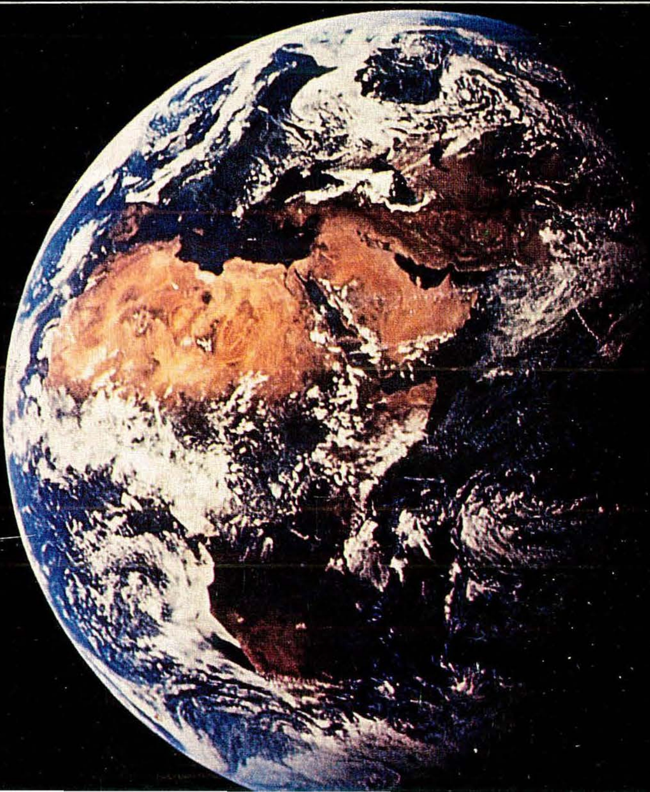
EUROPE'S FUTURE IN SPACE

A Joint Policy Report

'Clingendael' · DGAP · IAI · IFRI · RIIA



CHATHAM HOUSE SPECIAL PAPER

EUROPE'S FUTURE IN SPACE

CHATHAM HOUSE SPECIAL PAPER

EUROPE'S FUTURE IN SPACE

A Joint Policy Report

Forschungsinstitut der Deutschen Gesellschaft für Auswärtige Politik (Bonn)
Institut Français des Relations Internationales (Paris)
Istituto Affari Internazionali (Rome)
Nederlands Instituut voor Internationale Betrekkingen 'Clingendael' (The Hague)
Royal Institute of International Affairs (London)

The Royal Institute of International Affairs

Routledge & Kegan Paul
London, New York and Andover

The Royal Institute of International Affairs is an independent body which promotes the rigorous study of international questions and does not express opinions of its own. The opinions expressed in this publication are the responsibility of the authors.

First published 1988
by Routledge & Kegan Paul Ltd
11 New Fetter Lane, London EC4P 4EE
29 West 35th Street, New York, NY 10001, USA, and
North Way, Andover, Hants SP10 5BE

Reproduced from copy supplied by
Stephen Austin and Sons Ltd and
printed in Great Britain by
Redwood Burn Limited,
Trowbridge, Wiltshire.

Library of Congress Cataloging-in-Publication Data

Europe's future in space : a joint policy report [Forschungsinstitut der Deutschen Gesellschaft für Auswärtige Politik et al.].
p. cm. – (Chatham House special paper)

ISBN 0-7102-1444-8

1. Astronautics and state – Europe.
I. Deutschen Gesellschaft für Auswärtige Politik, Forschungsinstitut.
II. Royal Institute of International Affairs.
III. Series.
TL789.8.E9E886 1988
387.8'094 – dc19 *87-27009*
CIP

CONTENTS

CONTRIBUTORS

This report was prepared by the following members of the participating institutes:

Forschungsinstitut der Deutschen Gesellschaft für Auswärtige Politik (DGAP)
Institut Français des Relations Internationales (IFRI)
Istituto Affari Internazionali (IAI)
Nederlands Instituut voor Internationale Betrekkingen 'Clingendael'
Royal Institute of International Affairs (RIIA)

Admiral Sir James Eberle, Director, RIIA
Professor Karl Kaiser, Director, DGAP
Eva Kulesza, IFRI
Dr Pierre Lellouche, IFRI
Dr Cesare Merlini, President, IAI
Dr Thierry de Montbrial, Director, IFRI
Professor Henk Neuman, Director, Clingendael
Dr Stefano Silvestri, IAI
Dr Helen Wallace, RIIA
Dr Stephan Frhr von Welck, DGAP

Several experts assisted our deliberations by submitting written papers to our meetings:

Dr Jacques Battistella, Matra
Professor J. A. M. Bleeker, Utrecht University and SRON
Dr Roberto Cajati, IAI
Dr Wolfgang Finke, previously in the Federal Ministry for Research and Technology, Bonn

Carol Geldart, RIIA, rapporteur
Keith Hayward, North Staffordshire Polytechnic, rapporteur
Dr Hans M. Kappler, MBB-Erno, Bremen
Dr Mahindra Naraine, Lancaster University
Dr Geoffrey Pardoe, General Technology Systems Ltd

Many other experts helped us by commenting on drafts at meetings in Colleferro and London:

Ing. Stefano Abba', Space Division, Aeritalia
Peter W. Bauer, Planning Staff, Foreign Office, Bonn
Ing. Giorgio Bianchi, Selenia-Spazio
Dr Walter Brado, Head, Office of the Director-General, European Space Agency
Professor Carlo Buongiorno, Ministry for Scientific Research and Technology, Rome
Wing Cdr Christopher Carrington, Ministry of Defence, London
Jean-Pierre Contzen, Director-General, Joint Research Centre, Commission of the European Communities
Ing. Giuseppe Grande, SNIA BPD
Dr David Green, Butterworth Scientific
Ken Inglis, British National Space Centre
Pat Knight, British Aerospace
Jack Leeming, British National Space Centre
Dr Peter Linssen, Dutch National Aerospace Institute
Reinhard Loosch, Federal Ministry for Research and Technology, Bonn
Professor Luigi Napolitano, University of Naples and Telespazio
Dipl.-Ing. Wolfgang Pittelkow, Dornier System GmbH, Friedrichshafen
Captain Naquet Radiguet, Ministry of Defence, Paris
Y. Rebillard, Centre National d'Etudes Spatiales
Dr Trevor Roberts, British National Space Centre
Dr Alain Simon, Centre National d'Etudes Spatiales
Rear-Admiral John Slater, Ministry of Defence, London

PREFACE

The five institutes of international affairs of France, Germany, Italy, the Netherlands and the United Kingdom, building upon their tradition of close cooperation and previous joint studies (see, in particular, *The European Community: Progress or Decline?*, 1983), have here come together to analyse the challenges which space presents to Western Europe, to review Europe's achievements and potential, and to develop proposals for action.

The institutes were able to enlist the support of the Commission of the European Communities, the Fritz Thyssen Stiftung (Cologne), the Algemene Loterij Nederland (The Hague) and the Sijthof Estate (The Hague). Our institutes would like to express sincere thanks for their help, without which this collective work would not have been accomplished.

A working group, composed of authors augmented by advisers, met in Paris, Bonn, Collefero, London, Friedrichshafen and Barcelona to draft this joint report. We owe a special debt of gratitude to Dr Helen Wallace, who cheerfully accepted the extra burden of creating a modicum of coherence out of rough texts originating from a variety of disciplines and linguistic backgrounds. Warm thanks are also due to the many people who have typed, translated and edited successive versions of the manuscript.

The report falls into three parts. Part I reviews the relevance of space to Europe, then examines the space programmes of the world's major space powers and concludes by analysing West European achievements at both the national and the multilateral level. Part II offers a detailed analysis of all the possible uses of space, such as communications and security, and of the available means, such as launchers, satellites and space stations. Part III draws up a balance-sheet of Europe's strengths and weaknesses in space, defines European priorities for future action and concludes with our recommendations for a European space policy.

The reader who is short of time may wish to concentrate on the Summary, on the analysis of the relevance of space in Part I and on the three sections of Part III, in particular the recommendations. A glossary has been provided for the non-specialist.

Monetary units are expressed, wherever possible, in European Accounting Units (EAU), which is the accounting unit used by ESA and is approximately equivalent to the European Currency Unit (ECU).

We would like to make it clear that the opinions expressed in this report are merely those of the individuals responsible as authors and not those of the institutes with which they are associated.

Bonn, The Hague, London,
Paris, Rome, September 1987

J.E.
K.K.
H.N.
C.M.
Th. de M.

SUMMARY

The extent to which nations or groups of nations are able to explore and exploit space will increasingly determine their standing and influence in the world of tomorrow. The five institutes of international relations of France, Germany, Italy, the Netherlands and the United Kingdom, after reviewing Europe's record in space, reach the conclusion that Western Europe can take pride in a number of impressive achievements. But it does not achieve its full potential. A quantitative and qualitative jump is necessary towards a truly collective space policy, if Western Europe is to have anything more than a walk-on part in the world.

The global economy and the nature of international society are changing rapidly, precisely for the reason that satellites transform the flow and availability of information. Among the various applications of space, *telecommunications* was the first, after weather forecasting, to demonstrate the commercial value of space. New techniques and technologies are now being fast developed, and will be put to several uses, including search-and-rescue and direct broadcasting. Space technologies foster the flexibility and innovation required to create new jobs and promote economic modernization.

Remote sensing permits both the specialized mapping of land masses and the monitoring of the atmosphere and of the physical conditions on the sea's surface, thus providing an inventory of a wide range of resources. Satellites will in the future help to satisfy the economic and social needs of developing countries. *Space science* is continually adding to mankind's knowledge of the origin and

evolution of our solar system. Microgravity conditions permit experiments and processes which will subsequently have applications on Earth. The *industrialization of space* will provide important economic opportunities.

The uses of space for *security* purposes are self-evident. Satellite-based technologies are already essential instruments for reliable military communications, for the transparency of the strategic balance and for the verification of arms control agreements. These technologies may well prove to be a key to international stability.

Nations or regions wanting to strengthen their contribution to the *cultural life* of the world will find a new opportunity to do so through the use of space.

From a brief survey of the space programmes of the main *non-European countries*, it appears that the two leading space powers, the Soviet Union and the United States, spare no effort or expense to forge ahead in this area of human endeavour. Japan, and also less affluent powers like the People's Republic of China and India, have dynamic space policies; they are perfectly open about their ultimate goal of becoming independent.

An analysis of the space programmes of France, the Federal Republic of Germany, Italy, the Netherlands and the United Kingdom shows that *European space activities* have so far been carried on within a double framework, part national – serving particular political, economic or security purposes – part collaborative, first in ELDO and ESRO and then, since the mid-1970s, under the aegis of the European Space Agency, ESA, a unique example of a multinational space organization. ESA's contribution to the development of a collective European space capability has been fundamental.

In Western Europe, scientific research has been a primary field of space exploration and one in which European states and organizations have been particularly successful. Western Europe has also managed, in a relatively short time and with limited means, to achieve notable results in space technology and space industry, of which the development of a family of indigenous European launchers is an essential part.

On balance, however, it seems clear that European space efforts fall considerably short of a truly effective joint policy. No single West European nation can muster sufficient resources to become what only Europe collectively can be: an autonomous space power.

Europe is not held back by scientific obstacles or intrinsic inferiority. Its financial, technological, industrial and human *potential* is on the same scale as that of the United States or the Soviet Union. The problems are those of approach, purpose and the best use of resources. There is a persistent fragmentation of effort and a relative shortage – compared with the dominant powers – of resources devoted to space activities. The objectives lack sharpness of definiton, and the time perspective is too limited. The public as an end-user is not sufficiently aware of the extent of services provided by current space activities, especially communications, meteorology and other information flows. Few people realize that in many European countries the savings resulting from satellite use for telephone links often exceed the total cost of national civilian space programmes. There is no real appreciation among the broad public of the value of Europe's presence in space. This sometimes shades into a wider public disenchantment with high-technology ventures, both military and civilian.

The nub of the problem is, however, that it would be extremely short-sighted for Western Europe to look at the matter only from the accountant's point of view. The *balance-sheet* must include the foreign policy and security dimensions for a Europe moving into the twenty-first century, the cultural impact and links with developing countries. Space offers an area in which two of the most important aspirations of Western Europe come together: unification and the promotion of high technology. Access to crucial technologies via other powers cannot be taken for granted. European security interests are not coterminous with those of the United States, and an independent source of reconnaissance data is a necessary complement to US-derived information. The course of action to be taken is outlined in the final part of this report.

The ESA member states have committed themselves to achieve *autonomy in space*. This should mean that Europe develops a capability to reach, operate in and return from space, and to do so not on sufferance of friend or foe, but according to its own perception of what is to the common good. This requires indigenous launchers for manned and unmanned transport into space, an independent space station that could be manned and that would be a highly visible symbol of Europe's capabilities and common will, and an adequate system of relay and other satellites and ground infrastructure. Implementation of ESA's Programme of Action is, therefore, the indispensable minimum.

But *more is needed.* Europe should, in order to have its own eyes and ears in space, develop and operate a joint reconnaissance satellite system in low earth orbit for safeguarding its political and diplomatic interests, as well as for arms control verification, the monitoring of military movements and crisis control. This system should be based on existing remote-sensing techniques (optical and microwave) and could be complemented by a jointly operated electronic intelligence-gathering package.

In order to protect its satellites against potential Asat threats, Europe should actively prepare for and participate in negotiations on a code of conduct for the peaceful uses of space, based on a regime of confidence-building measures and rules for space use. At the same time, Europe should study means of protection for its satellites in the context of the right of self-defence.

Europe should maintain a *strong scientific programme* to improve its position in the exploration of the universe. The ESA programme 'Horizon 2000' points in the right direction and deserves full support by the European governments.

Greater *economic efficiency* should be sought by urgent efforts to improve the competitiveness of the space sector and to liberalize markets. Europe must deregulate, unify its internal market, europeanize public procurement, consolidate viable transnational consortia of space companies, supply a larger share of the home market for the ground segment, and improve its capacity to bid successfully for international contracts.

Over time, ESA should consolidate its role as the central policy-making body for Europe in the civilian field, as well as representing Western Europe vis-à-vis the rest of the world.

The development of European security collaboration in space should not wait for, but will eventually require, an appropriate institutional framework. A strengthened WEU may become the focus of such collaboration.

The implementation of the recommendations outlined in this report would require approximately the doubling in volume terms of the current level of annual European expenditure up to the year 2000. This would provide the resources for our recommended ESA plan, a new European security programme and continued national expenditure. This figure of on average about 4.5 billion EAU per year over 13 years, while considerable in absolute terms, would represent only about one-quarter to one-fifth of current US spending – a reasonably modest price to pay for European autonomy.

These and other practical measures will achieve their goals only if they reflect the political will of West European governments to look – and to have their publics look – upon space policy as crucial for the future definition of Europe's political role vis-à-vis the other major space powers and, indeed, the world.

Part I
WESTERN EUROPE AND SPACE POLICY

1

THE RELEVANCE OF SPACE TO EUROPE

Space: a European horizon

Western Europe has to confront some hard decisions about whether it wishes to operate as a major actor in space, a field of human endeavour which will play a growing role in determining influence, prosperity, technological achievement and security in the global environment of the twenty-first century. If Europe, where the roots of modern technological civilization lie, does not realize its potential in this field in contributing significantly to the conquest of mankind's last empty space, it abdicates as a major actor in world politics. Influence on the future international space regime will be wielded only by those who have real space assets. The challenge of space can be met only with a common European effort. No single West European nation can muster sufficient resources to be an autonomous space power. Indeed, space is a major area in which Europe can consolidate a common identity and develop its unity.

The global economy and the nature of international society are changing rapidly, not least because new means of communication and information have developed, in which satellite links play a crucial part. In the field of security, satellite-based technologies open the way to increasingly sophisticated military communications, reconnaissance, intelligence and verification of arms control agreements. The exploration of space thus creates new economic opportunities, promotes industrial innovation, makes new services possible and provides new instruments for foreign, cultural and overseas development policies.

Europe has come to a crossroads in its space policy. A quantitative and qualitative jump in European space efforts would be required to respond to the challenges outlined here and to harness the benefits which lie ahead. Western Europe has achieved impressive successes, including the Ariane launcher, the 1986 Giotto mission and many other satellites, but its all-round performance woefully lags behind the space efforts of the United States and the Soviet Union, not to mention the emerging challenge of competition from China, India and Japan. Only 40 of the total of 3,500 satellites in orbit at the end of 1986 were European. Political, economic and organizational constraints, including persistent national blinkers, prevent a better European performance. The continuation of European policy at current levels is likely to make Western Europe marginal in the space politics of the next century. The Europeans initially missed many opportunities in space. Thanks to the European Space Agency (ESA), much ground has been recovered. But Europe still lacks the all-round capabilities to maximize its potential.

Part of the explanation for Europe's limited efforts thus far has to do with a narrowness of approach in most European countries. Only the French consistently and with foresight have pursued an active and wide-ranging policy. So far both national policies and European collaboration, notably through ESA, have produced a disjointed bundle of space activities for scientific, technological, and economic reasons with, to date, very few military applications. A more wide-ranging strategy to exploit space would require more sharply defined objectives and a more long-term perspective. ESA members have declared a commitment to achieve European autonomy in space, but this aim requires not only a greater investment of resources but also a broader conception to link the scientific, technological and economic dimensions to the future role of Western Europe in the world, in the fields of security, cultural impact and links with developing countries. Public awareness of the economic and technological dimensions is limited, knowledge about the political and security implications confined to a few experts. Few people realize the relevance of space to Europe's political future and security. Without wider public appreciation of what a European space policy might achieve, there is little prospect of a more ambitious and more rounded approach emerging.

Scientific and cultural endeavours

The driving forces of the American and Soviet space programmes are military and symbolic, fuelled by enthusiasm and imagination. In Europe, by contrast, scientific research was from the outset a primary motivation of space exploration and one in which European organizations and states have been particularly successful. Modern space technology has revolutionized the scientific exploration of space at an astonishing pace. Satellites, re-usable laboratories, telescopes stationed in space and exploration satellites probing deep into space have opened new vistas for scientific research. Scientific experiments conducted in the fields of biology, physics or medicine offer new insights, and some of these may well have significant practical applications. To maintain a European foothold in these areas would require further technological development. But we should note that the enthusiasm of European scientists has not been matched in the wider policy or public debate.

The exploration of space has produced dramatically new means of communication. Not only can satellites transmit extraordinary amounts of data at speed and decreasing cost, but they have established a network of communications that transcends national frontiers and continents and indeed the entire globe. Satellites provide direct access to other societies. Hence the use of space is likely to play an increasingly important role in the fields of influencing public opinion, advertising products, and exercising cultural influence. Europe has traditionally excelled in the cultural field. The use of space offers a new opportunity to strengthen its contribution to the cultural life of the globe. But without a collective approach Europe cannot realize its potential.

