving the quality of life.

Germany's space activities are concentrated within the framework of European co-operation. Future European space endeavours are envisioned as being organised and structured around a network of specialised „centres of competence". While monopolistic structures will be avoided, there will be a clear assignment of spheres of competence. A competitive process will yield proposals of merit, which will be carried out jointly. In order to make this new form of organisation a reality, the partners will have to accept that their roles be redefined. In place of the goal of achieving autonomous capability, the partners must be conscious of and prepared to accept the need for mutually supporting roles that span national borders. The emergence of a national profile is essential to this process.

Space – a key part of the knowledge-based society

One of the core prerequisites of the knowledge-based society is for instantaneous, global availability of information. Satellite television and world-wide mobile telephony are the precursors of the multimedia age just beginning. To reach any point on earth with broadband communications at any time, an orbital infrastructure is required. Satellites provide the necessary availability of information independently of location, while advanced space-based communications systems furnish the networking and control of information flows.

The infrastructure and technology that have been created by space activity have unleashed tremendous market potential, which has already reached some US$ 55 billion annually and is expected to increase to US$ 170 billion by 2006. While launch services and the manufacturing of satellites and satellite components represent only a small fraction of the total market in financial terms (indeed, the ratio is diminishing), the strategic leverage exercised by these technologies on the entire industry is enormous. Technical authority in a privileged position at the start of the value-added chain and involvement in the establishment of standards and the associated interfaces makes it possible to exercise a decisive influence on downstream sectors.

The current situation is favourable for a major upgrade in Germany's role in the global commercial space market, with the domestic industry well established and added potency gained through the consolidation of the European aerospace industry against the background of a market that is, in general, growing vigorously. Not only are the prospects positive for employment growth in the primary markets, but it will be possible also to achieve stimulating effects on the downstream markets of satellite-based information and entertainment services.

Space – an indispensable tool for the protection of life on Earth

With growing realisation of the environment's significance for the quality of human life, its vulnerability and the risks associated with environmental changes, these factors are increasingly affecting the way we think and act. Satellite-based information is playing an important role in this process. Continuously monitoring the state of the environment is one of our most important collective tasks. It is possible from space not only to determine the extent of environmental damage but also in many cases to identify the causes and those responsible. Verification of global, internationally binding environmental protection agreements is becoming increasingly important. For this, space-based systems are indispensable.

Protecting the environment is a core objective of German government policy. Greater use must therefore be made of satellite Earth observation to meet the demands of environmental protection. Apart from purely ecological issues, there are related objectives including disaster management, security and transportation support services, to the pursuit of which the German Space Programme is seen as a substantial contribution.

Space – a key to understanding the universe, our Earth and the ecosystem

Space travel has contributed to our understanding of the physical universe in ways that have revolutionised our views on the solar system and deep space. We have found out how directly the Earth is affected by storms on the Sun, we have been deeply impressed by the variety of planets in our solar system and we have learnt that the universe came into being some 12 to 15 billion years ago in the course of a "big bang" or again that black holes really do exist. The new insights have reached the consciousness of the general public, while many crucial questions still remain to be answered, particularly topical issues at the present time being the existence of earth-like planets in other solar systems and the existence of extraterrestrial life.

Our understanding of these issues can be expected to grow considerably with future ventures. The Earth sciences have profited in a similar way, using the global perspective provided by satellites to make new discoveries that have changed the way we look at planet Earth. The unique opportunities available in space will continue to furnish fundamental knowledge about Earth and about the biosphere. Use of the special conditions that exist in space, weightlessness in particular, for life and materials science experiments is also expected to make a useful contribution.

Orbital observatories and laboratories will be used in conjunction with terrestrial systems, and the extent of international co-operation and specialisation will further increase.

Space – human beings and technology move outwards

The most technologically developed nations have begun to open up space. They are doing so together and for exclusively peaceful purposes, including that of obtaining a sustained human presence in space. Germany and Europe are contributing to this effort with their participation in the development, construction and operation of the International Space Station. This is an opportunity to test out new forms and rules of international co-operation on a major project for which there is no existing parallel. This orbital facility will allow scientists and engineers to pursue research and development work in space. Areas of activity will include growth sectors such as biotechnology and IT. Human beings working in space, whose creativity and adaptability have so far proved irreplaceable, will help solve earthly problems that cannot be addressed solely in earthly conditions. New knowledge will prompt innovation in materials science, pharmacology, biology and medicine. The human scientist and astronaut will at the same time be increasingly relieved of routine activities by automation, while robots will take over many of the more arduous and hazardous tasks.

Forty years into the space age, this new dimension in human activity continues to exercise a special fascination. The pioneering spirit and intellectual curiosity it stimulates are an excellent means of interesting young people in advanced technology and generating a craving for knowledge.

B. Strategy

1. Background

The space sector in Germany

For many years, long-term programmes and ambitious space projects have enjoyed political support and received uninterrupted financial backing from the federal German government. Public monies, on the federal and the Länder level alike, go to the general and institutional support of science, research and education. This unique combination has led to the creation of a number of specialised organisations in Germany for planning and carrying out space projects. They may be broken down into:

- **A highly capable space industry.** A complex of major corporations, medium-sized system and sub-system suppliers and small component and service providers forms an industry that is achieving success in parts of the international space market.
- **Internationally recognised scientific experts** in the various space research disciplines. In universities, sometimes with support from the Deutsche Forschungsgemeinschaft, but also in non-academic research institutions such as the Max-Planck society and the Helmholtz Centres, they make outstanding scientific contributions on their own initiative, while also contributing to forming and educating the future generation of scientists.
- **Competent and highly-motivated staff and facilities** for designing, developing, testing, operating and utilising space transportation systems and a management organisation within the DLR responsible for steering the German Space Programme within the overall guidelines laid down by government.

In terms of cost of goods manufactured, the space sector narrowly defined (i.e. excluding companies which use space systems to generate value-added services) is quite small, with total sales of DM 3.5b in 1998 (corresponding to some 0.4% of total manufacturing value-added, excluding construction) and some 6 000 sector employees. However, because this is a high-technology sector, characterised by high-value, capital-intensive rather than labour-intensive products and relying on major R&D, space projects tend to produce considerable indirect and secondary economic benefits. The experts polled on the subject in the second Delphi study[1]) considered that space, especially satellite technology and applications for communications and traffic systems, would have a disproportionately high impact on Germany's economic development.

While the corporate consolidation process has for the past ten to fifteen years been limited to national industries, the European aerospace industry is now undergoing industrial concentration across national frontiers. This is motivated by the world market demand for turnkey systems, a demand that in the long term can only be met by powerful conglomerates which possess the requisite financial strength and which, in addition to their prime capability, have also become globally competitive through horizontal integration, by utilising synergies and economies of scale.

Public-sector funding of space activity in Germany fell by approximately 12% in nominal terms from 1992 to 1998. It has since been stabilised at a higher level consistent with planning stability. The total spending provision amounts to about DM 1.9 billion in 2001, representing some 0.4% of the federal budget and about 5% of all public spending on research and technology. Funds come for the most part from the BMBF, at DM 1.7b. This represents 14.5% of all BMBF spending on R&D. The rest is made up of expenditures by other federal ministries on space applications within their competence; this includes Germany's DM 145 million contribution to EUMETSAT.