Economic and social benefits

The use of space already provides new fields of economic activity and growing markets. The space industry has become an important sector of technology, parts of which are already commercially profitable. There is considerable commercial activity in the construction, sale and operation of satellites, and space transportation has become an important service in which Europe competes successfully through Arianespace. Communications satellite systems are furthest down the road to profitability; observations from space of what happens on Earth are the next in line to have commercial application. In the longer term the production in space of new pharmaceutical and biotechnological products as well as of new materials may prove economically viable.

In all of these fields Europeans have scored considerable successes, but in increasingly intense competition with other leading technological nations. Only through further efforts can Europe avoid technological dependency and be assured of a continuing, even increasing share of world markets, actual and potential. As in other fields of technology, access to know-how and the ability to exploit it efficiently will be necessary to prevent Europe from being held to ransom by others.

But equally important, space technologies shade into many other key areas of high technology with both civilian and military relevance: advanced avionics, information technology, robotics, new materials and many more. Thus this range of space-related industries has a still wider economic and technological significance, not least in the management of large and complex systems. We should not look at space technologies in isolation; taken together, they foster the flexibility and innovation required to create new jobs and to promote economic modernization. Space therefore helps the European economy in competing with Japan and the United States. Space projects induce scientific and industrial cooperation and thus underpin European integration.

Services

Few people realize how the use of space has revolutionized the service sector. Modern satellite-based communications systems have become an indispensable part of the modern information society in which masses of data, television images, telex, telephone, etc., are transmitted with growing rapidity and in increasing amounts. Europeans are major producers of these systems, and modern European society and culture are unthinkable without them. Not only has the access to new data, information and cultural events been dramatically improved but costs have been decreased significantly through modernization. Few people realize that in many

European countries the savings resulting from satellite use for telephone links often exceed the total cost of national civilian space programmes. The use of space-based information transmission is likely to increase in the future, creating new links across frontiers and a multitude of new economic activities. Moreover, there is the possibility in the longer term that orbital planes which enter space for portions of their trajectory may drastically shorten travel time between continents.

Observation satellites have significantly improved services which are of great use for individuals, economic activities and transport, as well as defence. Weather forecasting is perhaps the best known application, and other applications include crop forecasting or, in the field of environmental policy, techniques for monitoring emissions and for early warning in case of threatening damage to the environment. The images of the stricken nuclear reactor at Chernobyl vividly illustrated just how far space technology had advanced.

In all of these areas European countries and organizations have developed significant skills and activities. The rate of progress has been breathtaking and is likely to produce a number of new fields of economic activity, with services to people and whole economic sectors, for improving standards of living, environmental conditions and the cultural richness of life.

Europe's role and influence in world politics

The political role of states or groups of states in the global society of the twenty-first century will be significantly influenced by their ability and willingness to explore and use space, to develop the necessary technologies and to create the required industrial infrastructure. If West Europeans aspire to a serious influence in international politics, they have to take account of this and to recognize just how much importance other countries, especially but not only the superpowers, attach to enhancing their own capabilities in space. The conduct of cultural, economic and political affairs will be linked with the use of space, as will the conduct of security policy and the pursuit of arms control and disarmament.

Countries or regional groups like Europe which participate in the exploration and use of space will increase their power in the pursuit of their interests. Europe today remains among the technologically advanced regions of the globe. It shares that status with the United States, Japan and the Soviet Union. There is no reason why in the coming century only the United States and the Soviet Union – and possibly Japan, China or India – should exploit the full range of space activities.

This is not to say that Europe should simply imitate the two superpowers. In the economic domain, competition will remain a characteristic of the global society, even if states are tied together in alliances or systems of economic cooperation as is the case between Western Europe, the United States and Japan. Access to crucial technologies via other countries cannot be taken for granted, access which is being increasingly restricted in the case of the United States and which is effectively closed to Europe with regard to the Soviet Union.

The Americans and the Soviets have no preordained right to monopolize manned space exploration. Europeans have so far provided an occasional guest on their spacecraft, but have also shown themselves capable of taking the first steps towards manned space flight. A rounded space programme implies some element of manned exploration, and Europeans can further pursue this goal, even though the scope and the methods may well be different from those of the United States and the Soviet Union.

European attention, which tends to focus on the European Community (EC) in matters of European unification, has barely noticed that space has become an area of highly successful European cooperation and integration. Thanks to the work of ESA, European countries have successfully pooled their resources in joint ventures with which all Europeans, in particular European youth, can identify. Barriers have been removed, industries and laboratories have merged their efforts, genuinely joint facilities operate successfully and new projects open the possibility for additional and enhanced cooperation. Space offers an area in which two of the most important aspirations of Western Europe come together: unification and the promotion of high technology.

ESA has so far been Europe's primary instrument for developing its role in space and is likely so to remain. But other organizations with different interests and memberships have a role to play. Eutelsat and Eumetsat provide some collective services for telecommunications and meteorology. The EC has relevant competences in the areas of technology *and* industrial and trade policies. For commercial exploitation special organizations are required, as already achieved for Ariane. An extension of European space collaboration in the field of security would require the use of some framework other than ESA, such as WEU. But developments beyond the current level of cooperation would depend on a new European consensus and a willingness to override narrow national interests, both commercial and military.

Europe's goal should be to achieve autonomy in space. This would require indigenous launchers for manned and unmanned transport into space, an independent space station that could be manned, and an adequate system of relay satellites and ground infrastructure. Such autonomy is not to be confused with total self-sufficiency: an autonomous European space policy would still be open to international cooperation not only with the United States, but with other countries as well, notably the Soviet Union, Japan, and developing countries. But as the history of American-European space cooperation has shown, the United States will recognize Europe as an interesting partner, and grant it terms that correspond to European interests, only if Europe has a significant space capability of its own.

We should also recognize the importance of setting the international rules for the use of space. Given the growing relevance of space to the activities of states, notably in the areas of power politics and security, Europeans have a keen interest in contributing to an international space regime that enhances stability. European influence will depend both on the extent of European capabilities in space and on the degree to which policy is collectively shaped.

Space and European security

The controversies surrounding the Strategic Defense Initiative (SDI) of the United States have somewhat blurred the real issues that space poses for European security. Fears of this further 'militarization of space', for which not Europe, but the two superpowers are responsible, may lead Europeans to a self-denying regimen. It is one thing to resist calls for space weaponry, but quite another to opt out of the use of space to safeguard security. Europeans should be made aware of the relevance of space policy both for arms control and for supporting existing conventional military capabilities.

Major dimensions of modern arms control would be impossible without the technological possibilities that the use of space offers. Recent and likely future agreements on arms control and disarmament require verification, in which remote-sensing satellites will necessarily play a major part. These will need strengthening, as further attempts are made to constrain and reduce nuclear and conventional arsenals. So far only the two superpowers possess a satellite capacity adequate to verify agreements on arms control and disarmament. All information available to Europeans is of American origin, and not all information is passed on. The Soviet Union does not share any data at all. Europe is technologically capable of building up a satellite capacity of its own. European security interests are not coterminous with those of the US, and an independent source of reconnaissance data could be useful to complement US-derived information.

Similar considerations apply to confidence-building measures. If these are to work effectively and to be expanded as a means of decreasing tension and enhancing stability, the observation of military developments in Eastern Europe through satellites will be very important. A European capacity in this area of data collection might therefore serve to improve transparency and calculability in East-West relations.

The use of space has taken on great importance for the system of nuclear deterrence between the superpowers, a system which, of course, also protects Western Europe. But space is increasingly used for other defence purposes. Optical and electronic reconnaissance satellites help to provide constant information about wide-ranging military developments and deployments, including early warning and crisis monitoring. Moreover, satellites for weather prediction, navigation and military communication are of growing importance for the defence of Europe. Weather satellites are the only ones for which Europe has an effective system of its own. France and Britain have some independent capabilities and, as for the rest, they and their fellow Europeans have to rely to varying degrees on Nato or directly on the US.

In a number of European countries the non-civilian use of space is viewed with apprehension. An enhanced European programme could cause controversy. The propaganda battle surrounding SDI has made a rational debate more difficult, but such a debate is nevertheless necessary. If Europeans are to become more responsible for their own security, they cannot avoid considering the use of space. Even sceptics are likely to recognize its relevance in the field of arms control and disarmament. But the questions need to be assessed more broadly.

Space and developing countries

The use of space is increasingly relevant to the needs of developing countries. Satellites offer new possibilities to assess harvests, to identify raw material deposits, to predict weather, to survey environmental developments or to predict natural catastrophies. Perhaps even more important, communications satellites provide a relatively fast and cost-effective means of pursuing national integration and regional cooperation, modernizing agriculture, and expanding education and health care. Europeans have an opportunity to help developing countries to acquire the means to exploit these technologies.

Towards a new European perspective on space

So far in Europe space exploration has been seen and justified to democratic publics and parliaments primarily from the point of view of its use for scientific research, technological advance and economic gains. To be sure, even these advantages of space use are not fully appreciated. But a justification of further space exploration in disjointed scientific, technological and economic terms is unlikely to generate support for the larger public expenditure which European autonomy in space implies or for the range of applications which are likely to be relevant in the future.

The time has come for a qualitative jump in European thinking on space. The publics in Europe need to become more aware of the political dimensions of the use of space. When decisions of great magnitude on space activities are at stake, it is short-sighted to look only at the costs and benefits in financial, technological and economic terms. The balance-sheet must include the political and security dimensions of a Europe moving into the twenty-first century.

This report is therefore designed as a contribution to greater understanding of both the imperatives for European action and the policy issues involved. It deliberately ranges across a wide spectrum of uses of space and pinpoints those that are likely to become increasingly relevant to Europe's role in the world over the next decades and into the twenty-first century. It seeks to identify both the options and the constraints. The thrust of the argument points to the need for a far more vigorous European space policy in the future. But none of this will be achieved unless Europeans have the imagination and ambition to harness effectively their considerable potential for making the most of space.

2

PARTNERS AND COMPETITORS

Current and potential space policies for Western Europe need to be seen against the backcloth of the space programmes being developed elsewhere in the world. The American and Soviet programmes are of course the longest established and the most ambitious across the range of civilian and military applications. But equally importantly many other countries are in the process of developing their own capabilities for a mixture of civilian and military reasons. Several countries include in their aims the pursuit of autonomy in launch capabilities and in both space and ground segments, with the ability to compete for international business. This section of the report briefly surveys the most relevant features of some of these programmes; it pays particular attention to the American and Soviet programmes and gives an overview of the fast developing programmes of Japan, India and China. Further statistical details are given in the tables and figures at the end of the report.

(a) UNITED STATES

A brief survey can hardly do justice to the long history of the American space programme, let alone to the difficult choices currently facing American policy-makers. Successive American governments have sought to drive forward ambitious projects from scientific exploration through economic exploitation to innovative and often controversial defence and security applications and with major projects in manned missions. From a West European perspective, the evaluation of American space capabilities is especially important because of the extent to which they exceed in scale and in market share the efforts of other Western countries, and because of the transatlantic defence and security relationship, in which space-based technologies have acquired increasing importance. There are many lessons, both positive and negative, for Europeans to derive from the history, operation and aspirations of American policy.

Objectives

The objectives of the American space programme have been complex. To be sure, the development of military rocket and missile technology underpinned the early experiments, and these were driven by a determination to keep a military edge vis-à-vis the Soviet Union. But in the 1950s under President Eisenhower there was a strong, and indeed organizationally separate, civilian dimension with scientific and technological aims. It was the shock of the Soviet success with Sputnik in October 1957, ahead of the first successful launch by the US of a satellite in January 1958, which led to a more integrated policy and more determined competition with the USSR. But even so, in 1958, the new National Aeronautics and Space Administration (Nasa) formally had only a civilian responsibility, while the Department of Defense (DoD) retained charge of the military programme with intense competition among the three services. Crucially, though, Nasa won control of manned missions.

In 1961 the civil programme enjoyed a major boost when President Kennedy endorsed the race through the Apollo programme for the first landing on the moon (achieved in 1969) in the belief that an American 'victory' would be a key symbol of both technological prowess and international stature. These high ambitions captured the public imagination and had a major impact on US prestige throughout the world, though there were always vociferous critics. But it is also important to underscore the early priority attributed to satellite applications for communications, reconnaissance and scientific experiments. Comsat was created in 1962 to promote the commercial development within the US of communications in satellites, and the 'open skies' policy was embraced. The Americans took the initiative which led to the creation in 1965 of Intelsat. They had a dominating role in its original subscription arrangements and were to prove the major industrial beneficiaries. Under President Johnson increases of funding were agreed to reinforce the scientific, technological and industrial dimensions, and a vigorous space industry developed fast.

In the 1970s, however, the ambitious goals and projected funding attracted recurrent Congressional criticism and sharp debate among experts. The ensuing constraints led to efforts by President Nixon to trim Nasa's budget and to focus attention on exploitable applications of space technologies (both launchers and satellites). Nonetheless, the determined, if less visible, efforts of the DoD achieved increased levels of funding for military applications of space not only to support the American defence forces and to provide intelligence, but also to maintain a R&D capability for new applications. The civil programme lost momentum after the Apollo programme and was to suffer from over-reliance on the Shuttle programme as its centrepiece. By the 1980s and Reagan's 1982 space review, the balance of government attention had tilted towards the military, paving the way for the announcement of the SDI in March 1983. Meanwhile Nasa, under some severe constraints, sought to retain an ambitious manned flight programme and new ventures such as the 'international space station' (announced in July 1984) and deep space probes.

Programmes and projects

Launchers

The US has employed ten major types of launcher in over fifty versions over some thirty years of space activity. Of these only four types are still available for use. This proliferation was partly a result of inter-service rivalry in the early years and led to much duplication. Nasa initially had to rely on the military and their contractors, and the available expendable launch vehicles (ELVs) were nearly all based on military missiles. The wide use of the Atlas and Titan launchers, both of which were ICBMs, grew out of the close cooperation between Nasa and the DoD, in particular the Air Force, which from 1962 had been given the primary responsibility for the armed services space efforts. The US also tried over many years and at great cost to apply nuclear and electrical propulsion systems to space travel, but budgetary constraints prevented their development. Proposals abounded for alternatives to ELVs, both space planes and other re-usable vehicles. The large number of launches (over 800 in the first 25 years) increased reliability from about 30 per cent to some 95 per cent. By the end of 1986 there had been some 869 launches, of which 113 failed.

The Saturn series of heavy-lift launchers was used for the Apollo lunar programme. Saturn 1 had a capacity of 9 tonnes to low earth orbit and Saturn 5, the most powerful launcher until very recently, almost 100 tonnes to low earth orbit (cf. Ariane 5 – 15 tonnes, Shuttle – 30 tonnes, and Soviet Proton – 27 tonnes, all to low earth orbit, but now allegedly capped by the new Soviet Energiya). The Saturn vehicles were officially scrapped at the end of the Apollo and Skylab missions.

At the end of the Apollo era, the high launch costs rekindled interest in re-usable vehicles, one of the discussed missions for which was Nasa's proposed space station. Nasa proposed a fully re-usable vehicle for the 1970s, but Congress vehemently opposed the costs. Instead, in 1972, President Nixon approved the Shuttle programme, a simpler and cheaper but only partly re-usable vehicle, for all users including the military. The Shuttle was to establish a new space system that would allow easier and lower-cost access to space and permit a wide range of space activities. The intention was to move away from ELVs to total dependence on the Shuttle not only by Nasa but also by the DoD, which was to use 40 per cent of Shuttle flights. Delays with the programme and high cost overruns led the DoD to retain the option of the Titan launcher; meanwhile Nasa was able to fall back on the Delta and Atlas-Centaur, though neither was optimized for commercial payloads. (See Table 6.)

The complexity of Shuttle operations and the vulnerability arising from dependence on a single vehicle with technical deficiencies was dramatically confirmed by the Challenger disaster of January 1986. This has led to modification of old ELVs and the development of new ones. The DoD has contracted for a heavier Delta vehicle to launch its Navstar satellites; it will also be available to the commercial market. Most recently the DoD has requested funding for a new heavy-lift vehicle (some 60 tonnes to low earth orbit), perhaps based on Saturn 5. The Air Force is requesting proposals for an Advanced Launch System which will permit production and launch on a routine basis. The target is to reduce launch costs by a factor of ten to lift payloads of up to 100 tonnes into low earth orbit. In the meantime, there is a backlog of American satellites awaiting launch and of satellites from elsewhere which had booked space on Shuttle flights.

Unmanned missions

Since the early 1960s the United States has developed a huge array of satellites – about 1,000 by the end of 1986 – for both civilian and military purposes, with large private-sector involvement in civil applications and an impressive share of world markets. Experiments and procurement have been handled by the DoD and Nasa both separately and in combination, though the DoD has been responsible for over 70 per cent of payloads. Some satellites perform more than one function, and so no classification is entirely satisfactory. Table 7 summarizes the range and approximate numbers of missions.

Manned missions

Since 1961 the United States has carried out 54 manned flights in five series of programmes. The major manned programme was the Apollo programme. There were eleven flights in this programme from 1968 to 1972 (six of which landed men on the Moon using the Saturn 5 launcher) at a cost of $25 billion.

Although the initial lunar landings captured the imagination of people all over the world, interest within the US waned after the first few successes, to be revived only temporarily by the ill-fated Apollo 13. Indeed Harris and Gallup polls during the 1960s showed American opinion to be equivocal about spending large sums of money on manned missions. Shortly after President Kennedy's announcement in 1963 of the $40 billion project to put Americans on the moon, 58 per cent of respondents opposed the project, with only 33 per cent in favour. In only one poll, taken in 1965, did those in favour – 45 per cent – outnumber the 42 per cent who were opposed. By 1967 support for a lunar mission had dropped to 34 per cent. Changing political and social priorities, against the backcloth of the Vietnam war, had undermined support for Nasa's manned space programme. Growing Congressional opposition to the lunar programme resulted in the cancellation of the last three lunar missions. If funding is an indicator of commitment, support was at its most vigorous in the immediate period after Sputnik, peaked in 1964 and precipitously decreased after that date.

Nasa then commenced the Skylab programme as an attempt to determine the long-term effects of manned presence in space and to conduct experiments in space processing, Earth resources photography and astronomy observations. The workshop was a converted Saturn 4 rocket casing, and three flights of three-man crews were sent in 1973. More workshops were planned, but general disenchantment with space activities precluded them. The cost of the programme was $2.5 billion. In July 1975 an Apollo spacecraft docked with a Soviet Soyuz craft, at a mission cost of $225 million. No further manned flights were made until the Shuttle flights in April 1981. Twenty-three shuttle flights followed before the Challenger accident in January 1986 halted the programme. Details of the Shuttle programme and the proposed new space station are in Chapter 6 of this report.

Budget and resources

It is difficult to be precise on the total allocations for space activities because the military expenditure is not fully recorded. Moreover, spending patterns have been erratic and objectives have changed. It is generally held that over the past thirty years overall expenditure has been in the order of $160 billion, of which Nasa has spent $100 billion. Nasa funding increased rapidly from $0.5 billion a year in 1959 to a peak of $5.5 billion in 1964. There was then a dramatic fall in funding – as interest in space waned – until 1974, when expenditure levelled out. In 1985 the Nasa budget was much the same as in 1962. In 1986 allocations were some $4.6 billion. Although spending on military programmes had been generally at a much lower level than in the civilian programme, it steadily increased and by 1981 exceeded civilian expenditure. By 1986 it was well over double that for the civilian programme, and the emphasis on SDI will, it is assumed, result in significant increases in the level of funding for military programmes. Private-sector expenditure has been predominantly on communication satellites, but has amounted to less than 1 per cent of total funding.