European co-operation and national activities

Within ESA and also in bilateral undertakings, France, Italy and the United Kingdom remain our main space partners in Europe. In financial terms, almost three quarters of German Space Programme activity is carried out within ESA.

The EU is becoming increasingly active in the space sector through utilisation of the space resource in furtherance of its own policies, through the global representation of European interests and as an investor in specific applications. Effective action in a European framework is only possible therefore on the basis of the space strategy jointly developed by the EU, the European States, ESA and European industry.

[1]) Delphi '98 – Studie zur globalen Entwicklung von Wissenschaft und Technik; Fraunhofer Institut für Systemtechnik und Innovationsforschung for the Federal Ministry of Education and Science, Karlsruhe, Februar 1998.

In Resolutions adopted at the ministerial meeting of the ESA Council in May 1999 and at the December 1999 EU Research Council meeting, the EU Commission and the ESA Executive were instructed to jointly elaborate a coherent European strategy on space. In pursuance of this instruction, the two bodies went on to produce a joint document on a European Strategy for Space (ESS). This was approved by the relevant EU and ESA authorities at ministerial level on 16 November 2000.

The **main points** to emerge from the ESS and the associated Resolutions can be summarised as follows:

- the strategic importance of space for economic and political growth in Europe;
- the need for European independence in key strategic areas;
- the importance of Galileo (positioning and navigation) and GMES (initiative for Global Monitoring for Environment and Security");
- the need for sustained public support;
- the global competitiveness of European industry as a industrial policy priority;
- the need to make efficient use of the European space infrastructure, the ISS in particular.

The ESS also establishes itself as the fundamental reference for all further European R&D activities.

A successful national programme following established priorities, emphasising commercial utilisation of space technology and systems, and the DLR space division's institutionally funded R&D activities („Grundfinanzierung"), complement the international activities. This ensures Germany remains a respected, expert partner for co-operation and strengthens our position as a powerful competitor.

Strengths and weaknesses

Germany is involved in virtually every aspect of space, with the notable exception of military systems. Indeed, it has become a leading supplier in some areas, including: construction of scientific satellites, manufacturing components and subsystems for space vehicles and communications satellites, integration of orbital systems for manned spaceflight, space robotics, X-ray

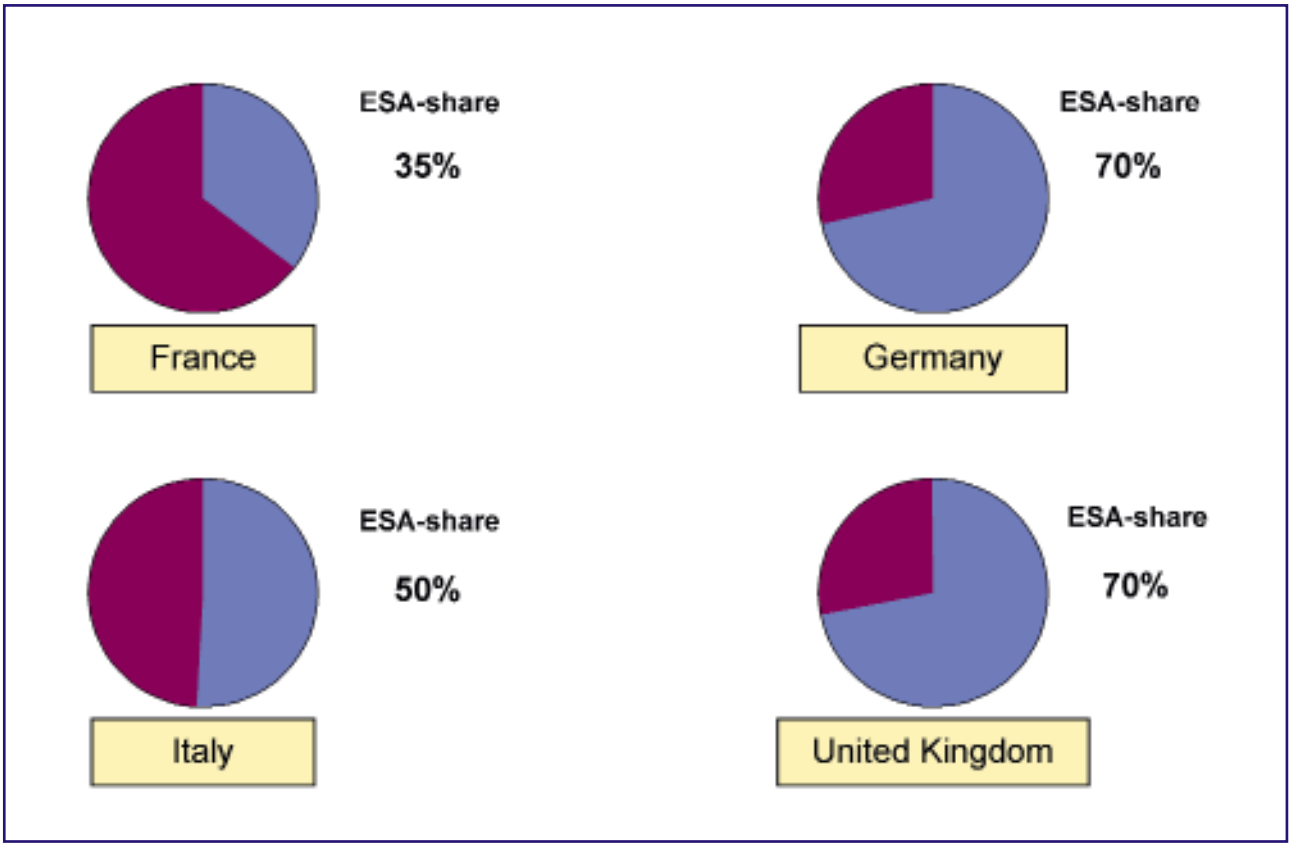

Figure 1: Civil space expenditures in France, Germany, Italy and the United Kingdom rounded and partly estimated 1999 figures; Germany excl. EUMETSAT, MPG and DFG (Source: Jane's Space Directory, CNES, ASI, BNSC)

astronomy, sensor technology (especially SAR), weather and climate research, satellite-assisted meteorological and ocean monitoring, processing and enhancing of EO data, and the design and manufacturing of highly temperature-resistant materials and structures.

Decisions taken at the ESA Council's last meeting at ministerial level (Brussels in May 1999) have created continuity and a stable planning environment while setting some new priorities in future-oriented applications areas: new impulses were given to scientific Earth observation and to satellite navigation, while bearing out and consolidating earlier programmes in extra-terrestrial research, space transportation, and space station development and utilisation.

At the present time, a considerable proportion of Germany's available resources is committed to two ESA infrastructure projects, the international space station and the Ariane launch vehicle. Added to the contributions for ESA's mandatory science programme, this limits our scope for participating in new optional applications programmes within the German Space Programme. Looking further ahead, the proportion of funding assigned to space applications projects should however begin to rise again.

Growing significance of commercial space activity

Governments remain the main customers for space activities, and public budgets the main funding source. However, for the past several years the presence of private enterprise has been growing, in space projects targeting a rapid commercial return under normal market conditions. The federal government expects continued sustained growth in commercial space activities.

Research performed by EUROCONSULT also indicates in the years ahead a combination of stagnating public expenditure and growing commercial markets for space applications and services (see Figure 2, page 11).