Nasa's funding has been a recurrent source of controversy, notably in Congressional committees. Its budgets have been very susceptible to cuts, a feature that has jeopardized many international cooperative ventures. In contrast, the high profile and powerful lobbies associated with the military, as well as the primary importance of national security and anxieties about Soviet efforts, have ensured high and increased funding for military programmes.

At the 1964 peak of Nasa funding, some 400,000 people were employed in civilian space activities, of which 10 per cent were employed by Nasa; by 1974 this number had declined to 100,000. There has been a slight increase recently because of space station activities, but this has been offset both by a tailing off of domestic demand for satellites and by delays in launches. Eurospace, for example, estimates that some 136,000 people are involved in primary civilian space activities, with an additional 116,000 said to be involved in military programmes. About one million people may be associated with secondary and related space activities.

Organization

Space policy has been managed on a pluralist basis in the United States. Nasa, founded in 1958, has been the most visible agency with responsibilities for R&D, big projects and launch facilities both directly and through its associated research centres. But the DoD, and to varying degrees the three armed services, have maintained their own programmes. Nasa largely absorbed the Army and Navy space capabilities, but the DoD and the Air Force continued to operate separately with various liaison mechanisms – especially the National Aeronautics and Space Council – to coordinate with Nasa. Successive attempts have been made throughout the history of American space activities to forge a coherent and overall space policy with high-level presidential reviews and keen attention from Congress. Funding has fluctuated partly in response to this political scrutiny, partly because it has depended on the apparent 'success' of particular programmes, and partly as a result of the other expenditure commitments and priorities of successive administrations. None of these debates has yet produced a single framework of policy or an entirely coherent organization of capabilities, even though the boundaries between civil and military applications have become increasingly blurred, especially with the Shuttle programme.

Nasa's work has sometimes fallen within the presidential domain, commanding a high profile, but at other periods suffered a fall from grace. Problems have arisen from typical inter-agency conflicts. Some space functions have been removed from Nasa: for example, the transfer of Earth observation and weather to the National Oceanic and Atmospheric Administration (NOAA). In November 1984 President Reagan authorized the creation of a Unified Space Command with a consolidated operations centre at Colorado Springs. This absorbed the Air Force's and Navy's independent space commands and took charge of orbital surveillance, the anti-satellite (Asat) programme and GPS/Navstar, as well as the space-related aspects of SDI.

Over the years there have also been weaknesses of management and tight technological constraints. Given the combination of ambitious symbolic goals for the American space programme and fluctuating funding, it is perhaps not surprising that there should have been temptations to cut some of the technological corners, or that the DoD should prudently have preferred to retain some independent capabilities. Experts in the field were already well aware of the problems, but it took the tragic Challenger accident to reveal the consequential stresses and strains, not least in Nasa's relationships with its contractors. In the ensuing months, anguished debates and evaluative reports edged the Americans towards a reappraisal of both policy and management.

On the other hand, at the commercial end of the scale, the American programme benefited from an entrepreneurial and innovative business culture, not only among producers of space systems but crucially in the buoyancy of demand for space-derived services. Here Nasa and the private sector, helped by increasing market liberalization and the Technology Utilization Programme, have tried to forge a partnership to develop commercial applications. However, Nasa has not always had a good sense of user needs, and deregulation came too late for AT&T (for example) to capture an early foothold. It should also be noted that the large community of space specialists in American universities is now suffering from the cut in Nasa's civilian research programmes.

Foreign policy dimension

In space issues, as in so many areas of international cooperation and management, the United States has played a leading role among Western countries. One element has been collaborative, through the opportunities it has offered to other countries to take part in American-led missions. The great adventures of scientific exploration were from early on identified as opportunities for international participation, even to the extent of one US/USSR joint mission.

The succession of manned missions also opened up collaboration with the Spacelab project and, recently, the American-inspired 'international space station'. Not surprisingly, such issues as the balance of partnership, mission definition, mission control and provision of space and ground segments have all raised awkward choices for the partners of the United States concerning the trade-off between access to the project and dependency. The US has not always been an easy partner.

Another source of controversy has been international regulation, in which, for example, the United States both took a lead in establishing Intelsat and has subsequently played a predominant role. This reflects the level of American investment or subscription, but also the sharp competitive edge of American companies in tendering for Intelsat contracts. Current US attitudes to Intelsat and Landsat may reduce their value to European countries and LDCs, particularly if US companies are allowed to compete with Intelsat. If, however, tariffs were reduced as a result, then consumers could benefit. What is clear is the powerful role of the Americans in chasing international markets (actual and potential) in an important area of high technology. Significantly, the American government, especially under the Reagan administration, has drawn back from using the United Nations (UN) as a forum for regulating the use of space.

Security policy dimension

American defence and security policy has become increasingly dependent on space-based systems. For a long time the major concentration of DoD space activities has been on the development of communications and intelligence-gathering facilities through space technologies. The US relies on space for accurate strategic intelligence and the verification of arms control agreements. Space has also become an essential element in the command and control of globally deployed US forces. Seventy per cent of all peacetime long-haul communications are handled by satellite. The GPS/Navstar system will provide a revolutionary degree of positional accuracy for SSBNs, aircraft, ships and ground forces, even down to individual soldiers. This will enhance US (and Nato) all-weather capability for refuelling, target acquisition and ordnance delivery. Early-warning satellites give the US extra time for crisis management. Meteorological satellites provide the only real-time weather updates, again of considerable value for tactical and strategic operations.

While much of this activity has been dedicated to American military requirements, international collaboration has also been developed both within Nato and through privileged relationships with particular partners. Thus the Nato system of communications satellites has rested so far on American capabilities. As for intelligence-gathering, recurrent and close collaboration has persisted between the United States and the United Kingdom, while more intermittent and *ad hoc* cooperation has been practised with other Alliance partners. In these cases the extent of access to US data has been conditional and dependent on American assessments of what was relevant and desirable.

The announcement of the SDI by President Reagan in March 1983 added a new dimension to the US military space programme. SDI envisaged a mixture of space- and earth-based anti-ballistic-missile systems. This project, highly controversial both politically and technologically, appeared to provide a major injection of money into almost all aspects of space technology. Some of the R&D performed under the SDI umbrella will enhance US space capabilities, as well as contributing to a general improvement in US technology. America's allies feared that if they were not able to participate at this new 'frontier of science', there would be detrimental effects on their own technological standing. Aware of these fears, and of the need to marshal the best of the allied research effort to meet the challenges of SDI, the US Department of Defense in March 1985 invited the Nato allies, as well as Australia, Israel, Japan and South Korea, to participate directly in the SDI research programme. Memoranda of Understanding (MOU) on SDI participation have since been signed on a bilateral basis with the United Kingdom, the Federal Republic of Germany, Israel, Italy and Japan. SDI research contracts have also been awarded in France, Belgium and the Netherlands. The US presented the SDI as a major opportunity for cooperation within Nato. To date, however, the reality has failed to live up to the promise.

(b) SOVIET UNION

The Soviet commitment to space started in the mid-1950s, with developments in ballistic missiles. The first Soviet ICBM, the SS-6, was fired in August 1957, while the first satellite, Sputnik 1 – the first man-made object ever put into orbit – was launched by a slightly modified version of the same missile on 4 October 1957. Since that time, the Soviet Union has conducted steadily growing space programmes to serve scientific, economic and, above all, national security purposes. With the world's highest rate of successful launches (91 missions for 114 payloads in 1986) and dramatically improving technological know-how in almost every sector of space activity, and with the launch of Energiya and the success of Mir, the USSR has even overtaken the United States as the world's leading space power. On the other hand, the USSR has to contend with the facts of geography and orbital geometry, which dictate that their launches require more power per payload than any Western launch. The programme is also handicapped by problems with component reliability and miniaturization.

Objectives

Soviet involvement in space has been shaped by a complex series of motivations during the past three decades or so. First and foremost, Soviet space programmes serve the dual political goal of enhancing the international prestige and power of the Soviet Union and stimulating the national pride of the Soviet population. Space has also been systematically used as a propaganda theme. Soviet exploitation of space for peaceful purposes is contrasted with American militarization of space, especially in the aftermath of SDI.

In the mid-1960s, however, the idea took hold of exploiting the applications of the various services of space systems, by building up a comprehensive, multi-purpose satellite network. Today, even though civilian application satellites are still less numerous than the military ones, space-based systems certainly represent an important contribution to the Soviet national economy, especially in the fields of agriculture, forestry, water resources and meteorology. Moreover, the establishment of a permanent presence in space has become a major driving force of Soviet space programmes. Consequently, the setting up of modular space stations, together with the goal of extending the length of time humans can stay in orbit, has been given the highest priority. Already the Soviets have spent nearly 100,000 hours in space.

Although the Soviet Union presents its space activities as peaceful, it is obvious that military uses of space are an essential element within its military doctrine and its strategic posture. Not only has the Soviet Union built up an impressive network of space systems to support military functions; it has also been involved in two space weapons programmes, namely, the fractional orbital bombardment system (FOBS) in the late 1960s, and the anti-satellite co-orbital interceptor, which can hit targets in low earth orbit (LEO). The second of these programmes started tests in 1968 and has been judged operational since the early 1980s.

Programmes and projects

Launchers

In terms of launch capabilities, the Soviet Union is today in a very favourable position in comparison with other space powers. Its space industry produces routinely about one hundred launchers a year. In 1986 the USSR was able to carry out 91 launches, an average of one launch every four days.

So far the Soviet Union has used eight types of operational launch vehicle. All are adaptations of long-range ballistic missiles, with the exception of the Proton vehicle. Interestingly, since the early 1980s, Proton has been the only Soviet space rocket put forward for commercial use by potential foreign customers. No Western country has yet taken up this offer, essentially for political reasons. However, an Indian payload is due to be put into orbit by Proton in autumn 1987. Commercial companies in the West have considered following suit, and are giving increasing attention to both the vehicle's operational reliability (reportedly only 7 failures out of 97 missions) and the attractive financial terms offered by the Soviets. Until recently Proton was the Soviet rocket with the heaviest lift capacity for the launching of orbital infrastructure elements, lunar and interplanetary probes and geostationary satellites.

Another Soviet launcher – the 'A' or Semyorka – is derived from the SS-6 intercontinental missile, and is still the mainstay of the Soviet programme. In operation since 1978, it has been used more times than any other orbital transportation vehicle in the world, essentially for manned space missions. In addition, a new Soviet booster of medium-lift capacity has been flight-tested since 1985. Called the SL-X-16 by US specialists, it has a reported payload-to-LEO capability of 15 tonnes.

Most recently, on 15 May 1987, the Soviets succeeded in the first flight-test of Energiya, a new heavy-lift launcher, which has a reported payload-to-LEO capability of well over 100 tonnes – more than the US Saturn 5 rocket, previously the world's most powerful launcher. Significantly, it can launch more than three times the payload of the US Shuttle. It is expected to carry into orbit modules of the Soviet space station and heavy military satellites, and to contribute eventually to manned missions to the Moon or Mars. The development of Energiya has confirmed the Soviet lead in space.

The Soviets are also developing two re-usable spacecraft: the first perhaps comparable to the US Shuttle, and the second a much smaller 'spaceplane'. The Soviet heavy shuttle is reportedly undergoing tests at the Tyuratam space centre and could be flown piggyback on the Energiya booster as soon as 1988. The 'spaceplane' has made four successful orbital flights in a sub-scale version and could become operational by 1990.

Unmanned space missions

The total number of satellites launched annually by the Soviet Union is approximately three times greater than that of all other countries combined: 114 payloads were put into orbit in 1986. But this spectacular number is essentially explained by Soviet satellites still being less sophisticated than Western ones and staying in orbit for a shorter period of time. The most important Soviet satellite programme, the Kosmos series, which started in 1962, has become a blanket label covering all Soviet military missions. So far more than 1,800 Kosmos satellites have been put into orbit.

Currently the Soviet Union launches an average of 30 military photo-reconnaissance satellites a year, including area surveillance satellites, which have been used several times for crisis monitoring. It operates a six-satellite constellation of electronic intelligence (Elint) satellites, as well as a large network of satellites for military command, control and communications. The latter may belong to either the Kosmos or Molniya 1 (highly elliptical orbit) categories. Soviet early-warning satellites use 12-hour orbits to facilitate the largest possible ground coverage with a relatively small number of satellites. For ocean reconnaissance missions, two basic satellites are used by the Soviet military: active radar-equipped, nuclear-powered, ocean reconnaissance satellites (Rorsat); and passive, sensor-equipped Elint ocean reconnaissance satellites (Eorsat). The Soviet Union employs two constellations of navigation satellites, comparable to the US Transit system. Recently it has begun operating a new generation of Navsats, called Glonass, akin to the US Navstar system.

In the field of civilian applications, the Soviets have a wide satellite telecommunications network (the Molniya, Reduga, Ekran and Gorizont systems), and earth and ocean resources detection capabilities, as well as meteorological satellite systems (Meteor).

Scientific space missions represent the smallest proportion of the Soviet space effort. Among the most recent scientific space programmes, the interplanetary Vega 1 and Vega 2 probes constitute undoubtedly one of the greatest achievements. The Soviet Union is preparing to launch a dozen or more important scientific space missions, including at least ten Earth-orbit science payloads and two missions to Mars. Many of the Soviet space science programmes are carried on in collaboration with West European as well as Soviet-bloc nations.

Manned space missions

Since the early 1970s, missions involving space stations have represented the bulk of Soviet manned space programmes. Seven Salyut-series space stations had been launched between 1971 and 1982, and the new Mir station has operated since February 1986.

In the early period, there were apparently two different space station programmes, one each for military (Salyut 3 and 5) and civilian (Salyut 4 and 6) purposes. It seems, however, that such a distinction has been abandoned since the launching of Salyut 7. The Soviets probably believe that it is more efficient and cost-effective to develop new stations that combine civilian and military capabilities.

On 19 February 1986 the Soviets sent into orbit a new space station called Mir. The station, similar in size to the Salyuts, has six docking ports to which modular station segments can be attached. This confirms Soviet willingness to build up huge space complexes by joining successively to the main element several multi-purpose (laboratory, scientific, residential) modules. It is probable that within the next few years the Soviet Union will be able to deploy space configurations that will be permanently occupied by the crews.

Two long-duration missions have already been sent to the Mir station: the Kizim-Soloviev 125-day flight in 1986 and the Romanenko-Laveikin mission, initiated on 6 February 1987. The latter has set up a new manned space flight duration record of well over 200 days in orbit and has successfully conducted several extra-vehicular activities, as well as Earth and space observation and laboratory activities.

All manned missions launched since the beginning of 1987 have used the modernized Soyuz T11 space transportation vehicle, the computational capability of which has been greatly increased in comparison with the previous versions of the Soyuz-series spacecraft. Resupplying and refuelling of the orbital stations while in space is assured by the Progress-series vehicles, first launched in January 1978.

Budget and resources

Only rough estimates are available of the budget and resources which underpin Soviet programmes and of the breakdown between civilian and military applications. Comparisons with the US are also imperfect because of the large private-sector involvement in American satellite operations. One study by the US Congress hypothesized an annual budget of $23 billion in 1985, perhaps as much as 1.5 per cent of Soviet GNP. The same study suggested that some 600,000 people, mainly engineers and technicians, were involved in the programme. Key features of the Soviet economy and society partly account for the lesser emphasis on commercial applications.

Organization

The Soviet military plays a fundamental role within the organizational framework of Soviet space programmes. Although details of the Soviet organizations for civil space development and production are scanty, both military and space programmes are managed by the Main Production Administration for Strategic Missiles and Space Systems on behalf of the Soviet Ministry for General Machine-Building. The Strategic Rocket Forces are responsible for all Soviet space launchings and exercise operational control over the three Soviet launching-sites of Tyuratam (Baikonur), Plesetsk and Kapustin Yar. The two branches of the Air Defence Forces, the VPRO (Anti-Missile Defence Forces) and VPKO (Anti-Space Defence Forces) are in charge of (space-based) anti-missile defence and anti-satellite warfare programmes. Finally, Soviet space personnel training facilities are administered by the Air Force, and the majority of Soviet cosmonauts are military pilots.

On the civilian side, the Space Research Institute of the Academy of Sciences plays an essential role in the conception and coordination of Soviet civilian applications as well as scientific space activities. In 1985 a new institution, Glavkosmos, was established, apparently in order to simplify the administrative structures of civilian space programmes and to enhance their efficiency. Glavkosmos is also in charge of negotiating cooperative space agreements with Western countries. Intercosmos has a similar role as far as cooperation with socialist countries is concerned.

The Soviets disclose little information on the industrial infrastructure of their space activities. It is believed that the Ministry of Defence has a close relationship with, and probably also actual control over, the industries which manufacture launchers and other Soviet space hardware.

Foreign policy dimension

Soviet attitudes towards international cooperation have three major characteristics. First, political considerations predominate in determining the limits of cooperation. Thus cooperation with Western countries develops during periods of detente and decreases when there are growing East-West tensions. Second, cooperation with Eastern Europe and the Third World almost certainly has political purposes. But third, in contrast, the Soviets have been keen to cooperate in such areas as the scientific exploration of space and human space flight.

Organizational arrangements for space cooperation between the USSR and other socialist countries were created within the Intercosmos programme, set up in 1967, and the international organization Intersputnik, established in 1971. Intercosmos covers a broad range of space-related problems in physics, meteorology, communications, biology, medicine and environmental uses. The primary purpose of Intersputnik is to provide a system of space communications for all allies of the Soviet Union. Space cooperation has a role as an integrating force for unity in the Soviet bloc.

The USSR also cooperates extensively with India, in the building and launching of Indian satellites, in manned space flight, and by helping the Indians to develop their own facilities and skills for space monitoring and probably launching facilities. Among West European countries, France has been the most important partner of the Soviet Union in space cooperation. There have been continuous exchanges between the two countries which culminated in 1982 in the participation of a French astronaut in the Soyuz T-6/Salyut 5 mission. A new Franco-Soviet agreement on space cooperation in manned space flight was concluded in October 1986. Soviet bilateral cooperation with other non-communist countries has been minimal for a long time. In 1986, however, a Soviet-British space agreement was reached. Joint Soviet-ESA space endeavours, such as the exchange of data collected by the Soviet Vega 1 and 2 missions and the European Giotto probe, have not yet been formalized.

Soviet-US cooperation is the most dependent on the general evolution of international relations. It was at its apogee during the period of detente, with the joint Apollo-Soyuz flight of July 1985, but more recently it has been seriously affected by the Soviet invasion of Afghanistan and above all by the consequences of SDI. In May 1987 a new Soviet-US space agreement on civilian research was signed, giving American scientists access to the Soviet unmanned probe of Mars and its Moon photos in 1988.