Government spending on space will remain constant in the medium term. A growing demand can however be expected in connection with social measures and preventive action by government, especially with regard to environmental monitoring and security aspects. Growth in the space sector in Germany must come above all from a substantial increase in the commercial market for space goods and services and from greater private-sector involvement both upstream and downstream (see Figure 3, page 12). The national space programme will be instrumental in achieving this result, through for example support for user and market-oriented product development and methods or again the promotion of innovative ventures and pilot projects.

The international context

The number of countries actively pursuing their own programmes for developing and operating space technology is growing world-wide, and is no longer limited to the developed industrial states in the G8 group, but also includes a growing number of newly industrialised countries. Almost all countries rely on space technology and associated services to some extent. The traditional spacefaring superpowers, the United States and Russia, still have the largest and most diversified space programmes. In terms of spending Europe, taken as a whole, holds second place world-wide. Most countries of western Europe have a national space programme which they pursue in parallel to the joint ESA programme. However, there are large differences amongst them with regard to the size of their programmes, the programme contents and degree of specialisation. This may be illustrated by comparing the four largest ESA members, France, Germany, Italy and the United Kingdom, as shown in Figure 1, page 9. In Figure 4, page 13, funding for space is compared to overall economic significance for a number of European countries and the USA.

The USA and Russia continue to use space extensively for military and security purposes, as they have since the early days. Inside Europe, France and the United Kingdom possess substantial military space budgets, while Italian and Spanish activities in this sector are comparatively minor. Germany has not developed any military satellite systems to date. To meet the communications demands of German troops in UN units the usual approach is to lease transmission capacity from civil satellite operators or NATO partners. The need to identify and monitor potential crisis situations at an early stage and the evolving role of German forces in the new security environment point to an increasingly evident demand for a surveillance capability. Experience gained during the Kosovo conflict emphasise the urgent need for a national core capability in satellite reconnaissance. A core capability of this kind provides autonomous access to original imagery and is also the basis for participation in a European association to which the partner nations bring complementary capabilities. In the framework of the common foreign and security policy (CFSP) a European position on these issues is currently being elaborated with the EU.

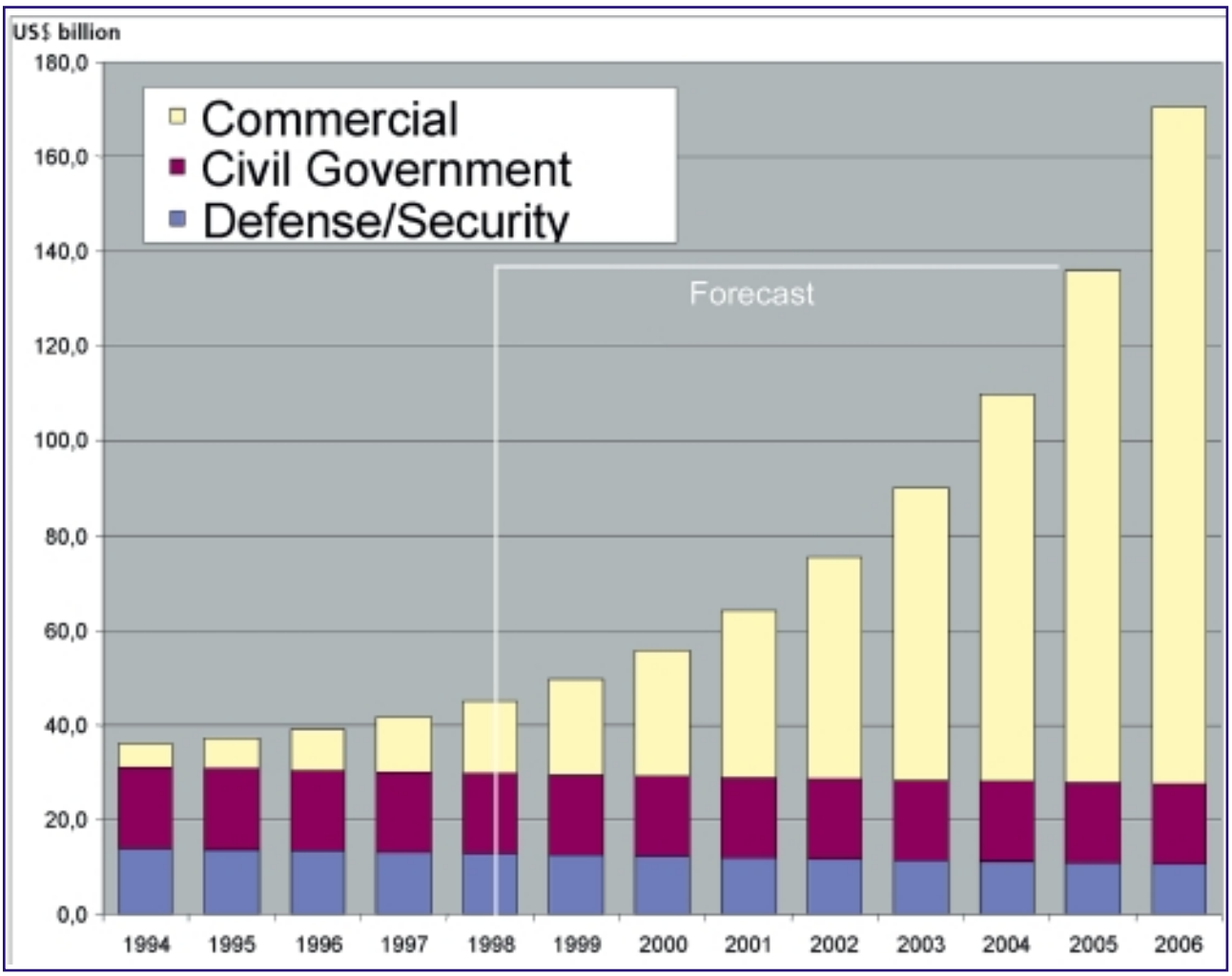

Figure 2: Evolution of world space markets (Source: Euroconsult, DLR)

Co-operation with Russia is relatively recent, but has already led to numerous successful joint projects, such as the two flights to Mir by German cosmonauts, as well as creating a number of private-sector joint ventures. The German-Russian intergovernmental agreement on co-operation in the exploration and utilisation of outer space for peaceful purposes, concluded on 10 April 2001, lays the basis for even closer co-operation.

Outside Europe, Germany's international co-operation in space exploration and technology is most prominent in the long-standing relationship with the United States, our most important partner. Other important non-European partner countries are Japan and India, the latter above all in Earth observation.

2. General objectives

Space as a high-tech domain demonstrates an advanced level of engineering and industrial capability. In addition to the numerous innovative applications which space technologies find in science and industry, their mastery is of considerable strategic significance. Joint projects exploiting the strengths of the national industries make space an integrating factor in international relations. A hallmark of the German space effort is the emphasis on international co-operation, first and foremost on the European level but including also partnerships that bridge the Atlantic and span the globe. The ambitious projects which this entails demand sound technical, economic and financial planning and management. In addition to being a means to an end, international co-operation also contributes to European integration, maintains the fruitful historic ties with the USA and continues partnerships with Russia and other countries.

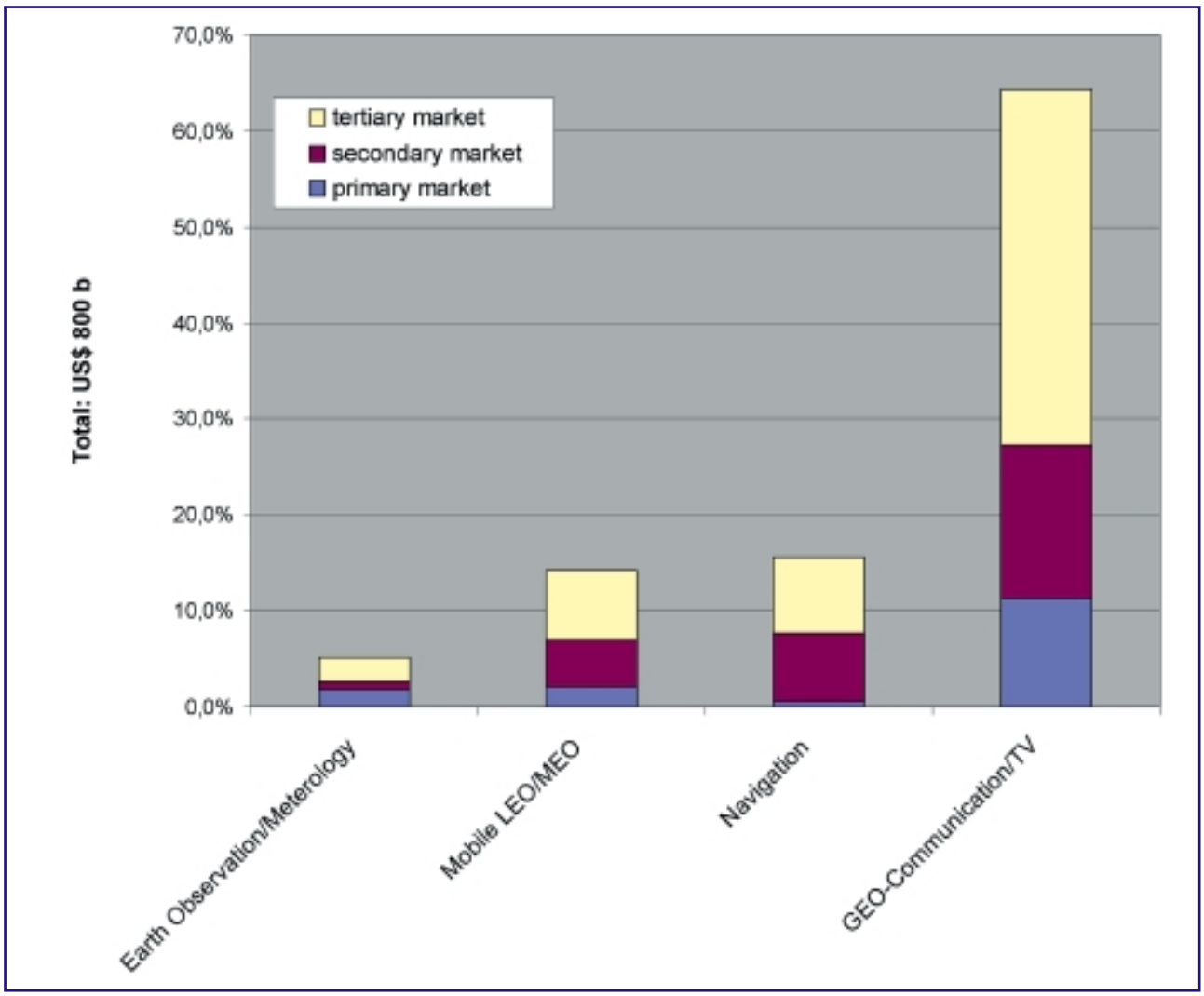

Figure 3: Evolution of primary, secondary and tertiary markets to 2006 (the elements cannot be divided with any confidence) (Source: Euroconsult, DLR)

The German Space Programme is based on the following **general programme objectives**:

- **Societal objectives:** Taking the necessary action to maintain the material basis for human existence is an ongoing, high-level duty for governments. Space activity can and must make a major contribution to such action in the fields of meteorology, environmental monitoring, disaster prevention and management, resource management, mobility and the preservation of peace. The aim of this space programme is to expand the resources available for these purposes, both qualitatively and quantitatively, and ensure those resources are used. Space activity is also particularly well suited to encouraging young people to acquire a scientific or technical education.
- **Economic objectives:** State support for space research will increasingly be directed at projects offering economic opportunities, with applications and utilisation potential. This will help firms working in the space sector build on the potential of the space industry to develop products and services that will create significant new commercial markets on a global scale. This will not only consolidate employment in the high-tech sector but also create new high-quality jobs. The German Space Programme should promote and support this process, this being the area of space activity in which the greatest growth can be expected.
- **Scientific objectives:** The unique capabilities of space technology should be exploited to achieve groundbreaking new insights into the nature of our planet and the universe. The key criterion for support is the scientific excellence of the projects concerned. Technological spin-offs can thus be generated, profiting other scientific and economic areas. For it is one of the aims

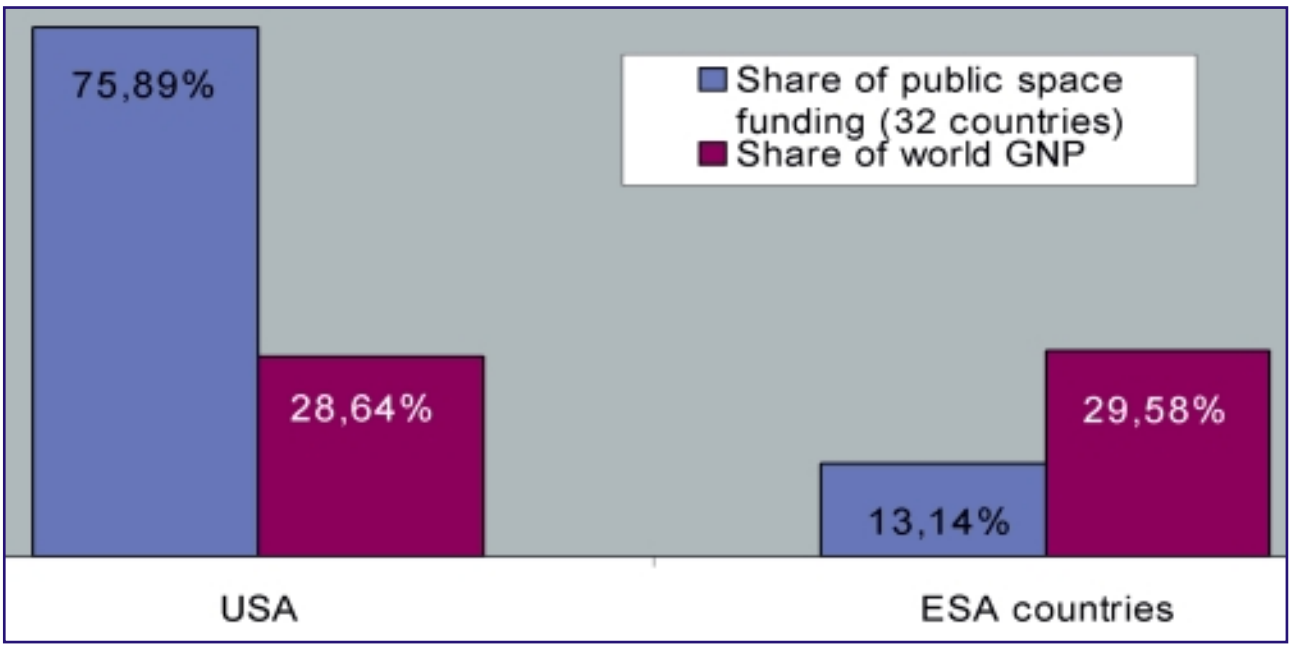

Figure 4: Relative space expenditures and economic potential (1998) (Source: Euroconsult, Worldbank)

of space activity to modify the image men and women have of themselves and of their place on Earth and in the Universe. Space is also about overcoming existing limits and awakening a thirst for knowledge as a driver for further progress.