The Soviet Union has been among the major actors in the UN Committee on Peaceful Uses of Outer Space (Copuos). On some issues, such as the Moon Treaty and direct broadcasting, sharp differences with Western countries have arisen. Finally, the Soviets carry on multilateral cooperation in space-related matters within other international organizations, such as Inmarsat, ITU, WMO, Cospar and the International Astronautical Federation.

Security policy dimension

Despite official disavowals, the Soviet space programme is dominated by military concerns. Throughout the 1970s and 1980s, over 75 per cent of Soviet space missions have been defence-related, and many known to have two distinct configurations, and cosmonauts have carried out reconnaissance, C3I and Elint tasks. Like the US, the USSR relies on satellites for political and military reconnaissance, and makes use of space for navigation, Elint and general C3I tasks. Equally, the USSR has deployed a constellation of early-warning satellites. It has also put considerable effort into ocean surveillance in both radar and electronic forms. A Soviet Asat capability has been demonstrated, but to date its success rate has been poor and incapable of reaching the bulk of Western space assets. Finally, while the Soviet Union has not revealed a programme comparable to SDI – indeed, the evidence is that it is apprehensive about matching such systems either technologically or financially – it is developing laser and particle-beam technology and has a well- established ABM programme.

The significance of space for Soviet security, however, must be placed in the context of Soviet strategic thinking and military doctrine. In peacetime, the Soviet Union undoubtedly values space-derived intelligence as highly as the USA. Global crises and military activity are invariably reflected in the pattern of its satellite launches. It has a special interest in tracking Western naval operations and uses satellites for European and global communications. Even the KGB has its own dedicated systems. However, the Soviet Union's primary military interests lie within the Eurasian land mass. In the event of war, even the Soviet Navy will fight mainly from home waters. The bulk of Soviet SSBNs will launch from defined locations and will have less need of satellite navigation systems. Furthermore, communications for tactical and strategic forces will rely more on conventional means of transmission. In short, the USSR would suffer less from any loss of space-based systems than the US and Nato. The Soviet Union's routinized launch capability would provide a useful surge and replacement facility, but, in terms of wartime and military operations, space is auxiliary to mainstream Soviet activity. This is not to say, however, that the USSR would not derive a military advantage from maintaining a superior space capability or, more significantly, by degrading the West's increasingly vital satellite systems.

It is difficult to assess the impact of SDI on Soviet space programmes. On the one hand it is certain that the Soviets are trying to find an appropriate technological as well as a political response to this new challenge. However, there is no firm evidence that they have a space-based strategic defence programme similar to that of the United States.

What the Soviets fear above all is the financial and economic consequences of a new arms race in space, given their scarce resources and Gorbachev's proposed economic reforms. The Soviet Union may continue to oppose US military space policy by diplomatic means, including its proposal to establish a new international organization devoted exclusively to peaceful uses of space. If this proves unsuccessful, it could relatively easily orient its own space activities towards an even more intense military programme, given the already blurred line between military and civil applications.

(c) JAPAN

Since the mid-1950s, Japan has developed a space programme through which it has established itself as a major force in the application of space technology for scientific and economic purposes. Although the programme is still modest by American standards, it is comparable in scope and breadth to the West European space programme. It has the potential to become one of the major space programmes in the world for the commercial exploitation of space. Already Japan regards itself as No. 3 among the leading space powers – behind the two world powers but ahead of Western Europe.

Objectives

The objectives of the Japanese space programme are primarily economic and are part of the country's overall aim of establishing and strengthening its competitive position on the world market for advanced technology. So far, security considerations have had little overt impact on Japan's space policy.

Initially Japan's space programme relied heavily on cooperation with the US and access to American technology. This prevented transfers of space technology to third countries or launches of third-country payloads. However, Japan's long-term objective is to achieve technological as well as political autonomy in space. This reflects the underlying conviction that as a major industrial country Japan must establish an independent presence in space if it wants to remain a competitive player on the world markets of tomorrow and a political power during the next decade.

Programmes and projects

Since 1970 Japan has developed, launched and operated 15 scientific and experimental satellites and, since 1975, 20 application satellites, which are used for telecommunication, broadcasting, television and meteorology. The launch of the first domestic remote-sensing satellite is planned during 1987.

Japan has developed its own space transportation systems: small solid propellant launchers (M-series) to carry scientific and test satellites of up to 750 kg into low earth orbit; and medium-sized liquid and solid propellant launch vehicles (N-series) to carry application satellites of up to 350 kg into geostationary orbit. Most of these launchers have been produced under licence from US companies. A large expendable launch vehicle is under development (H-series) which uses advanced liquid oxygen/hydrogen propellant technology to carry payloads of up to 550 kg into geostationary orbit. The first experimental launch of the H-1 launcher took place in August 1986. The Japanese space programme envisages the launch of an enlarged H-2 version for the transport of payloads of up to 2,000 kg into geostationary orbit (comparable to Ariane 3) by 1990. The Japanese intend to offer commercial launch services on the world market.

Japanese plans include active involvement in the 'international space station' project, and negotiations are under way with Nasa. In the long run, they aim to build and operate an autonomous space station to be used for commercial purposes and served by a re-usable manned space vehicle. The underlying goal is to establish an autonomous capability for using the specific conditions of space for commercial purposes.

As for the ground segments necessary for using payloads in outer space, Japanese suppliers have been especially active in developing highly advanced technology. As a result they have become a major player in the ground segment market, including within Western Europe.

Japan now has a broad and technologically advanced infrastructure for its space programme. It has two major space centres with launch facilities, one for scientific, the other for space application activities, and a number of additional development centres and ground facilities, including a major space centre at Tsukuba Science City.

Budget and resources

Although Japan's space programme is comparable to that of Western Europe in scope and range, the annual budget is much less. This suggests that the programme is more efficient and that the amount of private money spent on space activities is considerably higher than in Europe. Annual public expenditure for 1986 totals about 117 billion yen, or 640 million European Accounting Units (EAU), divided into some 620 million EAU for the space application programme, 10 million EAU for the space science programme, and another 10 million EAU for all other agencies involved in space activities. All in all, there is a high degree of efficiency and cost-effectiveness in the Japanese programme. In addition, Japanese industry spent roughly 250 million EAU on space applications in 1986.

Organization

The fifteen-year space plan, which runs up to the year 2000, and the space budget are established by the Space Activities Commission, an advisory committee to the Prime Minister under the chairmanship of the Science and Technology Agency. The programme is mainly implemented by the National Space Development Agency (Nasda), which has prime responsibility for the practical applications of space developments, and by the Institute of Space and Astronautical Sciences (ISAS), which promotes activities in the field of space science and has prime responsibility for research, development and operation of scientific satellites. Nasda is supervised by the Science and Technology Agency; ISAS is under the supervision of the Ministry for Education. The Ministry for Post and Telecommunications is responsible for the use of communications, and the Ministry of Transport for the use of weather satellites by the Japan Meteorological Agency.

Industry is heavily engaged in the space programme. As early as 1961 it established a Space Activities Promotion Council, which seeks to coordinate the space activities of the major companies and to cooperate with the government through the Ministry of International Trade and Industry. Some 60 companies are members of the Council. More recently the Keidanren, the umbrella association of Japanese industry, and the six largest trade companies have formed the Space Station Promotion Council, which coordinates the interests of more than 230 companies in Japanese participation in the development, operation and utilization of a permanent space station. Since the financing of the space programme has to be justified on economic grounds, the active interest of industry is essential. Most companies are looking beyond the short-term profits to their potential profits from the push in industrial innovation, which they expect to result in the long run.

Foreign policy dimension

The Japanese have relied heavily on cooperation with the United States. The conditions attached to this dependence have impeded

Japanese exploitation of the world market. Consequently national policy aims for greater technological independence from the US, mainly in satellite and launcher technologies. In other respects there is a low profile stance vis-à-vis other countries which avoids giving the impression that Japan is making a strong move into future space markets. A similarly low profile policy is pursued in the UN Copuos. However, in the more technically oriented specialized organizations, such as Intelsat, Inmarsat, ITU and WMO, Japan is more proactive.

Security policy dimension

The early years of Japan's space programme were marked by a self-imposed reluctance to fund technologies that might be perceived as having military applications. This self-restraint with regard to dual-use space technology (mainly launcher technology) was abandoned late in the 1960s when Japan became heavily involved in the development of modern launcher technology under licence to American companies.

Today, Japan's space programme is civilian, though with military options, which could be developed relatively quickly. The government has recently decided to allow Japanese companies and research establishments to participate in the SDI research programme. A formal agreement with the United States was signed in September 1986.

(d) CHINA

The People's Republic of China began developing rockets in the 1950s. Today China belongs to the small club of 'space powers' which have successfully launched their own satellites, using indigenously developed launchers. China is now offering space transportation services on the world market. Swedish and US companies have already signed agreements for the launch of their satellites with Chinese rockets.

Objectives

The objectives of the Chinese space programme are primarily political and military, and geared to the establishment of a strategic deterrence capability, especially vis-à-vis the Soviet Union. However, since the mid-1970s economic policy considerations have played an increasing role. The Chinese leadership is convinced that the promotion of space research and technology will help to increase the country's scientific and technological potential and lead to major improvements in the telecommunications infrastructure, weather prediction and the exploitation of natural resources. All three types of satellite can be used for military as well as civilian purposes.

Programmes and projects

Like those of the US and the Soviet Union, Chinese launchers have been developed from military rockets – thus indicating that China has a significant ICBM capability. The launchers currently at China's disposal – Long March 2 and 3 – are able to transport payloads of up to 2,000 kg into LEO or up to 1,300 kg into GEO. The upper stage of Long March 3 uses a high-efficiency cryogenic fuel. The plans are to increase Long March 3's geostationary booster capacity to 2,500 kg in the coming years and to double launch frequency – at present 3 to 4 launches per year. In September 1981 China launched its first multiple payload: three satellites were launched using one rocket. The launches take place at two launch sites: one for low orbital satellites with Long March 2, and one for geostationary satellites with Long March 3.

Altogether 19 satellites were launched between 1970 and 1986. Payloads from some 8 of these satellites have been recovered, suggesting that these had been on reconnaissance missions. In April 1984 the first television communications satellite (STW-1) was launched into GEO. However, the capacity of this satellite and its successor is not sufficient to satisfy China's needs in the field of telecommunications. Hence the launch of a considerably larger communications satellite (STW-3) is planned for 1987. A further increase in capacity is planned for the 1990s.

The launch of an indigenously developed weather satellite for polar orbit is expected in 1988, and the development of weather satellites for GEO with high resolution is planned for the 1990s.

A manned space programme was initiated during 1979/80, but discontinued because of financial constraints. It has recently been revived with the aim of achieving manned missions in the 1990s.

Budget and resources

There are no official data available on the budget. Western experts have estimated it to be in the order of 3 billion EAU. In 1986 a workforce of roughly 100,000 people was thought to be engaged in the Chinese space programme, a quarter of whom were engineers and researchers.

Organization

The fundamental goals of policy and the budget are determined by the State Council, which consists of the chairmen of 8 State Commissions as well as 36 Ministers under the leadership of the Prime Minister. The Ministry of Astronautics is responsible for the formulation and implementation of the space programme. Three further institutions are directly subordinate: the Chinese Academy of Space Technology, the Shanghai Astronautics Bureau, and the China Great Wall Industry Corporation.

Foreign policy dimension

In its early phase the Chinese space programme was modelled closely on that of the Soviet Union. Since the Cultural Revolution, the Chinese have sought technical and economic cooperation with the West in the exploration and use of space. They also cooperate with some socialist countries, but not the Soviet Union.

China is actively involved in space matters in the UN, in particular in the Copuos and the Conference on Disarmament. Here the Chinese government has claimed a role as the representative of the developing countries. China is a member of the WMO, ITU, Intelsat and Inmarsat.

Security policy dimension

A military orientation permeates Chinese policy in space, and a key purpose has been to support Chinese ballistic and submarine-launched missiles. This accounts for the emphasis on the development of military communications and reconnaissance satellites.

At the same time, however, China actively opposes the militarization of space in the United Nations, most specifically the development and testing of 'space weapons' and the stationing of such systems in space. China's criticism focuses in this context on SDI. It is apparent that behind this political position is the conviction that for technological and economic reasons China itself will not be capable of stationing weapons in space in the foreseeable future.

(e) INDIA

India has been engaged in the exploration and use of space since 1961. The principal characteristics of India's space policy are long-term planning, straightforward implementation and concentration on a few clearly identified objectives. This policy is based on a broad national consensus.

Objectives

The objectives of the Indian space programme are primarily of a socio-economic nature: namely, to make significant contributions to the solution of problems which are characteristic of day-to-day life, such as frequent natural disasters, mass illiteracy or lack of raw materials.

In addition, the programme has political motivations: it is designed to strengthen India's position as the dominant political power in South Asia, as a leading power within the group of developing countries, and as a political rival of China and an antagonist of Pakistan. Therefore, a principal objective is self-reliance, that is, the ability to explore and use outer space with indigenous launch vehicles and satellites without having to rely on technical assistance from other countries.

Programmes and projects

So far the results of India's space programme have been impressive, given the economic and social context in which the programme has been built. The country has developed a small communication satellite (650 kg) which was launched in 1981 by Ariane. The current emphasis is on a system of multi-purpose satellites – Insat – which can be used for telecommunications, television, broadcasting and meteorology. After an aborted launch in 1982, the first of these satellites (Insat 1B), developed and built according to Indian specifications in the US, was launched by the Shuttle and has been in operation since autumn 1983. A successor satellite (Insat 1C) has been ordered in the US and will be launched in 1988. The second generation of these multi-purpose satellites (Insat 2) is to be developed and built by India, and launched in 1990 with a non-Indian booster, and from 1993 with Indian launchers.

In addition, several small and experimental satellites (450 kg) for remote sensing have been developed in India and launched with

Soviet boosters in 1979 and 1981. A larger 850 kg version, called IRS, to be operated for surveys of natural resources and ocean monitoring, is currently in the final stage of development and will be launched in 1987 with a Soviet booster. Two further IRS satellites are due to be launched in 1989 and 1990.

India has a small inertially guided, solid propellant, launch vehicle (SLV-3) to carry payloads of up to 50 kg into low earth orbit. Since 1980 three rockets of this type have been successfully launched. The first launch of an enlarged version (ASLV – Augmented Satellite Launch Vehicle), for payloads of up to 150 kg in 400–500 km orbits, failed in March 1987. A second generation for 1,000 kg payloads into polar orbits (PSLV – Polar Satellite Launch Vehicle) is planned for the early 1990s.

Budget and resources

The Indian space budget for 1985/6 was 2.1 billion rupees, equivalent to about 250 million EAU, which amounted to slightly more than 0.4 per cent of the national budget. The Indian Space Research Organization employs some 11,000 people, about 4,000 of whom are engineers and technicians.

Organization

The Indian space programme is characterized by strong centralization. The Indian Space Research Organization (ISRO), established in 1969, is an integral part of the Department of Space (DOS), an agency directly responsible to the Prime Minister. The head of the DOS is also chairman of ISRO. Coordination with other space-related departments and agencies is carried out at cabinet level through the Indian Space Commission, which is also chaired by the head of the Department of Space. ISRO has four main space centres for development, production, launch and operation of rockets and satellites. The involvement of Indian industry in the programme is increasing, although more than 90 per cent of the development and construction is still conducted in government research centres.

Foreign policy dimension

Space policy plays an integral part in India's foreign policy. It enhances the country's leading role within the non-aligned movement as well as within the group of developing countries. India cooperates with all the major space countries (except Japan), especially with the Soviet Union, and takes an active part in the work of the UN Outer Space Committee, Intelsat, Inmarsat and WMO.

Security policy dimension

So far space policy has had little direct relevance to India's defence and security policy. However, as the programme matures and becomes more sophisticated, India will acquire the option of using space for defence purposes too. In this respect, the main official interest is likely to be in using space assets for reconnaissance and military communications, although, combined with Indian nuclear capability, they could provide the basis for a ballistic missile system. Either way the space programme is an important adjunct to Indian aspirations to be the leading political power in South Asia.

3

THE RECORD: NATIONAL PROGRAMMES

In contrast to the policies of the five countries just reviewed, European space activities have so far been conducted within a double framework. On the one hand, most European countries have been involved in collaborative space endeavours, first in ELDO and ESRO, then, since the mid-1970s, under the aegis of ESA; indeed, they have also conducted several space projects with space powers outside Europe. On the other hand, several European states have simultaneously built up national space programmes serving particular political, economic or security purposes. This structural ambivalence acts as an obstacle to the development of a comprehensive European space policy, though it reflects the political, economic and cultural diversity of Western Europe today.

The following presentation of the national space policies of five European countries – France, the Federal Republic of Germany, Italy, the Netherlands and the United Kingdom – reflects the present state of affairs. Information in the tables and figures at the end of the report fills in many of the details. The panorama of Europe's current space effort reveals a complex intertwining of persisting traditions oriented towards national interests, together with a growing consciousness of the need to strengthen European space policy on a collective basis.

(a) FRANCE

France was the first West European country – and, indeed, the third country in the world, after the USSR and the United States – to initiate a national space programme, from the early 1960s. At the outset goals of national independence in relation to both security interests and prestige certainly played an essential role. Initial efforts, aimed at building up a French launching capability, finally succeeded when, on 26 November 1965, the Diamant A launcher put into orbit the first French satellite, Asterix. This symbolized the French ambition of acquiring an attribute that only the greatest powers could afford: presence in and autonomous access to space. Indeed, involvement in space was another way for de Gaulle's France to affirm its independence vis-à-vis the other world powers, and its ability to succeed in a field apparently reserved for the US-Soviet duopoly.

The development of an autonomous civilian space capability with indigenous launchers was also closely linked to French efforts in the field of ballistic missile technology. Indeed, it benefited from the decision to build up an independent nuclear deterrent. Significantly, the Diamant-A programme, initiated and supervised by the civilian space agency, the Centre National d'Etudes Spatiales (CNES), was conducted by the Délégation Générale pour l'Armement, part of the Ministry of Defence, and used the hardware developed under the validation programme for ballistic missiles.

These goals of the 1960s, which rested on national ambition, have not entirely disapppeared. They are still reflected in the commitment to manned space flight, in the decision to develop the Hermes space vehicle, and most of all in the military programme. However, the French have realized that international collaboration has become necessary to the fulfilment of its space activities for scientific, technological and financial reasons. This realization is evident in the increased commitment to a large number of collaborative programmes.

Above all, commitment to the joint European space effort is an essential aspect of French space policy. This started with membership of ELDO/ESRO, but significantly France played a large part in the 'package deal' constructed in 1973 which led to the creation of ESA in 1975. The French convinced their partners of the need to develop a European launch capability on the basis of their own experience. The French government also offered launch facilities at Kourou in French Guiana as common ESA facilities for European missions. Largely because of its role in developing the Ariane launcher, France is the leading contributor to ESA. In 1986 its eventual contribution to ESA was 2.31 billion francs (337.03 million EAU), or 29.6 per cent of ESA's budget.

Successive French governments have actively promoted the development of advanced space technologies. They have acknowledged the economic spin-offs offered by space activities, and the growing importance of commercial space applications such as communications, direct broadcasting or Earth observation. Within the framework of French science and technology policy, this increased effort in sponsoring space industries is viewed as having had a positive impact on both employment and the international competitiveness of French industries, particularly in the sectors of electronics and computer engineering. Successes in space technology are perceived by the French public as a proof of the country's ability to hold its own in a highly competitive area of activity with great potential.

Consequently, there is wide public support for the national space programme. The public impact of space is undeniably greater than in other European countries, and this reflects its association with national pride. According to an opinion poll carried out in 1985, 85 per cent of French citizens interviewed were in favour of space activities. Public attitudes towards national achievements in space are similar to their approval of the 'force de frappe'. Space thus emerges as a natural extension of the independent deterrent. In addition, national successes in space are used more and more frequently by almost all the political parties as a theme to generate political support.

Programmes and projects

The major part of the French civilian effort in space is today developed on a collaborative basis, either bilaterally or multilaterally, mostly within ESA, but also with other space powers, such as the USSR and the United States.

France initiated the decision by ESA in 1973 to develop a European launcher on the basis of the L3S project of the CNES, the eventual Ariane, a fundamentally different conception from the Europa project, for which each country built one stage. The French are project leaders of Ariane and currently contribute a 59.25 per cent share of the capital of Arianespace from various companies and institutions.

In 1978 the CNES started preliminary studies on the new Ariane 5 launcher and Hermes manned spaceplane configuration. A technical proposal for Ariane 5 was presented to ESA member states in 1984 and endorsed by the January 1985 ESA ministerial conference. The French then pursued their studies of Hermes and invited other European governments to take part. Twelve countries in ESA have agreed to participate, with the French financial contribution initially at 39 per cent of the total.

As for application satellites, France has participated in the development and production of a series of ESA programmes, including ECS, Marecs, ERS-1 and Meteosat. However, two important programmes are conducted on an almost exclusively national basis.

In 1979 the Directorate-General for Telecommunications initiated the Télécom 1 programme, for which two satellites – Télécom 1A and Télécom 1B – were launched in 1984 and 1985 respectively, and are now operational. A third – Télécom 1C – is to be launched in November 1987. The programme has four major functions: digital telecommunications; conventional telephone and TV traffic between metropolitan France and the French overseas territories; video communication links; and communication links for government and military use.

The Spot programme is an ambitious project for Earth observation. The first satellite, Spot 1, was put into orbit on 21 February 1986, and with three further satellites is scheduled to operate for ten to twelve years. A new commercial company, Spot Image (actually a branch of the CNES), was set up to market the resulting images. Belgium (4 per cent) and Sweden (6 per cent) participate in the programme.

France has developed two satellite programmes with the Federal Republic of Germany. First, under the Symphonie programme, two telecommunications satellites were launched in 1974 and 1975. Second, in 1980 France and the Federal Republic signed an agreement to develop a pre-operational direct broadcasting system for each of the two countries, TDF-1 for France and TV-Sat for Germany. The TDF-1 and 2 programme has encountered difficulties linked to the political debate in France on the future of TV techniques and structures. Criticized by some liberal ministers as 'technically obsolete', the programme nonetheless was approved by the Prime Minister in February 1987. TDF-1 is to be launched in January 1988 and TDF-2 perhaps in mid-1989.

Other collaborative ventures include the French-US Argos and the Franco-British Eurostar. The French also participate with Canada, the US and the USSR in Cospas-Sarsat, a new localization and data collection programme for a worldwide search and rescue system.

Scientific programmes remain important, with extensive involvement in ESA missions (such as Exosat, Hipparcus and Giotto) and bilateral cooperation with the US and USSR. An important new French-US project, the Topex-Poseidon oceanographic satellites, is to be launched in the early 1990s. Franco-Soviet cooperation dates back to the mid-1960s, the first agreement having been in 1966. General de Gaulle was the first Western head of state to visit the Soviet Tyuratam (Baikonur) space centre. More recently, the Soviet Vega missions have used French drifting balloons for the study of Venus, and France will take part in the Soviet Phobos and Vesta missions.

France has also carried out two manned space missions, the first one, carrying Jean-Loup Chrétien, with the Soviet Soyuz-T-6/Salyut 5 in 1982, and the second one, carrying Patrick Baudry, with the American Shuttle in June 1985. Under an agreement signed in 1986, a French astronaut will take part in a Soviet Mir space station mission.

Budget and resources

France dedicates a relatively large share of GNP to space activities, more than 0.11 per cent per year for the last few years. The budget of the CNES largely represents the aggregate civilian effort. In 1986 the CNES devoted a total of about 5.848 billion francs (860 million EAU) to its various space activites. Of this sum, 37.99 per cent (2.221 billion francs) covered multilateral collaborative programmes; 21.06 per cent (1.231 billion francs) was spent on national programmes; 12.69 per cent (0.74 billion francs) went to bilateral programmes; 13.91 per cent (0.81 billion francs) was spent on technical support; and 14.35 per cent (0.84 billion francs) on administration. Some 11,500 people are employed by space industries, administration and research institutions. This is over a third of the total European work-force engaged in space activities.

Organization

Space policy-making is in practice confined to a relatively small group of high-level specialists. Political and administrative elites have been neither very interested nor significantly involved. The orientation of space policy is not a matter for nationwide debate, in contrast to how it is in America.

The CNES was established in 1962 as a primarily civilian research agency under the authority of the Ministry for Industry and Research. In 1986 it had a staff of some 2,000 people, of whom 70 per cent were engineers and technical specialists. It is responsible for managing and coordinating civilian space activities and for identifying trends in space technology.

The board of directors of the CNES operates within the framework of long-term space policy set by the President of the Republic and the government. Restricted sessions of the Council of Ministers are held annually or biennially to make major decisions on space policy. The space budget is supervised by the Ministry of Finance, with annual budgetary allocations voted on by the Parliament.

The CNES has a dual role, both policy-formulating and operational, an object of some criticism. Indeed, its legal statutes, adopted in 1961, no longer correspond to the realities of the space business, given the growing importance of commercial and military applications of space in comparison with purely scientific space activities. There has notably been a debate between the CNES and the Ministry of Defence over the division of labour between them and the allocation of responsibilities for developing military programmes. In 1986, a decision was finally taken: the Ministry of Defence's Délégation Générale pour l'Armement (DGA) is now responsible for the execution of all the military programmes; the CNES's contribution is limited to general technical support. Consequently, the current organization of the French space effort has become, in some ways, comparable to the Nasa-DoD model.

French achievements in space could not have come about without the vitality of the major industrial firms. In the launcher sector, experience in the field of ballistic missiles has been crucial, but equally relevant was the infrastructure already developed in the sectors of aeronautics and electronics. This is why the production of space systems is generally done by large companies active in other sectors of industry. For the same reason, the space industry is very concentrated. Two-thirds of French space products are manufactured by four large companies: Aerospatiale (general architecture of Ariane, satellite production), Matra (satellites), Alcatel-Thomson-Espace (satellite electronic equipment) and SEP (propulsion systems). The rest is produced by some 50 companies, mostly small or medium-size firms which specialize in components for space systems.

In 1985 the French space industry employed about 9,000 people: 50 per cent in the field of launchers; 45 per cent in satellite production; and 5 per cent in ground-based stations production. The total annual turnover of the space industry is over 4 billion francs. The major companies collaborate, in both satellite and launcher sectors, with other leading European space firms through consortia arrangements.

Military programmes

The military have been involved in French space programmes from the outset, but specific military programmes are much more recent. The evolution of both strategic concepts and modern warfare has given a growing importance to space as a new dimension of the military balance between the world powers, especially since SDI. The first French reaction to SDI was to reject the US project of an anti-ballistic-missile space shield as both unrealistic and destabilizing, especially for Western Europe. At the same time SDI served to trigger a realization in France of the military importance of space, reflected in President Mitterrand's speech in The Hague of February 1984, in which he claimed that a 'European space community would be the response best adapted to the military realities of tomorrow'. In spring 1985 France proposed a European civilian R&D programme – the Eureka project – some fields of which were similar to those covered by SDI. This attitude reflected conflicting desires to oppose SDI as a strategic concept, yet to maintain technological competitiveness vis-à-vis the Americans. The French government did not prevent French companies from participating in SDI industrial contracts. The new government elected in March 1986 was at first more favourable towards SDI, but has in practice maintained the same broad policy stance.

France remains opposed to the extension of the arms race to outer space by placing weapons in orbit, but recognizes the need for some military space programmes to underpin its defence capabilities. French space arms control policy has been marked by two proposals. In 1978, at the first special disarmament session of the UN General Assembly, President Giscard d'Estaing made a proposal for the establishment of an international satellite monitoring agency (ISMA). In 1984, another proposal, this time for the limitation of anti-satellite systems (essentially by the prohibition of any high-orbit operational Asat and by the introduction of a series of multilateral guarantees protecting satellites other than those of the United States or of the Soviet Union), was formulated at the UN Disarmament Conference in Geneva.

The military effort has two main functions: first, to increase the credibility of the French nuclear deterrent, mainly by reconnaissance and early-warning capabilities; and, second, to support France's military presence and intervention capability in the regions of the world considered essential for the country's security (in particular Africa, the Indian Ocean and the South Pacific). The most important space applications for the military are thus communications and intelligence.

The Syracuse 1 network for military telecommunications is based on the civilian Télécom 1 satellite telecommunications system. It covers approximately one-third of the Earth's surface, and has been in operation since 1984. Ground- and sea-based stations guarantee the inter-connection of the space segment with other military communication networks. Syracuse 1 will be replaced by Syracuse 2 in the early 1990s. The present Syracuse 1 system has cost about 1.36 billion francs.

The French have sought to reduce the present dependence on military intelligence provided by US satellite systems; hence the research effort since the late 1970s to build up their own satellite reconnaissance system. This first project, Samro (Satellite Militaire de Reconnaissance Optique), was a slightly modified military version of Spot. In 1982 negotiations to promote a Franco-German satellite for military reconnaissance were initiated on the basis of the Samro concept, but proved abortive.

In February 1986 the French government authorized the development of Helios, a modified project for an optical reconnaissance system, with three or four satellites using the multi-mission space-based platform developed for Spot. The Ministry of Defence will be responsible, with inputs from the CNES, and hopes to operate Helios from 1993. Initial cost estimates were 12 billion francs (1.7 billion EAU), now revised down to 8 billion francs (1.1 billion EAU). The French authorities are open to collaboration on Helios with other West European countries. The Italian government decided in February 1987 to join the project and share 15 per cent of the costs, and the Spanish may follow with a 5 per cent share.

The decision on Helios dramatically increased the French military space budget between 1986 (697 million francs or 102.5 million EAU) and 1987 (1,707 million francs or 251 million EAU). To coordinate current and future military space activities, the Ministry of Defence set up in March 1985 a Space Study Group (Groupe d'Etudes Spatiales).

(b) GERMANY

The Federal Republic of Germany has engaged in the research and exploitation of space since the early 1960s. From the outset German policy rested on a resolve to create a joint European approach and to foster transatlantic cooperation. Military goals were not pursued. Until the late 1970s German space activities were almost entirely funded from the government's research and technology budget, with particular support for basic research and the development of areas promising solid economic returns. In the 1960s and 1970s, German space activities leaned rather strongly towards the US, especially during the critical period before ESA emerged. German-American space collaboration reflected technical factors and personal links, but it was also politically motivated. It reached its culmination with the federal government's decision to take the lead in developing the European Spacelab for the then new US Space Transport System (Shuttle) and to carry more than half of the costs.

Since the early 1980s the points of emphasis in Germany's space commitment have gradually, but clearly, shifted. Interest in the further development of an indigenous European space transport capacity, including manned systems, has increased. Cooperation with the United States is still endorsed, but rests on satisfying aspirations for a much stronger European role. This is clearly reflected in the negotiations over European participation in the space station project proposed by President Reagan. Discussion about German participation in European space-based systems for verification and reconnaissance has been reopened. The Ministry of Posts, the Weather Service and the media have now all begun to devote resources to space systems for their own use. Medium-range planning for the future envisages a substantial increase in state funding of space research, development, and operations. An internal reorganization of German activities is being discussed.

For a long time German involvement in space, and all that that implies, was more often passively accepted by successive governments than actively promoted. It is only recently that the developments in certain fields of high technology, including space technology, have received increased attention as an element of foreign policy. The decisions to strengthen the scientific programmes of ESA and to support Ariane 5, Columbus and Hermes all confirm this trend. The planned increases in the space budget calling for a simultaneous increase in the proportion of the budget allotted to European projects underline this new pro-European accent.

The parliamentary parties in the Bundestag have, with the exception of the Greens, spoken supportively on space matters but not enthusiastically. Space issues have not been controversial apart from the recent debate over SDI. The media in Germany were often more reserved and tended to take a negative view of projects apparently undertaken for reasons of prestige. This attitude has recently combined with a growing scepticism towards exotic technologies. As a result, the media have frequently portrayed a distorted image of German space activities. In clear contrast, German public opinion has repeatedly demonstrated a broad and positive interest in the opening of the space frontier and Europe's association with this, a trend that is likely to continue.

Programmes and projects

German space activities span the entire spectrum except military applications, and include the full capacity to organize and conduct manned missions, as the D-1 mission in autumn 1985 demonstrated. The first priority remains the scientific investigation of space, utilizing sounding rockets, satellites, space probes, and also the Spacelab system. German scientists have shown particular interest in the physics of the solar system and the clarification of solar-terrestrial relationships. The two Helios solar probes, which during their active life from 1974 to 1985 covered an entire solar cycle, provided important information in this field. German participation in the research satellites of ESA (and previously ESRO) made no small contribution to their success, as was demonstrated again, recently, by the camera and the particle experiment of Giotto. The Rosat project will be a major step forward in the systematic investigation of X-ray sources in space. It is already at an advanced stage with some American and British involvement. German institutes and occasionally German firms have made numerous contributions to other, especially American, space research projects.

As for Earth observation, strong German participation in the European Meteosat programme was followed by a substantial role in the ERS programme of ESA, including the industrial prime contractorship for ERS-1 and the provision of various optical and microwave sensor systems. Earth observation data are processed and evaluated on a large scale by the German DFVLR. In addition, a small but growing number of private enterprises are active in this field, and there is close cooperation with developing countries.

Germany is among the European pioneers in the use of satellites for telecommunications. The two Symphonie satellites, built by German and French industry, served for almost a decade in a range of experiments in telecommunications and transmissions. Subsequently the federal government took the initiative of building the first direct TV broadcasting satellite (DBS), and in 1980 France joined the system. The German TV-Sat is due to be brought to its GEO when an Ariane launch is available, and will be followed by TDF-1, its French twin, within a few months. The installation of an operational DBS system and a second TV satellite are planned. In addition, the German Postal Service has made considerable progress in developing its own satellite system – DFS Kopernikus – for telecommunications and TV distribution; it is due to operate in 1988. German industry is substantially involved in the manufacture of the ECS satellites for the Eutelsat system and the Marots/Marecs satellites for Inmarsat. It has also supplied subsystems for the fifth and sixth generation of Intelsat satellites. In cooperation with the DFVLR, German industry has made a most impressive contribution to the development of a satellite-based worldwide search and rescue system. A large-scale participation is planned in European systems for radio transmission between satellites and with space stations and platforms in low orbits.

Research on weightlessness has been of particular interest, especially since the decision to support Spacelab, and many studies and experiments have been carried out, including parabolic flights, sounding rockets and the German-built Shuttle Pallet Satellite. The majority of the European experiments conducted during the first Spacelab flight in 1983, with the German-born ESA astronaut Ulf Merbold, were prepared in German institutes. The Spacelab flight D-1 in autumn 1985, with ESA astronaut Wubbo Ockels and the German scientists Ernst Messerschmid and Reinhard Furrer, was entirely organized and controlled from the DFVLR control centre in Oberpfaffenhofen. Another mission, D-2, is now in preparation, but launcher problems will probably delay it until 1991. The Intospace company has been founded with the express purpose of stimulating industrial interest in such research work and providing advice.

For ten years (1973–82) Spacelab was the most important and most expensive project on space technology in the Federal Republic. Its development supplied an extraordinary amount of information and experience. The laboratory proved its worth under operating conditions. However, its use is now severely crippled by the Challenger accident. Led by German industry and with a German contribution of 38 per cent of the costs, ESA is now developing the unmanned space platform Eureca, designed primarily for experiments on weightlessness. Germany is taking the lead in the preparation of the Columbus programme.

Germany has been involved throughout the development of European launcher systems. It provided the third stage for the Europa launcher. The German share of 20 per cent in the Ariane programme was the second largest and will be slightly larger in the development of the new Ariane 5. After protracted debate the Federal Government eventually decided to participate in the Hermes preparatory programme with a share of 30 per cent. Recently a German proposal was put to ESA for a new generation of space transporters, the two-stage Sänger II. German interest in European space transport systems is increasingly evident.

Budget and resources

Germany has excellent foundations for an active space role in the field of science and a sound industrial capability. Government funding has been continuous and indeed higher than the European average, albeit lower than that of France and far lower than that of the US. In 1986 the Ministry of Research and Technology spent a total of 898.5 million marks (436 million EAU) on space research and technology; of this, 559.2 million marks (271.5 million EAU), over 62 per cent, went to ESA. Of the remaining sum, 247.7 million marks (120 million EAU) were earmarked for national research and development purposes, including the German contribution to bilateral and trilateral projects. A sum of 91.6 million marks (44 million EAU) was allocated to the relevant expenditures of the DFVLR. A further increase in the total expenditures is planned in the medium term.

In addition, the 1986 budget of the German Ministry of Posts included 777 million marks (377 million EAU) for space-based activities, and the German Weather Service appropriated 38 million marks (18.5 million EAU) for its participation in Meteosat. No data are available on the space expenditures of the German radio and television networks, publishing houses and other organizations, nor on expenditure by German companies. But we can assume that the respective amounts are relatively low as compared with total expenditures.

Organization

Since 1962 governmental responsibility for space research and the development of space technology has been in the hands of the Ministry of Research and Technology, though the Ministry's staff working in this field is quite small. It is supported by a larger working-group within the DFVLR. The DFVLR also runs the German Space Operations Centre, test facilities for rocket engines, a training centre for astronauts and special institutes for Earth observation, telecommunications and weightlessness. Space research in the strict sense is carried out in several institutes of the Max Planck Society and several university institutes. Furthermore, one of the three largest European space test centres, with extensive simulation and experimental facilities, is situated in the Federal Republic near Munich in the 'Industrieanlagen-Betriebsgesellschaft' (IABG). ESOC, ESA's Satellite Operations Centre, is located in Darmstadt. The headquarters of Eumetsat will soon be established in the immediate vicinity of ESOC. Finally, the German postal service has its own facilities for communication with and operation of satellites.