The German space community is faced with the challenge of reacting to rapid and far-reaching changes by constantly redefining its objectives and adapting its ongoing and planned activities to the new conditions. Many of the necessary measures to be taken will have implications for some or all of the overall objectives already identified.

They can be grouped under four action areas, as set out below:

I Space – concentration on benefit and utility

II Space and Europe – concerted action

III Space globally – co-operation and competition

IV Space – doing more by improving efficiency

Having identified these principal action areas, it will be possible to draw up a detailed road-map not only to meet the anticipated challenges over the next decade but also to actively shape future developments.

I Space – focus on benefit and demand

Space activity seeks to furnish the necessary infrastructure to achieve societal, economic and scientific goals.

Future projects will be given priority if they offer concrete solutions to specific problems. They will have to form part of an identified value-added chain or address fundamental scientific questions. The „end user" must in all cases be identified. Actual demand and utility will be the governing criteria rather than a project's technical attractions.

The emphasis on demand and utility requires a high degree of involvement by, but also co-responsibility of, space system and space services users at an early stage in the design, funding and implementation of space projects. Some of the more important user groups are:

– federal government agencies that rely on space-based services;
– regional and local authorities;
– universities and research institutes; and
– commercial entities, and in particular industrial and service companies.

Space activities should be concentrated on promising areas in which Germany enjoys a leading position or

where there is a real prospect of achieving such a position.

German industry has the capabilities and must be involved in exploiting the growth potential of new space markets. The goal of the German Space Programme is to significantly augment German industry's share of the world commercial space market, partly through public-private partnership. In co-operating with the private sector a major concern will be to develop the concept of **public-private partnership** as a way of opening up and securing a place in commercial markets.

Public-private partnership is clearly distinct from the models that have prevailed hitherto – relationship between commissioning authority and contractor or between the body awarding a subsidy and the recipient thereof. Such partnerships are for a limited period of time and are specifically directed at achieving the aims of the project. They are characterised by:

- clear economic potential that cannot be realised without state involvement ;
- close co-operation in a partnership determined by a community of interests;
- project implemented in the light of the commercial goals;
- management responsibilities determined with reference to the commercial environment, the agreed risk-sharing arrangements and the partners' financial commitments;
- continuous monitoring of current market conditions in relation to the projected return on investment, primarily on the part of the industrial partner;
- contractually binding relationship between the partners.

By relying on the PPP model of project management, projects will be designed to meet the criteria of demand and economics. The PPP model increases industry's and users' participation in funding and promotes risk-sharing, helping to relieve the pressure on the public space budget and freeing resources for attractive new ventures. At the same time the state enters into a longer-term commitment, which may extend beyond the development phase.

Technologies, processes and products developed in the space sector have a potential for enhancing competitiveness in other areas. Such potential needs to be identified early on in design and development and corresponding action taken where appropriate. All technology transfers should be guided by market demand; all necessary support measures should be taken, including assistance with marketing and financing.

II Space and Europe – concerted action

Increasing concertation of European space efforts is part of the political development of Europe, and is necessary to meet the global competition. For this reason, the common European space activities remain at the centre of Germany's efforts. Numerous successful joint projects have made Europe a space leader. In recent years, however, the situation has changed fundamentally, marked by increasing global competition and commercialisation, for example. The consolidation of the European space industry under the influence of tougher competition is rapidly creating larger organisations.

Development of European strategy is particularly important for Germany, which already carries out about 70 % of its space activities in an ESA framework (see Figure 1 on page 9) – unlike the other major partners, Italy and France. This is why Germany involved itself in this process at an early stage, incorporating the following basic positions in European space strategy:

- greater co-operation between and integration of all European space programmes;
- reorganisation of co-operation arrangements between the main players, such as the EU, ESA and the national agencies;
- creation of a European network of public centres;
- greater emphasis in applications programmes on user demand and the market, through public-private partnerships in particular;
- further increases in efficiency;
- further development of industrial policy, with a view to encouraging internal European competition and to strengthening the SME/supply industry sector;
- negotiation of fair trading regulations at world level;
- full use of the space resource to pursue co-operative policies in Europe (e.g. Global Monitoring for Environment and Security, GMES, or the Global Navigation Satellite System, GNSS).

As a European organisation responsible for long-term satellite missions, EUMETSAT is in this connection acquiring increasing importance in the area of Earth

observation from space. As the largest contributor to EUMETSAT, Germany is actively shaping the future EUMETSAT programmes to meet the above demands.

The EU and ESA

- Science and infrastructure programmes presently constitute the bulk Germany's contribution to ESA. Programmes with a scientific content, i.e. deep-space exploration, earth observation for scientific purposes, and basic research in microgravity conditions, should be allowed to develop continuity and greater autonomy in the framework of a mandatory programme.
- Applications programmes conducted in an ESA framework should be arranged in the light of the programme's specific demands, with decision-making processes and organisational forms adapted to the requirements.
- Within the EU programmes, applications and market-oriented projects must be allowed to develop more freely with a view to strengthening the competitiveness of the European space sector at world level.
- A longer-term aim is to bring ESA closer to the EU in organisational terms. This will provide scope for ESA to act under delegation from the EU. First steps in this direction will have to include co-operation on joint projects, especially Galileo, and management by ESA, under delegation from the Commission, of Commission-led space activities.

European National Space Agencies

The consolidation process initiated by the industry should lead to a corresponding movement on the side of the agencies, as part of the continuing political integration of Europe. This movement will go from strictly strategic co-ordination to a co-ordinated space network of technical centres and ultimately to a thoroughgoing division of labour with dedicated centres of competence. The priorities are as follows:

- In the short term, the public space agencies must work to achieve closer strategic co-ordination, against the background of industrial consolidation. This could be done through the creation of space forums, to contribute to the assessment, harmonisation and integration of sector-based programmes, of technology development lines and strategies.
- In the medium term, a co-ordinated network of public-sector space facilities should be set up in the form of a European competence centre system or "union of centres".
- German centres having systems capabilities are essential to complement the core capabilities of German industry in selected areas (Earth observation, scientific satellites, operation and utilisation of manned and unmanned systems are some examples).