Taken as a whole the organization of space policy has thus far functioned without mishap, though critics maintain that it has often been far from optimal. Its status within the Ministry of Research and Technology as one among some dozen sectors causes increasing problems, since this neither does justice to the importance of the field nor does it guarantee adequate impact vis-à-vis Nasa, ESA, and CNES. However, there has at least been the advantage that German space activities have not suffered from excessive bureaucratization. Meanwhile, increased political interest at home and new developments in neighbouring countries, in particular the UK and Italy, have led the federal government to study options for reorganizing space activities. A preference is emerging for a more independent management agency.

The primary producers of space systems in the FRG are the aerospace industry (Dornier and MBB-Erno), the electrical and electronics industry (eg., AEG, ANT, SEL, Siemens), companies active in the fields of optics, precision mechanics, scientific instruments and related branches (eg., Kaiser-Threde, Teldix, Zeiss) and some specialist firms of mechanical engineering (eg., MAN). Some 6,000 highly skilled employees are directly involved in space activities ranging from the systems management of large projects to the delivery of single small elements. Greater industrial collaboration within Europe may diminish the problem of continuing dependence on US sources for key components.

Foreign and security policy dimensions

The European and transatlantic dimensions have consistently pervaded German space activities and made imperative the inclusion of foreign policy interests in German space policy. By the same token space activities influence German foreign policy. The strong Western orientation of German space policy for a long time prevented cooperation with the German Democratic Republic, other East European countries and the Soviet Union, and even now links are few and largely confined to space science. Within the West European framework, Franco-German cooperation has taken on a special quality, made concrete in the Symphonie satellite programme and the TV-Sat/TDF-1 programme. Together France and Germany have steadily provided more than half of the funding for European space cooperation within ESA. With regard to the two large development programmes of the 1970s and early 1980s – Spacelab and Ariane – their joint contribution was even higher: more than 70 per cent in the case of Spacelab and more than 80 per cent for Ariane. A similar though somewhat more equal distribution of financial burdens will apply for Hermes. Yet the GNPs of the two countries have always amounted to less than 45 per cent of the total GNP of all ESA member states. Indeed with the increase in membership of this organization, the figure has now dropped to 40 per cent.

So far the Federal Republic's activities in space have been limited to the civilian sector. In the early 1980s Germany, after accepting the French invitation to look at a common military reconnaissance system, then decided not to pursue it. Discussions about a variant of such a system are only just beginning. German industry is only minimally involved in Nato's military communications satellite. Under the American SDI programme, some small research contracts have been given to German industry under a bilateral memorandum of understanding, but these seem to offer little scope for expansion.

(c) ITALY

Italian interests in space have been largely determined by two factors. First, space is perceived as a competitive field of rapid technological development in sectors such as telecommunications, propulsion and remote sensing, and thus crucial in industrial and strategic terms. Second, Italy is keen to maintain its position as a full member of the family of technologically advanced nations. But the full array of space activities, some of which have uncertain or at best long-term returns, has appeared beyond the reach of the financial, industrial and scientific resources available at the national level. The guiding philosophy has thus been to rely on international collaboration: European first, then bilateral or multilateral with the US, and more broadly multilateral. This is evident in the structure of the National Space Plan (PSN), formulated since 1979 under the direction of the Ministry of Science and Technology. The PSN marked a shift from the planning of individual projects to a wider approach, sector by sector.

The outcome of this pragmatic approach is not unsatisfactory, especially in relation to the level of expenditure. First, a cooperative framework, stimulated by both private and public sectors that are particularly dynamic in this field, has meant that telecommunications have emerged as the *de facto* priority. Second, Italian industry and science have performed quite satisfactorily in a number of joint programmes within ESA and other international cooperative bodies: propulsion systems and space modules are good examples. Third, all this has been accompanied by diplomatic achievements, notably the success of the 1985 ESA ministerial conference in Rome.

Programmes and projects

National activities in the field of telecommunications started with the launch of the Sirio satellite programme on 25 August 1977. Today the most important telecommunications programme is represented by Italsat, the first domestic pre-operational satellite, with 11,000 new telephone channels and direct broadcast and data relay. It will use high-frequency bands for specialized services such as video-conferencing, high-density telephony and rapid facsimile transmission between computers in full network conditions. Italsat is scheduled for launch in 1988 and the programme will cost 595 billion lira. Outside the PSN budget, and under the auspices of the Ministry of Posts, two more satellites – the Sarit D for direct broadcast only and the Sarit M with telecommunication channels – are under consideration. Italy was fourth in the international market for ground stations from 1965 to 1982, with a 5 per cent market share (the United States had 39 per cent, Japan 37 per cent and France 13 per cent). New ground stations will be set up in the Italsat programme.

In remote sensing, the main Italian effort is in receiving stations and data processing. Techniques for processing and analysing remote-sensing data, methodologies aimed at producing maps of parameters for general application interest and new architectures of remote-sensing data pre-processing are being developed through the PSN. The PSN also distributes to Italian users the data supplied by Landsat, HCMM, Seasat, Nimbus and Spot satellites. In sensor technology Italy is cooperating with Germany in a project to develop a Synthetic Aperture Radar, SAR-X, at a cost of around 40 billion lira. This new instrument was scheduled to fly on a Shuttle mission in the 1990s.

The national weather service run by the Italian Air Force routinely uses satellite information, especially from Meteosat. A national network has been created to improve the utilization of satellite data and is centred at the Primary Data User Station (PDUS) in Rome. Five secondary data user stations are in operation.

Italian activities in space geodesy and geodynamics are carried out in cooperation with the United States and other countries. A ground station for satellite laser ranging has been installed at Matera in the Mezzogiorno, which (through a satellite network) will measure the motion of the Earth's surface. Italy will collaborate with the US in building Lageos 2, a new passive satellite, equipped with retroflectors.

The main PSN project in the field of propulsion systems is represented by the Iris programme (Italian Research Interim Stage). This is to be used in cooperation with the Shuttle to place into geotransfer orbit payloads of the order of 900 kg. Iris consists of two main modules: the ISS (Iris Spinning Stage) and the ASE (Airborne Support Equipment). The former is an expendable propulsion module equipped with a solid rocket motor, whereas the latter is a re-usable module which is needed to operate the propulsion module. But Iris will not have the capacity independently to launch even small satellites. Two studies are under way at the moment: one to investigate an entirely Italian launcher; and a second to explore a joint venture with Volvo, perhaps using Ariane hardware.

As for scientific research, the PSN envisages two satellites: the Sax (X-ray Astronomy Satellite) and the TSS (Tethered Satellite System). The Sax is due to explore the universe in the radiation band between 2 and 200 kev, with a Shuttle launch scheduled originally for 1989. It will cost 172 billion lira by 1988. The Italian share in the TSS programme is expected to cost 82 billion lira by 1988. The TSS should be launched in 1987. In 1983 Italy performed five experiments on the first Spacelab flight. Another programme which deserves mention is the Italian/Nasa San Marco project for scientific research in the upper atmosphere.

Technological research is currently being carried out in the following fields: electronic technologies, space telecommunications, robotics, chemical and electronic propulsion, thermal control, and in-orbit altitude and control. In addition, Italian industry has recently entered the field of software research.

Launching sites at the San Marco range and the Malindi station in Kenya are managed by the Centro Ricerche Aerospaziale (CRA) of the University of Rome and by the Italian Air Force. A series of launches have been performed in cooperation with the US and with other countries during the past twenty years. The base has also been used for the San Marco scientific programme, and current plans envisage its continued use.

Military activities include telecommunications satellites, for which the Italian Air Force has been developing the AM-136 programme since 1980. This has a capacity of 12,000 telephone channels and will be used for a wide range of services. Its coverage will be centred on Italy and the Mediterranean area and will be oriented towards communications with mobile (aircraft and ships) and fixed stations (ministries, airports, harbours, etc.). Two satellites, the Sicral-1A and the Sicral-1B, are expected to be active and will be used not only for military and police services, but also for civilian emergencies. AM-136 will be put in GEO in 1991, at a cost of 1,006 billion lira. Italy has also decided to participate (15 per cent) in the French surveillance satellite Helios.

Italy is heavily involved in the major ESA projects. In the Olympus programme, it has prime responsibility for payload, structure, integration and test of propulsion equipment, with a total share of over 30 per cent. In Columbus, Italy holds prime responsibility for the pressurized module and a 25 per cent share of the total cost. In Ariane 5, Italy holds prime responsibility for the large solid boosters and will develop the turbo-pump for the HM-60 cryogenic motor, a participation level of 15 per cent. Italy participates significantly in Eureca (17.3 per cent), ERS-1 (10.61 per cent), the ECS programme (14 per cent), and the Ariane 3 (17.55 per cent) and Ariane 4 (7.75 per cent) launchers. As for Italian participation in ESA scientific research programmes, from a total of 240 experiments proposed by the European scientific community, 15 were Italian, 7 of which have been selected.

Budget and resources

The budget for space activities has increased steadily over the past few years. The budget for national activities in the period 1986–91 is expected to be approximately 1,870 billion lira. Over the same period Italy will spend 1,248 million EAU (about 1,720 billion lira) on ESA activities. Therefore, the overall aggregate annual budgetary outlay should reach the level of 600 billion lira a year. This amount is still considered quite low by some, while others assert that the capabilities of the space industry are already overstretched. They point out that to expand the space industry would necessitate the training and specialization of more personnel, which would take some time.

The Italian government established the PSN in 1979 in order to stimulate the space industry and to increase its level of participation in ESA initiatives. The Plan also now supports some activities (such as TSS and Iris) in sectors which are not covered by ESA programmes. From 1980 to 1986 the PSN distributed its funds by giving over 35 per cent to telecommunications and about 18 per cent each to propulsion programmes and scientific research. Approximately 86 per cent of all the contracts allocated from 1980 to 1986 by the PSN went to industry, while 9.6 per cent were allocated to the National Research Centre (CNR) and to various universities. Projected PSN spending for the period 1987–91 includes a smaller share for telecommunications (30 per cent) and propulsion (7 per cent), but increases funds for scientific research to 30 per cent.

Italy is the third largest contributor to ESA programmes. The economic return has been low in the past but is now increasing, and a recent assessment estimates the return coefficient to be around 0.80. The Italian aim is to reach 0.95. On the other hand, collaboration within the ESA framework is considered largely satisfactory, in so far as ESA programmes emphasize sectors which are consistent with Italian interests and priorities.

Organization

Italy is an active member of ESA, but at the same time is developing national and bilateral programmes. Relations with ESA are handled directly by the Ministry for Scientific and Technological Research. The CNR manages space activity at the national level, for which it has established an *ad hoc* structure, the Servizio Attività Spaziale (SAS).

The CNR organizes, coordinates and itself finances scientific research, and as a public body it reports directly to the Prime Minister's Office. The day-to-day direction and supervision of the CNR were made the responsibility of the Ministry for Scientific and Technological Research under a decree of 15 September 1979. The Ministry also has the task of coordinating national and ESA activities.

Italian space policy is formulated by the Ministry of Scientific and Technological Research, whose proposals are in turn reviewed by the Interministerial Committee for Economic Planning (CIPE), which assesses the programmes and the budget. Parliament must take the necessary steps to translate all this into law. The Ministry for Scientific and Technological Research has no financial resources of its own and must go through other ministries in order to obtain funding. ESA contributions, for example, are appropriated by the Ministry of Foreign Affairs. The PTT and the Ministry of Defence also deal with space activities.

Within the space industry Aeritalia, Selenia-Spazio and SNIA-BPD are the three most important companies. They are the prime contractors for several ESA and national projects. In particular Aeritalia, which belongs to the IRI group, is the prime contractor for the following programmes: TSS with Nasa, Lageos, Iris, AFPM (autonomous fluid physics module) and Hipparcos. Selenia-Spazio, a company of the Selenia-Elsag Group in IRI-STET, is the prime contractor for the development, production and integration at the systems level of the Italsat, Sarit and AM-136 satellites. It is also responsible at the systems level for the Olympus satellite. In the private sector SNIA-BPD is the largest company. It belongs to the Fiat group and is the prime contractor for solid propulsion used on launchers of the Ariane family, and is also responsible at the systems level for the expendable stage of Iris. In the field of liquid propulsion SNIA-BPD is responsible for the propulsion system of Olympus. Other state-owned, private and multinational companies are also involved in producing components and developing projects.

The number of employees involved in the space industry has steadily increased in the past few years. Between the years 1980 and 1984 the number of employees increased from 1,000 to 3,000, and it is expected to reach 5,000 by the end of 1987.

(d) THE NETHERLANDS

For a country like the Netherlands, there are, in the main, two reasons for devoting time, energy and, especially, money to space research and space technology: first, to maintain a level of scientific excellence in a field where a tradition of national proficiency exists, and, second, to contribute to long-term economic survival through participation in a basic innovative enterprise which fits Dutch industrial capabilities.

Since the days of Christian Huygens, Dutch astronomy has always flourished. Many of its practitioners have earned the respect of their colleagues in other countries. For centuries, Dutch astronomers have found friends and sites abroad for their programmes, as was illustrated again in June 1985 with the inauguration of the international observatory at La Palma. Leading Dutch astronomers like Van de Hulst and De Jager played a substantial role in the preparation of European space research programmes.

Under the combined stimuli of the International Geophysical Year (1957–8) and the launching of Sputnik, the Royal Academy of Sciences in 1959 came to the conclusion that coordinated national activities in the fields of geophysical and space research were necessary. An organization was established for the selection of national space experiments and for the acquisition of launching facilities for these experiments. It was soon realized that Dutch participation in the emerging forms of international cooperation were of the utmost importance: first, to give national industry a chance to be involved in this kind of advanced technology; and, second, to enable the users in the country to make use of the facilities in space.

The Netherlands was in 1962 one of the founder members of ESRO and ELDO. The Dutch started to reap the benefits of this international cooperation when, in the mid-1960s, Estec was established on Dutch soil, in the Noordwijk area. Estec is still the hub of ESA's research and technology.

Major projects

The Netherlands has, so far, participated in the setting up of nine scientific satellites: four in the American Nasa programme and five in the ESRO/ESA programmes. In 1966 Dutch astronomers and representatives of the industry submitted a plan for a Dutch astronomy satellite (ANS), in order both to further science and to strengthen the technological and competitive position of Dutch industry. At about the same time, the PTT and industry proposed the building of a national ground station for satellite communication (Burum 1). The construction of both ANS and Burum 1 made it necessary to increase government outlays for space research and technology and, consequently, to develop a coherent space policy for the Netherlands.

ANS was built within a period of five years by a consortium of Fokker-VVFW and Philips. Its successful launching on a Nasa

Scout rocket in August 1974 prompted the NIVR to re-examine the question of whether another predominantly national satellite could and should be built and launched. On the basis of proposals made by Dutch industry and in cooperation with Nasa (and later with the UK Science and Engineering Research Council, SERC), the NIVR developed plans for a satellite intended to observe the infra-red radiation of celestial bodies, the Infra-Red Astronomical Satellite (Iras). In 1976–7, the Netherlands government approved the Iras plans and authorized the NIVR to sign a memorandum of understanding with Nasa and SERC. Iras has become an outstanding success and has contributed considerably to the international reputation of the Dutch space industry and science. Within a timespan of ten months, the satellite has produced a wealth of astronomical data.

Iras was launched on 26 January 1983. It was built by US and Dutch industry; the UK provided the ground station and its operation. The Netherlands built the spacecraft and was responsible for systems integration and launch preparations. The US provided the infra-red telescope system, the launch vehicle and the ground data-processing.

Organization

Dutch space policy is developed by the Interdepartmental Committee on Space Research and Technology (ICR). The need for an executive agency which could implement this policy was fulfilled by extending the charter of the Netherlands Institute for Aircraft Development, which in 1969 was renamed the Netherlands Agency for Aerospace Programmes (NIVR). The industry-oriented NIVR is a foundation, similar to the science-oriented Space Research Organization of the Netherlands (SRON). Both organizations are represented in the ICR in an advisory capacity.

In the industrial sector the Fokker Aerospace Division has developed as the main Dutch contractor, operating either on its own or in cooperation with firms such as Dornier, ERNO, British Aerospace and Matra. It specializes in solar panels, structural, thermal and control systems, and robotics. Holland Signaal Apparaten has provided subsystems for international and ESA projects in the fields of data-processing and telecommunications. AT&T and Philips Telecommunications develop and construct small telecommunications ground stations. The National Aerospace

Laboratories (NRL), the Technical Research Organization and the Technical Physics Service, as well as a number of smaller organizations, are also involved.

In the early 1970s the Advisory Council for Science Policy suggested that the government limit its predominantly national experiments to ANS and otherwise seek international cooperation wherever possible. It also warned against fixing the financial contributions to European and other programmes at too low a level, since this would result in insignificant contracts for the industry. Without a tangible national effort the Netherlands would not long remain a worthwhile partner.

In 1973 an international firm of management consultants, at the behest of the Minister of Economic Affairs, confirmed that activity at the prevailing levels would result in real but modest gains. Industrial policy would have to emphasize electronics and aircraft construction. The firm suggested that the Dutch contribution to European programmes should be fixed as a proportion of national income and recommended approximately 5 per cent. This recommendation was not followed; the Dutch contribution was fixed at less than half that percentage.

In 1978 General Technology Systems of the United Kingdom were asked to investigate the implications of space technology for the Netherlands. The conclusion of GTS was that it would be necessary for the Dutch government to increase its space budget from around 80 million guilders a year in 1977 to 130 million a year in 1985 (1977 price level) in order to lift and maintain Dutch industry at a level comparable with European countries such as Germany, France, the United Kingdom and Italy. In other words, expenditure on space should be at the level of these countries when allowance was made for the difference in population and GNP per capita. Again, the recommendation was not followed; the Dutch contribution to European space programmes has fluctuated between 3 and 4 per cent, instead of being a percentage based on national income, which would have resulted in a 5–6 per cent share.

In May 1982, the Dutch government published a White Paper on space policies in the 1980s. The gist of it was that, while the government saw no immediate possibilities to reduce, let alone to terminate, its financial support for space research and technology, it looked to the producer industry and 'users' (i.e. ministries such as those of Transport, the Environment and Agriculture, and the business community) gradually to take over the role of major investors. Such a policy would be aimed primarily at practical applications of space for the various potential users in and outside the Netherlands. At the same time, the position of products and services of Dutch industry would be improved in both the European and the world market. The necessary technological developments would be fostered. The government's thesis, based on 1979 data, was that the Netherlands was not lagging unreasonably behind other countries, as far as outlays for R&D were concerned. Others argued, however, that the Dutch scientific and industrial infrastructure for space is more comparable in character to the French and the German capabilities than to those of the smaller countries, the space expenditures of which are similar to Dutch spending in terms of percentage of GNP.

The White Paper stated that the main emphasis in the following years would be placed on applications in the ESA context, such as communications and remote-sensing satellites. The Dutch contribution to Olympus would amount to 135 million guilders (12 per cent). The Netherlands would also contribute 4.5 million guilders towards the costs of ERS-2. National industry would benefit from these contributions. The White Paper also announced that the Netherlands would continue to participate in ESA's scientific programme, in particular research into microgravity, metallurgy and fluid dynamics. Experiments had been conducted in those areas in the German Spacelab mission in November 1985 by the first Dutch ESA astronaut, Dr Wubbo Ockels.

The Netherlands has little reason to be dissatisfied with its ESA membership. In terms of geographical distribution or the percentage of return on investment the country has, for the years 1984–7, a return coefficient of 1.16 in contracts placed. The total return coefficient for the period 1972–87 was 0.96. In 1986 the Netherlands contributed 35.9 million EAU spent on 3.5 per cent of ESA's income, as against 10.2 million EAU spent on national activities. ESA spent 114 million EAU or 9.9 per cent of its total disbursement in guilders.

Further discussion on Dutch space policy was stimulated by the preparation for and the results of the ministerial conference of ESA, held under Dutch chairmanship in Rome in January 1985. Since the conference decided to expand the activities of ESA, with a planned increase in expenditure of 60 per cent, the Netherlands had to look critically at what this implied. In the mandatory programmes it will continue to pay according to its GNP, but a decision has to be taken on the level of investment in the other programmes.

Policy dilemmas

The central dilemma for Dutch space policy today is that the expectation, expressed in the 1982 White Paper, that the 'users' would gradually take over the role of major investors has proved to be an illusion. There is a general appreciation of the fact that the country's economic future may stand or fall with technological innovation. But since a nation with limited resources is unable to do battle on all fronts simultaneously, a choice has to be made. Only if one takes a very imaginative long-term approach is it possible to argue that innovation derived from basic research, not just the improvement of existing technologies, offers the richest prospects of economic survival. But which basic innovation, in which field? The Netherlands has already, more or less, opted out of large computers, nuclear energy and technology for users. Space research, together perhaps with biotechnology, is one of the few remaining openings.

The Dutch government asked the NIVR and SRON for advice on these issues, and they responded in June 1985. The Ministries of Economic Affairs and of Education and Science organized in April 1986 a formal hearing with industry and with the scientific and operational 'user' communities. In the summer of 1986, the government decided to increase its space policy budget to 187 million guilders by 1990 (1990 price levels). Not all of this money will go to ESA; some will be used to finance 'collateral' national activities. Although this represents an increase of 20 per cent on current spending, it is below the 220 million guilders advocated as a minimum by industry, and well below the 235 million guilders (1984 price level) recommended by the NIVR. In all probability, therefore, the Dutch share in ESA's overall programme will continue to drop.

A plausible assumption is that the country will keep up its financial commitments under the mandatory programme. This will amount to approximately 59 million guilders in 1990. Contributions to new ESA programmes could, by the same year, total some 86 million guilders. This would leave approximately 42 million guilders for national activities (SRON, NRL, remote-sensing/telecommunications and Sax).

A point of some interest is that the Dutch Ministry of Defence has, for the first time, committed itself to contribute (for the time being in a modest way) to the national space budget. The reason it gave was that it considers itself a significant future user of high technology (telecommunications, Earth observation and/or position-finding).

(e) UNITED KINGDOM

The British government established in November 1985 a new British National Space Centre (BNSC), whose task was to identify a coherent national strategy for the exploitation of space technology. This marked a major reorientation in the UK and appeared to signal a higher priority for space policy than had been the case for many years. Britain was into the space business early on, but difficulties of a technical and financial kind, combined with a lack of robustness about the policy area in general, led to a long period of hesitation and fragmentation of effort. During the 1970s, however, the British government gradually became more involved in international and European collaborative efforts.

In the meantime two other factors served to maintain a British foothold in space activities. First, there was a recurrent commitment to developing defence-related applications of space, some in close association with the United States. Second, several British companies sought to establish themselves as prime contractors not only for British defence and science projects but for various international and European projects, particularly in the communications satellite field. But outside the highly specialized policy community the exploitation of space inspired little enthusiasm. Space policy did not fire the public imagination; it was not seen as glamorous or as a necessary and cost-effective attribute of a serious actor on the international stage. In other words, it lacked the motive forces which helped to drive the American and French programmes. The new British National Space Centre was designed to secure a basic change of approach.

The British had been among the early pioneers in the potential military use of space. The development of the Blue Streak was an ambitious and technically demanding but expensive programme to deliver nuclear weapons. After its cancellation as a national programme and the subsequent experiment with ELDO, the British opted out of launchers and came to rely first on American and later also on European launch capabilities. Instead, efforts by government and industry concentrated on satellites, their payloads, ground support facilities and some components for launchers. The rationale of this approach rested on the assumption that the UK did not need overall self-reliance across the range of space activities, but should rather concentrate on selective efforts in which British capabilities were strong and relatively cost-effective.

The early European orientation of British space policy deserves mention. The British government took the initiative which led to the creation of ELDO and later ESRO, even though ELDO's track record proved a disappointment and led to early British withdrawal. In the 1970s the British government chose (and the decision was not easily reached) to promote the creation of ESA and to participate actively, albeit relatively modestly. But that decision profoundly influenced the subsequent history of the UK's civilian space policy, during which a small national programme came to be dwarfed by the large concentration of effort on British participation in ESA programmes. From the early 1970s both government and the main British companies producing space systems and components have been locked into European collaboration through ESA and the industrial consortia. In 1980 the British government agreed to participate in the Ariane programme, although on only a modest scale.

On the civilian side both the main companies and government have continued to be involved in the production of scientific and communications satellites, the provision of ground stations and certain other equipment. The role of the scientific community in the UK has been very important in generating support for the development of space technology, albeit not always with commercial applications as a corollary. But the Ariel series of scientific satellites was a major development and generated demand for work from British contractors. This process has been mirrored in British participation in important scientific missions by ESA, notably the Giotto mission of 1986. The main thrust of British civilian efforts therefore came to depend on the rather diffuse momentum generated by the producer companies, the emerging prime users (eventually especially telecommunications) and the scientific community. Meanwhile a military programme was also developed, which concentrated on communications satellites.

Programmes and projects (updated in October 1987)
The British have now contemplated re-entering the launcher segment. British Aerospace (BAe) and Rolls-Royce are currently carrying out proof-of-concept studies of Hotol with government support. Hotol's design and innovative air-breathing engine are intended to provide an efficient and economic re-usable launch capability. Collaboration partners would be necessary for the next phase, most obviously from Europe. Other British companies have retained an involvement in subsystems for launchers. In the meantime some British satellites, including some of the Skynet series, are being adapted for launch by Ariane instead of by Shuttle. If Hotol is developed the UK will have a more rounded space capability. But increasingly it is recognized that this capability has to be effectively harnessed and must depend on sustained international collaboration. In this context the argument for promoting European autonomy is beginning to be articulated.

The British public and private sectors have over the years been involved in a range of civilian satellite applications and in the design of their overall systems. The Ariel programme of six successive satellites provided the British scientific community–especially through Ariel 5 and Ariel 6 – with an indigenous capability in X-ray astronomy and other investigations of cosmic radiation. British scientists and the industry have been associated with many international scientific ventures. They were heavily engaged in the Giotto mission to intercept Halley's Comet, with BAe as the prime contractor.

Communications satellites have been the primary field of interest. Here British industry had an early success in 1974 with Miranda and then established itself with one or other of the main companies in Europe as the leading contractor for successive generations of ESA communications satellites, including OTS, the ECS series (some for use by Eutelsat), the Marecs series and recently Olympus, a major project with potentially wide-ranging applications. Experience and technology derived from these satellites is also being harnessed for contributions to the Inmarsat series and to Eurostar, which has been developed jointly by BAe and Matra for Satcom International. Delays in plans within the UK to establish direct broadcasting have put back implementation of some new satellite programmes, and there is fierce competition with overseas suppliers for contracts. The first contract for the British Satellite Broadcasting consortium has recently been awarded to Hughes from the US, not to the British tender, on the basis of the financial terms and the delivery date promised by Hughes. As the use of satellite capacity becomes more cost-effective and economic, efforts are under way to develop new markets for satellite communication services in the business community, the mobile sector and in such fields as education.

A military programme was also developed, especially through the Skynet series of satellites. The UK was one of the pioneers of the concept of geostationary communications satellites, which were designed to replace the previous British global network for long-range telecommunications, of which the Royal Navy was a principal user. Skynet was thus designed to serve particular national purposes. But this programme drew on the persistent closeness of Anglo-American relations in the fields of military technological collaboration and shared defence intelligence, and was designed to complement both US and Nato systems. All this took place against the background of a defence budget faced with more demands for expenditure than it could satisfy.

The main indigenous capability remains the national Skynet series of military communications satellites. This series is now highly developed and the design was recently (January 1987) awarded a Nato contract, a major breakthrough for the companies involved, notably BAe and GEC-Marconi. For some space-based intelligence gathering, the British have so far relied on access to American systems. An independent British capability in electronic intelligence was the object of the rumoured Zircon project, now abandoned, although its mission was to complement, not duplicate, existing systems. So far, however, military programmes have not included any indigenous military reconnaissance capabilities or any European collaboration in this field. There is some British involvement in SDI under a bilateral memorandum of understanding.

As for remote sensing, the British have been involved in ESA programmes, such as Meteosat and ERS, with production capabilities concentrated on instrumentation and ground equipment. The National Remote Sensing Centre at Farnborough processes data and is developing a user-awareness strategy with industry; and techniques of radar sensing are under active investigation. Recent discussions over Columbus and the international space station have led to particular British interest in the polar platform and its primary utilization for remote sensing, with potential user needs very much in mind. Interestingly, the wide range of opportunities offered by a space station has excited a more active British interest in several previously underdeveloped fields.

Britain has developed ground segment production and been active in international markets for many years. This sector is attracting increased attention, partly in recognition of the importance of developing a competitive edge.

Budget

Expenditure on space is allocated through the budgets of the sponsoring departments. The Ministry of Defence declares annual spending of about £100 million on the national programme. The Zircon project would have represented a major increase. On the civil side, in 1985/6 the Department of Trade and Industry spent about £70 million, the Science and Engineering Research Council about £20 million and the Meteorological Office some £5 million – a total of £100 million. Of this some 80 per cent, a very high proportion, was committed to ESA programmes (15 per cent of the ESA budget), leaving a modest residual national programme. The total rose to £109 million in 1986/7, of which £79 million was dedicated to ESA. This last amount was concentrated on support for innovative applications in communications and Earth observation, longer-term research, mostly through the Royal Aircraft Establishment, Farnborough, and the Rutherford Appleton Laboratory (these two drawing on some 240 specialized staff), and the other science programmes, including the Ariel 5 X-ray astronomy satellite. Proposals recently under discussion included a significant increase in the civil space budget. Within this there was to be an enhanced commitment to ESA, but also a larger collateral national programme.

Organization

The BNSC is a small coordinating agency, with 40 central personnel staffed on secondment from government departments and industry, and with science and technology arms. Its first Director was Roy Gibson, former Director-General of ESA. Its creation has resulted from, first, accumulated pressures for a more targeted national policy; second, anticipation of a major round of international negotiations; third, the need to harness indigenous technological progress; and, fourth, recognition of a growing international market for space applications. It replaces the previous and decentralized policy framework in which the Department of Trade and Industry coordinated civil space policy through its space branch. The BNSC board includes members from the main organizations (public and private) with a direct interest in space and is intended also to improve liaison with the Ministry of Defence. The BNSC's remit covers the core ESA and national programmes as well as bilateral collaboration with other programmes, such as Nasa (in addition to Nasa/ESA), the Canadian Radarsat, China, India and the USSR. The Overseas Cooperation Unit of BNSC manages and looks to develop these activities.

The BNSC's first strategy document was recently before ministers. It argued the importance of making further investments in space technology and applications and of strengthening national capabilities to complement Britain's already intense involvement in European and international collaboration. Although it did not cover military sectors directly, the overlap of technology between the civil and military sides is increasingly recognized. The document called for a substantially increased expenditure in order to underpin a larger, more ambitious and more diverse range of space applications.

The proposed space plan did not win agreement from ministers. It proved difficult to align the military and civilian sides of the argument or to convince the Treasury of the merits of a substantial increase in public funding. The debate was much complicated by a new review of all public R&D which had not yet provided the criteria against which space could be judged. In July 1987 Mrs Thatcher announced that funding would remain constant, a decision modified in August by the announcement of interim funding to keep Britain in the preliminary studies of Hermes and Columbus. Despite surprisingly strong public pressure for the BNSC's plan, it was not accepted for the ESA ministerial meeting in November 1987.

Industrial infrastructure

Within the space industry the main companies – British Aerospace and GEC-Marconi – have established leading positions as prime contractors for many national, European and international satellites and payloads, with particular strengths in communications. Here Britain has the greatest depth and quality of industrial capabilities outside the USA. The same companies, along with others (including Ferranti, Logica, Racal-Decca and Thorn-EMI) providing sub-systems and equipment (including in the ground segment), have been actively involved in successful consortia for international contracts, again with particular strengths in communications, meteorology and space science, but also with emerging capabilities in remote sensing.

Perforce the space industry is very international in orientation in terms of contracts sought and won and of consortia links with companies in other countries. In civil applications industrial achievements have depended on establishing a quality edge and international markets rather than on the sustained direct patronage of the British government, though of course the government is a prime purchaser. A major change has occurred with the steps to deregulate telecommunications in the UK, a development which is both changing the operating context domestically and altering attitudes to the international arena.

Precise figures cannot easily be given on the economic weight of the British space industry. The companies which are the main producers of space systems have an annual turnover of about £220 million. They employ directly some 3,500 personnel. Roughly 100 British companies have a significant interest in space technology on the producer side, but their staff are often not working solely on space-related work. On the research side, there are some 500 staff in the university sector as well as upwards of 200 in government research establishments. If the operation of services dependent on space technology is included, then the economic relevance of the sector increases considerably. British Telecom, for example, already has the equivalent of around 1,000 full-time jobs in its satellite business and gross investments (in both satellites and the ground segment) of some £300 million.

4

WEST EUROPEAN COLLABORATION

First steps in collaboration

The first step towards European collaboration in space was taken in April 1960. Leading scientists from ten West European countries met in London and discussed the new possibilities. They agreed that the development of national space technologies would quickly overburden the economic capabilities of individual European countries and that it would, therefore, be preferable for Europe to pool its resources in order to set up an effective space research programme. Following their suggestion, at an intergovernmental conference held in November 1960 twelve nations signed the Meyrin Agreement, which set up the Commission Préparatoire Européenne pour les Recherches Spatiales (COPERS). At about the same time, the United Kingdom suggested the development of a European launcher.

These two initiatives were pursued almost simultaneously. In February 1964 the Convention of the European Space Vehicle Launcher Development Organization (ELDO) came into force, followed, in March of the same year, by the Convention of the European Space Research Organization (ESRO). Parties to the ESRO convention were Belgium, Denmark, the Federal Republic of Germany, France, Italy, the Netherlands, Spain, Sweden, Switzerland and the United Kingdom.

The initial years were not without their setbacks. On the whole, ESRO turned out to be more successful than ELDO. Part of the explanation was that the ESRO secretariat managed to achieve a certain autonomy in the implementation of its plan of action and in its organization, while ELDO was much more subject to the wishes and preferences of national governments. ESRO set up two main technical centres: the European Space Research and Technology Centre (Estec) in the Netherlands, and the European Space Data Centre (Esdac) in the Federal Republic.

The technological status of Europe was fully revealed in the design and development of its first scientific satellites: ESRO-I (polar ionosphere and auroral phenomena), ESRO-II (solar and galactic cosmic rays and particles) and Heos 1 (interplanetary magnetic field and solar particles). All three spacecraft were launched by American rockets in 1968. ELDO began the design, development and construction of a launcher using a British rocket as its first stage, a French rocket as its second stage and a third stage developed by Germany. But the programme was plagued by problems.

The development of the solar probe, Helios, was the first big project with transatlantic cooperation. These successes confirmed the scientists' enthusiasm and paved the way for the major decision to extend the missions of ESRO to application programmes (communications and meteorology in particular). Governments became increasingly interested in the social and economic benefits which they felt would accrue from the development of applications satellites. At the same time, the first real stirring of industrial interest became visible.

The dependence on American launch vehicles proved, however, to be a serious constraint. For example, the first European (i.e. Franco-German) communications satellite, Symphonie, was restricted by American launching conditions to experimental operation.

By the end of 1972, the European countries were confronted with a number of portentous decisions. The United States had accepted Europe as an emerging space power and had offered it participation in its post-Apollo programme, i.e., the development and construction of a Spacelab that would be carried by an American space shuttle in the early 1980s. The Federal Republic wanted to accept this American offer. France, however, mindful of the problems within ELDO, wanted priority for the development of a heavier launcher, Europa III. It found American commitments to provide launchers for European applications satellites insufficient and unsatisfactory. France wanted Europe ultimately to seek autonomy in the launcher market.

Eventually a compromise was worked out. The ELDO programme of launchers was discontinued. On the basis of a design by the French CNES, a European launcher, Ariane, was to be developed. Spacelab would be developed as a contribution to the US post-Apollo programme. It was also agreed to set up a single European Space Agency (ESA), entrusted with carrying out not only all tasks previously undertaken by ESRO and ELDO but also with new activities. The divergent priorities which the three member states attached at the outset to different programmes remained visible in the division of labour. The Federal Republic accorded first place to (and led the development of) Spacelab; France led the development of Ariane; and the United Kingdom opted for the European approach to maritime space communications, Marecs, and later L-Sat, subsequently renamed Olympus.

The creation of ESA

On 30 May 1975 the ten original ESRO countries, together with the Republic of Ireland, signed the treaty to establish the European Space Agency. Under the terms of its Convention, ratified in October 1980, ESA's task is 'to provide and to promote, for exclusively peaceful purposes, cooperation among European states in space research and technology and their space applications, with a view to their being used for scientific purposes and for operational space applications systems'. Austria and Norway have been full ESA members since 1 January 1987. Finland became an associated member on the same day. Canada concluded a cooperation agreement with ESA in 1979. ESA's headquarters is in Paris; it has various research and operational centres and a total staff of some 1,400.

It is also part of ESA's mission to elaborate a long-term European space policy and to recommend space objectives to member states. It coordinates the European space programme with national space programmes and seeks gradually, and as completely as possible, to integrate the latter into the former. Finally, it has to work out and put into operation the industrial policy appropriate to its own programme and to recommend to member states a coherent industrial policy. From this it follows that ESA's role in the development of European technology is far from negligible.

The policy of ESA is determined by its Council, which consists of representatives at official level from the member states and meets five times a year. The Council decides on scientific, technical, administrative and financial questions. The Ministerial Council meets infrequently. The first and main committee is the Science Programme Committee. Others include the Administrative and Finance Committee and the Industrial Policy Committee, while Programme Boards supervise individual programmes. There are two types of programme: mandatory and optional. Participation in the scientific programmes and contributions to the general budget (technological research, investments, data-processing, etc.), at a level proportionate to GNP shares, are mandatory for all members. The applications programmes, however, as well as the launcher and space infrastructure programmes, are optional. This coexistence of mandatory and optional programmes may well be one of the reasons why ESA works so smoothly. Each member state has one vote in the Council, except when the discussion is about an optional programme in which it has chosen not to participate. The level of financial resources to be put at the ESA's disposal for its mandatory activities in the next five years is decided upon by unanimous vote of the Council. Other decisions are taken with a simple or a two-thirds majority.