The consolidation of the European industry

The process of consolidation which the European industry is undergoing in a drive to make it more competitive on a global basis must be supported while protecting the interests of German industry. With growing concentration there is a need to ensure healthy competition and functioning market mechanisms. For this reason:

- the established core specialisations of German subsidiaries of European space concerns should be maintained and strengthened;
- the further development of suppliers and SMEs, through product specialisation and occupation of attractive niche markets for instance, should be encouraged in order to ensure they are competitive in their dealings with large system firms operating on a global basis;
- action should be taken to allow suppliers and SMEs to compete at sub-system, component and equipment level;
- industrial policy and support measures and the associated rules, particularly where support for SMEs is concerned, should be harmonised in Europe;
- ESA's machinery to guarantee industrial return should be brought gradually into line with EU industrial and support policy;
- public-private partnership models in commercially promising areas should be applied in a uniform way in Europe.

III Space globally – co-operation and competition

The goals of the German Space Programme represent major scientific, engineering, industrial and economic challenges. These can only be met by combining efforts through European and also international co-operation. The aim must be to promote German interests on a global scale through the framework of a European space strategy.

Germany will continue to pursue its objectives in such non-commercial space activities as space exploration,

space science and manned spaceflight, relying on long-term partnerships. In so doing, it will be important for German or joint European co-operative inputs to be substantial and significant components of the missions concerned.

Germany must remain a serious participant in the increasingly competitive world-wide markets for space services, as it is in other export-oriented industries. For this objective to be realised, it is important to

- concentrate on activities with a considerable strategic or economic potential and an established strong position of the German economy,
- accompany the process of consolidation of European industry by a common European industrial policy and a harmonised regulatory framework,
- work towards the recognition of conditions for fair competition on a world-wide basis, and
- form strategic national and industrial alliances as necessary.

IV Space – doing more by improving efficiency

At the May 1999 ESA ministerial conference the priority of applications and utilisation was recognised, with key decisions taken on space transportation, earth observation and navigation. This orientation will be followed through in the national programme with the reference projects („Leitprojekte") in the areas of multi-media and Synthetic Aperture Radar (SAR) technologies, with Rapid Eye, with the ASTRA space transportation technologies project, and with the increased emphasis on robotics. New projects must and will be accommodated in the medium-term budget framework.

This is why one of the primary goals must be to use the available resources economically and efficiently. To achieve this end, the following measures are recommended:

- a European network of centres of competence will promote rationalisation;
- European and national activities should be focussed and closely co-ordinated;
- users and operators must become more involved in space projects by playing a greater role in programme conception and assuming part of the financial responsibility (PPPs);
- competition should be encouraged in all phases of research, development and innovation by opening up the bidding process to suppliers and SMEs in particular;
- the principle of "design to budget" should be strictly respected for project management;
- impediments to efficiency should be removed (geographic return and automatic adjustment for inflation);
- costs should be reduced through performance-based incentives;
- subsystems and interfaces should be standardised and off-the-shelf components used wherever possible; and
- public operation should be transferred to industry wherever significant and lasting cost advantages may be expected to result.

3. Programme objectives

In what follows the strategic outlines of the core programmes are linked to the overall objectives developed above. For each of the eight core programmes, namely:

- **telecommunications,**
- **navigation,**
- **earth observation,**
- **space exploration,**
- **microgravity research,**
- **space station,**
- **space transportation, and**
- **space technology.**

a detailed account is given separately, together with operational objectives and milestones.

Broadly grouped under „applications technologies", **telecommunications, navigation and earth observation** offer the best prospect for obtaining leverage on public support for private-sector initiative, taking into account the complete value-added chain. Germany's commitments in this area must be guided by her economic and political interests.

- The emphasis in **telecommunications** is on broadband multimedia applications. COMED and optical satellite-to-satellite links will be important demonstration projects, with crucial technologies and components being developed to allow German industry to gain market entry and to create or consolidate its competitiveness

on world markets; the goal is to significantly increase Germany's share of the world market for satellites systems and components within five years.

- In **navigation**, Germany's space programme is aimed primarily at construction and utilisation of the European satellite navigation system, **Galileo**. A high degree of private-sector involvement is desired. With a significant degree of involvement by Germany, it is hoped that German and European industry will capture an appropriately large share of the rapidly growing, lucrative market for navigation services. Here, too, a sector responsible for substantial added value must be directly supported by developing technologies for ground equipment and for services under national programmes.
- **Applications-oriented Earth observation** is concerned with the development or further development of publicly-funded systems in the METOP and MSG series for meteorology and oceanography, with continuous environmental monitoring and with security-related reconnaissance. It is concerned also with the development for private-sector exploitation of operational and commercial applications for new markets and data services, such as cartography for agriculture and forestry, precision-farming, prospecting for raw materials, land resource management and disaster monitoring. Public support of commercial activities will give high priority to implementation of a satellite radar concept, which would be designed jointly with partner countries in Europe and would involve the national industries in a PPP framework. In the field of optical technology, the Rapid Eye system, again a public-private partnership venture, should shortly be going ahead. A satellite radar system and Rapid Eye could in the future become integral parts of a European global Earth observation system (Global Monitoring for Environment and Security, GMES). This initiative is concerned with the monitoring of international environmental agreements and the observation of factors that influence the environment.

There is a long tradition of **scientific study** of the structure and nature of the universe, including planet Earth, from the superb vantage point offered in space. Germany can point to major successes in this area, examples being the X-ray telescope ROSAT or again the ERS 1 and 2 environmental satellites. This track record will be added to as from late 2001 with the XMM X-ray satellite and the ENVISAT environmental mission. Scientific missions, with their advanced engineering, act to stimulate technical progress and have an important spin-off potential. The scientific use of space also possesses cultural relevance, with its profound influence on humanity's worldview. Even more than in the past, space-based scientific research must be seen as a complement to and extension of Earth-based research, and must be measured by the criterion of „scientific excellence".

- **Exploration of the universe** seeks to improve our understanding of the origin, structure and evolution of the universe as well as illuminating our own origins and the conditions and future prospects of life. Observatories in Earth orbits have unimpeded access to the full electromagnetic spectrum for studies of cosmic objects, being free of the influence of the Earth's atmosphere. Space probes explore distant objects, extending to direct contact or landings on planets and comets. Future astronomical research will address questions regarding the evolution of stars, galaxies and the universe as a whole, relying on observations made in different parts of the spectrum, especially the infrared and the gamma and X-ray spectrum. Within the solar system, it is the study of Mars which is of particular interest at present: comparative planetary studies promise to shed light on the evolution of the Earth-like planets and hence also of the Earth itself. Solar observation remains an important research area. The search for planets outside the Solar System that are capable of supporting forms of life similar to ours will gain momentum, relying on new technologies that are also required to answer fundamental physical questions such as the existence of gravity waves.
- **Microgravity research** involves the transfer of terrestrial laboratory facilities into the unique conditions of space, in particular microgravity and cosmic radiation, for life and materials science experiments and development work. The mainstay of this research, alongside the continued use of unmanned flight opportunities, will be the International Space Station, acting as a 'laboratory in space'. Life sciences research is focussed primarily on exploring human organ and system functioning and their interaction as the body adjusts to weightlessness. The knowledge gained will have great significance for routine clinical diagnostics and treatment procedures (e.g. telemedicine). Materials science research centres on detailed investigation of solidification processes and fundamental mechanisms in combustion. The aim here is to reduce the cost of developing innovative materials, optimise production processes on Earth and develop more effecti-

ve, more environmentally acceptable combustion processes. Work on three-dimensional colloidal plasmas (plasma crystals) – a state of matter still unknown only a few years ago – should, in addition to the fundamental aspects, generate longer-term applications potential for plasma processes in the field of technology.

- **Scientific Earth observation** aims at furthering basic scientific research into the conditions required for preservation of the ecosystem, studying for example the mechanism and the rate at which the stratospheric ozone layer is thinning, or the influence of man-made factors on global atmospheric warming. In addition, it prepares the way for the introduction of new operational Earth observation applications, primarily for meteorology and for environmental research and monitoring. Significant and continuing involvement in ESA's Earth observation programme is the priority. A major feature of the national support programme, in addition to complementary missions, is data processing, validation and calibration for users. In the DLR's internal R&D programme the focus is on data collection, processing and scientific evaluation thereof.

The construction of a **space infrastructure** is a task whose proportions, complexity and cost can only be dealt with in the framework of international co-operation, preferably on a European scale. For this reason, infrastructure projects will remain among the core activities of the German space effort within Europe.

- Europe and Germany are involved in the **construction and operation of the international space station** (ISS). Europe's share of total station costs is approximately 6%, and Germany is shouldering a major part of this, at 41% of the total cost of European development. This German contribution to ISS development, decided in 1995, is currently constraining Germany's ability to promote future-oriented projects with applications and growth potential. In the operational and utilisation phase, Germany's contribution will need therefore to be scaled down. Existing commitments will be respected. In addition to the important development role played by German industry, German facilities will perform important operational tasks. To improve efficiency and reduce the public sector's share of the risk carried, it is intended to delegate a large share of operational responsibility to private industry. It is imperative that Europe's contribution remain within the limits set forth for the programme, in particular the agreed cost envelope. For the second phase of ESA's ISS exploitation programme, on which a decision has yet to be taken, the aim is to increase involvement of other Member States in order to broaden utilisation potential and share the financial load.

  The success of this project depends on the space laboratory being integrated in the ground-based research infrastructure and resources being used intensively and efficiently. To create a stronger incentive for private-sector involvement, Germany will strengthen its promotion of user-funded research.

- For **space transportation** the main objective remains the preservation of Europe's autonomous access to space on a competitive basis. In the Ariane programme, at the heart of Europe's space transportation activities, the responsibility for responding to market demands (cutting production costs, improving mission flexibility and reliability, increasing launch capacity) should increasingly be transferred to industry. Germany's contribution to the continuing development of the Ariane launcher family within ESA is intended to protect Germany's substantial share of development and production work and the high-tech employment it involves, consolidating Germany's role as an indispensable partner for Europe's space transportation programme.

  For the future generation of space transportation vehicles, a major reduction of launch costs is the main goal. It seems likely that this can be achieved only through partly or fully reusable systems. Efforts should be directed towards achieving the leadership role which Germany can be expected to play within Europe in stage design, high-performance structures, control systems and propulsion components. Aerodynamics and propulsion will be the key to retaining system capability in the future; more use must be made of the expertise that is represented in German universities, in particular the DFG (Deutsche Forschungsgemeinschaft) research areas, and within the DLR itself. For this reason, much of this work will be conducted at the national level during the early stages. It is on the basis of such work that Germany will have a full voice in designing new European launcher systems.

  In the final analysis it will be market promise and costs, i.e. private-sector considerations, that will decide on the future of an expanded family of European launchers, including smaller vehicles. As far as Germany is concerned, this could be achieved using existing systems, such as the German-Russian joint venture Eurockot, within the framework of a reorganised Arianespace company.

- In **space technology** Germany's accomplishments as a leader in robotics design must be oriented to meet the projected demand in the space sector. This will make it possible to relieve the routine workload on the astronauts working in the space station and to replace them for some of the hazardous EVA work. It can also act as the stepping stone to future applications such as roving robot satellites used to maintain and repair satellites and space stations and highly autonomous systems that will be capable of exploring the surfaces of other celestial bodies. There is a great potential for non-space spin-offs from such systems and technologies. A mission in one of the named areas, for example in the framework of international space station utilisation, can only be accomplished by way of international cooperation between specialised bodies, due to the high demands for resources.

4. Programme organisation and allocation of resources

The complete German Space Programme, including the European programmes (ESA and EUMETSAT), the national programme (project support) and the DLR's R&D programme, works within a framework of eight core disciplines (Figure 5).

Unification of programme planning

With the DARA-DLR merger completed, the organisation is ready to pursue a single strategy encompassing all three areas of German space activity. While the three funding channels remain strictly separate, the management of future core programmes will aim at achieving the closest possible co-ordination of the individual programme elements, focussing their content and exploiting the respective strengths as part of a harmonised overall programme.

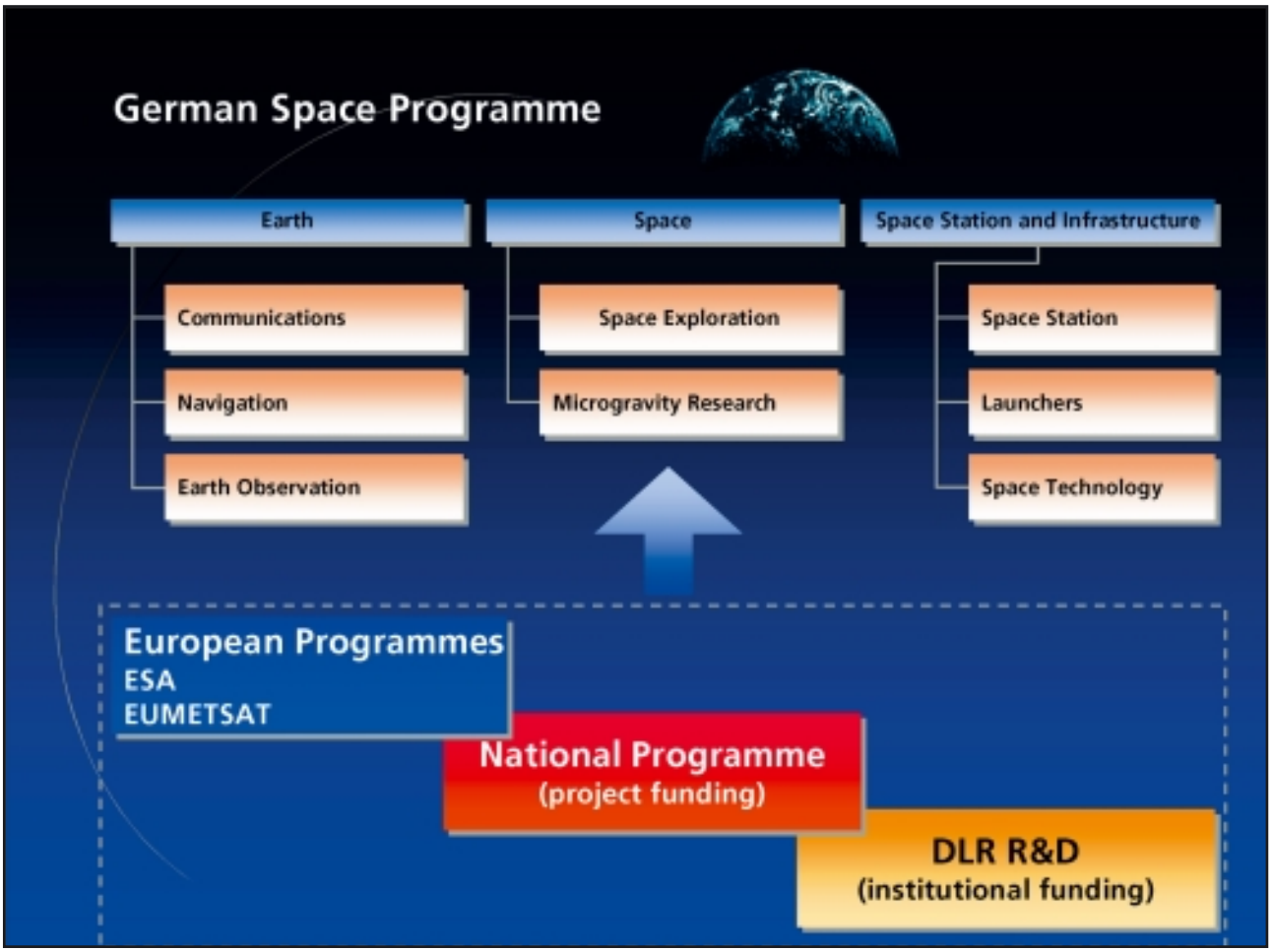

Figure 5: Organisation of the German Space Programme

The DLR's space R&D programme serves the public goal of planning for future needs and tasks, in particular for environmental protection, security, communications and transportation support services. There is thus a commonality of objective with the national programme, and both their evolution will be even more closely co-ordinated. The DLR's R&D programme is primarily concerned with development of space technologies in response to concrete requirements and market demand; it includes developing operational and support tasks and their transfer to the German industry. The DLR's institutes also make their own, highly respected contributions where their individual areas of scientific endeavour are particularly promising.

German universities and other public research institutions play an independent and indispensable role in Germany's overall space effort. Thus, they perform the vital function of educating future generations of scientists and introducing them to real-life practical projects. Those institutions have been involved in intensive discussions of the contents of the German Space Programme and will participate in advisory bodies and DLR strategy workshops in the interest of achieving greater harmonisation of all German space activities.

Funding and allocation of resources

Figure 6 shows annual average spending under medium-term financial plans for the period from 2000 to 2004. Spending funds come from various sources:

- The German contribution to ESA is largely funded out of the Education and Science Ministry's (BMBF) budget. Funding for some projects is also provided from other budgets; in particular, the transport ministry

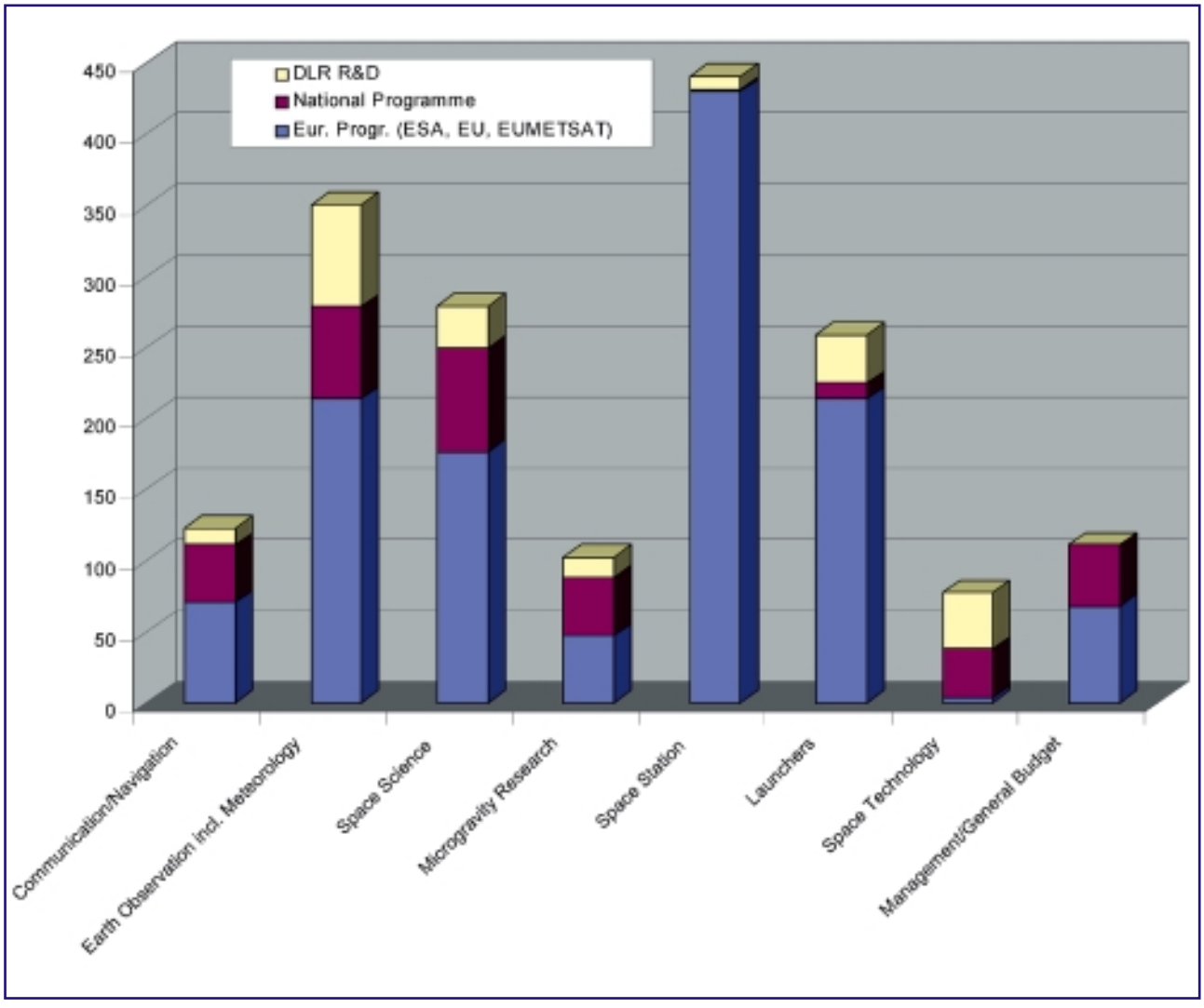

Figure 6: Annual programme expenditures (million DMs) averaged over the planning period 2000-2004

(BMVBW) contributes to funding for the Meteosat and Metop meteorological satellite programmes, to the budget of the operating organisation EUMETSAT and to construction of the Galileo satellite navigation system. Programmatic priorities and funding allocations for the medium term were established at ESA's May 1999 ministerial conference. Figure 6 on page 20 shows the allocation of average German contributions amongst European programmes from 2000 to 2004.

- The national programme is funded out of the Education and Science Ministry (BMBF) budget. Most of this spending is in the form of contracts and payments awarded for projects or programmes in German industry or research institutions. The national programme offers more possibilities for activities in support of national interests than does the ESA programme. It includes the costs for Germany's space management.
- The DLR's R&D activities are funded out of the budget of the Education and Science Ministry, out of Defence Ministry (BMVg) funds and by contributions from the federal Länder, the latter amounting to some 10% of overall funding. The DLR's spending is grouped into the four principal research areas: space, aviation, energy and transportation.

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