As a rule, the distribution of ESA contracts orients itself to the level of financial shares provided by the member states, for a long time reflected in usage of the term 'juste retour'. This has been defined not for individual contracts, but on a cumulative basis. Occasionally the question of 'industrial return' has given rise to problems. It is, of course, a difficult task to provide an equitable share of contracts to each member state while at the same time, for reasons of efficiency, awarding contracts through competitive tendering. In the larger countries national space development efforts often tend to give industry a certain competitive advantage, so that, from time to time, special measures become necessary to increase the industrial return for some of the smaller countries. (See Table 5.) ESA works on the principle of 'no profit, no loss'; as projects have approached commercialization, they have been handed over to industrial entities such as Arianespace.

ESA programmes

The first ESA applications satellites, Meteosat 1 (weather forecasting) and OTS (experimental telecommunications satellite) were launched in 1977 and 1978 respectively. Four new scientific spacecraft were placed into orbit: Cos B (gamma-ray astronomy) in 1975, ISEE-2 (a collaborative Nasa/ESA mission designed to study the magnetosphere and sun/earth relations) in 1977; Geos 2 (far magnetosphere) in 1978; and IUE (International Ultra-violet Explorer, a joint ESA/Nasa and UK project) also in 1978. A fifth scientific satellite, Exosat (X-ray observation), was added in 1983. (European programmes for satellites and vehicles are summarized in Table 2.)

On 24 December 1979, only six years after the European ministers confirmed that it was essential for Europe to develop its own launch capability, Ariane successfully completed its first test flight, the first of a series of four. Companies from ten Western European countries have cooperated in this, the most extensive ESA programme to date. The lion's share of the cost has been borne by France (63.87 per cent); Germany has contributed 20.72 per cent. In January 1980 the ESA countries decided to transfer the technical and commercial responsibilities for the production, marketing and launching of the eleventh and all successive Ariane rockets to Arianespace, an international private-law company established in France. French shareholdings are around 60 per cent, German 20 per cent, with the rest spread among the remaining ESA participants. Shares are held by space companies and banks. The launch services of Ariane are now offered worldwide by Arianespace. In addition, the way has been opened for Europe to achieve commercial space flight, mainly for communications.

Within Europe the demands of the space science community continue to push the state-of-the-art, both in the technology of spacecraft design and services, and in the instrumentation for the collection and retrieval of scientific data. The space science programme is making real breakthroughs. On 2 July 1985 the Giotto spacecraft, developed from Geos, was launched from Kourou in French Guiana. With remarkable technical precision, both in time and space, Giotto came very close to Halley's Comet on 14 March 1986. Other pioneering missions are currently under development for scheduled launches before the end of the decade, including Hipparcos (measurements of astrometric parameters of some 100,000 stars) and Ulysses, a joint ESA/Nasa solar polar mission. ISO (Infra-red Space Observatory) is scheduled for launching in 1992.

The first of ESA's maritime communications satellite programmes, Marecs, was approved in 1973. It is designed to reduce the isolation of ships at sea by linking them through ground stations directly to the international telephone and telex networks. Marecs A was launched in December 1981 and Marecs B2 in November 1984. These satellites are leased to Inmarsat.

ESA has also developed satellites that cover European requirements in the telephony, business services and broadcasting fields. The European Communications Satellite programme (ECS) followed the success of ESA's pre-operational satellite, OTS, which was launched in 1978. ECS-1, ECS-2, ECS-4 and ECS-5 were scheduled for launch by Ariane from 1983 onwards. The system is now operated by Eutelsat. Another communications programme, Olympus (the former L-Sat), is due for launch in 1987. This large multi-purpose satellite will extend European know-how in a field which has wide international repercussions, with global networks for teleconferences and the use of satellite links in the retrieval and transfer of information.

Some spacecraft are platforms from which to observe the earth and its immediate environment. ESA entered the Earth observation field in November 1977 with the launch of its first applications satellite, Meteosat 1, which remained in service till the end of 1985. Meteosat 2 was launched in June 1981. ESA operates a Meteorological Programme for Eumetsat (see below).

ESA's first remote-sensing satellite programme got under way in 1981, when plans were drawn up to launch a pre-operational observation satellite, ERS-1, in 1990. The satellite will carry a synthetic aperture radar sensor and is oriented towards ocean monitoring. Its expected lifetime is two to three years and it is intended to be the forerunner of a series that will become operational in the 1990s. Europe has its own network, Earthnet, for the acquisition, preprocessing and archiving of remote-sensing satellite data and for its distribution to the European user community, as part of a future European remote-sensing space programme. At present Earthnet is handling two US remote-sensing missions (Landsat, and Nimbus 7) and one Japanese mission (MOS-1). The Earthnet offices are at the European Space Research Institute (Esrin) in Frascati, Italy.

Spacelab is Europe's contribution to Nasa's Shuttle programme. It is a manned space laboratory, in which for the first time scientists and engineers as well as astronauts are able to work in low earth orbit. Between 28 November and 8 December 1983 a very successful ten-day mission took place, the culmination of ten years' work on the Spacelab programme. It proved that Spacelab is an excellent facility and an ideal tool for space research. Spacelab 1 marked the first flight into space of an ESA astronaut, Ulf Merbold from Germany.

Spacelab 3 (Mission Challenger 51-b) carried during its flight between 29 April and 5 May 1985 a predominantly microgravity science payload. The payload had an international flavour, with Europe represented by the CNES-sponsored Mercuric Iodide Crystal Growth experiment. ESA's Instrument Pointing System (high-precision stellar, solar and earth pointing) flew successfully from 29 July to 6 August 1985 with Spacelab 2. The first German-managed Spacelab mission, D1, took place between 30 October and 8 November 1985. During this flight, controlled by Nasa and the Oberpfaffenhofen Mission Control Centre, numerous experiments from France, the Federal Republic, Italy, the Netherlands, Spain and Switzerland were conducted.

After the loss of Challenger, Nasa issued a manifesto in October 1986 indicating that Shuttle operations were planned to resume on 18 February 1988. The first launch dedicated to Spacelab will not be until the first quarter of 1993. Since the size of the Shuttle fleet will be smaller and the launch turnaround slower, there will be a significant reduction in the amount of use Spacelab makes of it. Phase 3 of the ESA microgravity programme will be affected.

An analysis by Nasda, the Japanese Space Agency, shows that in the period 1978–82 the ratio of the total ESA budget to the staff complement managing it was higher than in any of the other organizations evaluated (Nasa, CNES, DFVLR, ISAS and Nasda itself). This notwithstanding the fact that ESA is an international organization, with all the attendant constraints.

ESA's future plans

Half-way through this decade, as key programmes reached completion, it was clear that a review of the future scope of ESA's activities would be timely. The smaller member states were keen to define the space activities for which ESA would remain the primary organization. Eventually, in January 1985, a ministerial conference met in Rome. On the assumption of a continuing Shuttle programme, it was decided to embark on the Columbus programme, as an optional programme in the field of in-orbit infrastructure and as a significant part of the 'international space station' programme proposed by the United States. The fully independent Columbus programme is also intended to be an important element of an autonomous European capability in automatic and manned orbital operations. Columbus consists of a manned module, permanently attached to the space station and carrying facilities for materials-science and life-science payloads. It has a man-tended free flyer (MTFF) and polar orbiting platforms to be serviced from the space station or by manned vehicles. The programme will also include the basis for an operational data-relay system.

The ESA programme agreed for the period 1985–95 also contained the following elements:

– the development of a new generation of powerful launchers, Ariane 5, equipped with the large cryogenic engine HM-60, to be completed by 1995;
– the continuation and extension of programmes in the fields of Earth observation (ERS-1 and follow-on missions for oceanographic and meteorological applications, a land applications project, participation in the development of the second generation of meteorological satellites, and studies aimed at solid earth, atmospheric and climatology missions), space telecommunications (advanced payload systems), and microgravity (enhanced utilization programme of Spacelab and Eureca leading to the utilization of Columbus and the international space station for microgravity R&D);
– the progressive increase of the level of funding of the mandatory scientific programme to reach 162 million EAU by 1989 (an annual increase of 5 per cent); and
– the progressive increase of ESA's overall level of funding to reach about 1,650 million EAU per year by 1990. The detailed costing of this plan is currently under review. (See Table 4.)

The Rome conference took note with interest of the French decision to pursue the proposed manned spaceplane, Hermes, and of their invitation to European partners to join the detailed studies. The conference invited France and associated partners to keep ESA informed of progress with these studies, with a view to including the Hermes programme, as soon as feasible, within the optional programmes. Over the following months, France advanced its studies on Hermes and presented a detailed dossier on the programme to

ESA's member states. At its 74th meeting in June 1986, the ESA Council approved the Europeanization of Hermes by adopting an enabling resolution for a preparatory programme.

ESA long-term plans include a range of programmes for the remainder of this century. In space science four missions are planned, the so-called 'cornerstones'. They will require much more precise control and positioning of satellites, with new inter-satellite communications for a cluster of satellites; new rendezvous techniques and drilling devices in order to bring back material samples from comets or asteroids; and new concepts of multiple telescopes with degrees of sensitivity not previously available to meet the demands of the spectroscopy missions. In the applications programmes, improving long-life reliability is a key factor. The telecommunications programme will be extended. After Olympus will come the development of data-relay satellites as part of the in-orbit infrastructure. Permanent or semi-permanent orbital systems are also envisaged for earth observation in the future.

The next ESA ministerial conference was scheduled after some delays for November 1987. The deliberations were to revolve around several important questions: the priorities of European space policy; the degree of European autonomy; and the pace at which to attain it. The conference had to determine the correct balance between mission-oriented programmes (such as earth observation, science, telecommunications) and infrastructure-oriented programmes (Ariane, Columbus, Hermes). And finally ministers had to decide whether they could accommodate their ESA ambitions within the budget agreed in Rome.

The collaborative context

ESA provides the foundations of European collaboration in space, and accounts for a huge proportion of the total public expenditure in Western Europe (see Figure 2). Indirectly it plays a vital catalytic role in fostering R&D programmes which may then be turned into commercial enterprises and operating services. Directly, however, ESA accounts for only part of the pattern of European collaboration in space and represents perhaps 20 per cent of the European space industry's business.

ESA's self-imposed limitation to 'peaceful uses' of outer space has meant that it has been excluded from discussions on any European defence and security programmes, such as the national programmes of France, Italy and the UK; from bilateral collaboration with the US, which is most fully developed in the British case; from specific collaborative projects, such as Helios (French-led with some Italian and Spanish involvement); and from the Nato Integrated Communications System (NICS). This last provides the European members of the integrated military structure with access to a system of permanent and secure communications via satellite links to Nato's American and European forces on land and sea. It is interoperable with both the American DSCS III and British Skynet 4 systems. The first generation was built in the US by Ford Aerospace. As for the next generation of Nato satellites, due to come into service in the 1990s, a first order has been placed with British Aerospace/Marconi, based on the Skynet design.

ESA's other deliberate limitation has been to concentrate on the pre-commercial phase of project development. Thus, once applications programmes have reached the point of take-off as self-sustaining services, new and functional operating entities have emerged. Eutelsat, the European Telecommunications Satellite Organization, was set up in provisional form by seventeen European PTTs in 1977. It was designed to operate, on a regional basis, two space segments: one for fixed service communications, which it retains; and the other for a mobile maritime service, subsequently transferred to Inmarsat. The Eutelsat organization became definitive in September 1985 and now has 26 members. Its activities are further discussed in Chapter 5a.

Eutelsat and ESA have agreed complementary roles. In effect ESA has been the R&D arm and thus far responsible for the procurement, launch and in-orbit support of satellites (first OTS and then the ECS series). The satellites have been leased to Eutelsat as the operator of the service which they provide for an enhanced European network – namely telephone, telegram, telex and broadcasting – accessible to members and other European countries. Thus, for example, Eutelsat provides the EBU with the capacity for Eurovision transmissions. Eutelsat is in the process of procuring its second generation of satellites, Eutelsat 2, and promoting studies for Eutelsat 3. It may also operate international segments of national satellites, such as the French Télécom 1. The ground segment is operated by the PTT signatories.

Eutelsat is required to strike a balance between serving the European users and maintaining a sound commercial basis. Designated signatories have investment shares and thus contribute to the capital endowment on a basis that reflects shifting patterns of usage. The tariffs charged to users pay for the operating costs of Eutelsat and provide a return on the capital investment. As deregulation and liberalization measures extend, so the role of Eutelsat will have to adapt, a point discussed in Chapter 7.

Eumetsat, the European Organization for the Exploitation of Meteorological Satellites, is a similar venture, though more limited in scope. It was spawned by ESA in 1983, when the Meteosat series of meteorological satellites began to produce an operational system. Eumetsat offers extensive coverage of Europe, Africa and the Atlantic on a regular basis, the pictures from which are carried on television across Europe. The signatories are the designated meteorological agencies of most West European countries. A further generation of weather satellites is currently planned by Eumetsat. This was the first earth observation programme sponsored by ESA to develop as an operational service.

The development of Eutelsat and Eumetsat rested on European decisions to provide European services with European procurement. But West European governments, public agencies and industries are also part of a global pattern of collaboration and competition. Designated signatories from West European countries, the PTTs, belong to Intelsat and Inmarsat. Intelsat was of course the first such international organization, created at a time when Europe had slender space capabilities of its own. Western Europe now holds a share of around 34 per cent in Intelsat, as well as operating the Eutelsat regional system. European companies regularly tender for Intelsat procurement contracts, though generally in association with American industrial partners. Although the European share of procurement has been low in relation to that of the US, the business generated has been significant.

The Inmarsat case is different. Inmarsat, the International Maritime Satellite Organization, created more recently in 1979, provides mobile communications systems for the shipping and offshore industries. It is attached to the IMO, based in London and has 48 members. It is now to provide the secretariat for the Cospas-Sarsat search and rescue satellite system. In this case the European option adopted as appropriate was to join in a broad international system. Inmarsat started out by leasing satellite capacity from elsewhere, including Marecs from ESA. It is now procuring its own satellites. Significantly the UK has been the most proactive European member, and British companies have played a leading role in supplying Inmarsat satellites.

The other major European organization with a growing involvement in space activities is the European Community. The EC's interest in space is fourfold. First, it provides a focus for developing some applications of space technology – remote sensing of crop forecasts is one example. Second, among various R&D programmes sponsored by the EC, several include a space element, directly or indirectly. The Race programme (Research and Development in Advanced Communications Technologies for Europe) is the clearest case, in that future developments in telecommunications are intimately bound up with satellite technologies and operating costs. In addition, some Esprit projects cover adjacent technologies in electronics, software, artificial intelligence and so on, as does Brite (Basic Research in Industrial Technologies for Europe) in areas such as materials.

Third, the EC has a central role in helping to define and monitor the market conditions within which the space industry operates. It plays a key role in international negotiations about the terms of trade, which are highly relevant for example to the debate about competitive pricing of launchers. The EC can and does legislate to promote common standards, to remove obstacles to trade, to monitor state aids to industry and to liberalize public procurement. The new emphasis on the need to create by 1992 a single European home market, endorsed in the Single European Act (SEA), has made this a key priority and highly pertinent to the fortunes of the European space industry and its customers.

Lastly, the EC has now acquired with the SEA a limited but explicit security dimension to European Political Cooperation which opens the way to a more active involvement. This has also to be seen in the context of the revival of Western European Union (WEU) as a focus for a European defence dialogue involving seven ESA members (Belgium, France, Germany, Italy, Luxembourg, the Netherlands and the UK). Several discussions have already taken place within WEU about its potential role in contributing to any space dimension to Europe's collective security.

There is a dense and dynamic pattern of European collaboration relevant to Europe's future in space. As technologies mature, new markets develop and additional policy tasks are defined, so the firm foundations of ESA are being complemented by other collaborative frameworks.

Part II
USES AND MEANS

5

USES

This chapter summarizes the technical possibilities available, together with current and projected developments in space technology. It shows the range of functions which can already be performed, indicates those which can already be envisaged as viable and highlights the rapid pace of technological change.

(a) COMMUNICATIONS

The use of space technology for worldwide telecommunication links was the first demonstration of the potential commercial value of space. There is already a competitive global industry in the civilian sector, as well as a capability for important defence purposes. These latter are dealt with below in section 5e, though, of course, civilian and military applications benefit from many of the same technologies, operate within similar technical and financial limits, and may sometimes share facilities. Communication satellites provide secure, flexible and economic links to fixed and mobile users in all domains on Earth. This combination of attributes has user-convenience and is a stimulus to economic development. But it is not enough to rely on industry to develop its own business. In such a fast- moving and competitive environment other policies, including the regulatory aspects, must be established to the benefit of both producers and users. And a sensible division of labour must be found with other forms of telecommunications.

As an indication of scale, Intelsat has spent over $4.8 billion just on procuring satellites (let alone launcher costs). Of this some $3.8 billion has been spent on industry in the USA, and some $3.2 billion of that has been spent in California alone! Since the USA is the largest, but still a minority (25.7 per cent) shareholder among over 100 countries, there is clearly some scope for improved benefit to Western Europe, which in aggregate holds a 34 per cent shareholding.

Spacecraft as communication relays

The spacecraft is designed to carry a payload with transponders which receive and re-transmit, through appropriate antenna arrays, a wide variety of signals for many different purposes. Separate communication systems in the spacecraft monitor its overall performance and convey operational signals.

Such links are of course provided for scientific satellites and space probes, as well as for inter-satellite data-relay links. The demands on technology and performance are extremely high for these systems.

Fixed telecommunication services

Commercial telecommunication services were first carried by satellite in 1965, when the Early Bird satellite was successfully launched into GEO, with a capacity of only 240 telephone circuits or one TV channel. Developments in satellite technology and power generation have led to the current range of satellites with capacities of up to 30,000 circuits plus 3 TV channels. New technologies could increase capacity by a factor of four or more before the year 2000.

Intelsat, which owned Early Bird, was created on 20 August 1964. Today, the space segment of Intelsat comprises 16 geostationary satellites, which it owns and operates; the ground segment is composed of 650 stations owned by the designated telecommunications entity in each member country. Intelsat currently has 112 signatory and shareholding member countries, with some other countries associated as users only. This global network carries telephone, teletype, data, facsimile and television communications in more than 160 countries via 250 antennas. Other ground services support domestic or specialized operations, some on lease.

In addition, four regional systems with dedicated satellites of limited coverage area have been established. These are Eutelsat, for Western Europe; Intersputnik, serving the CMEA countries; the Indonesian Palapa B satellites, which also service the ASEAN countries; and Arabsat for the members of the Arab League.

Eutelsat is the West European organization of PTTs which builds and launches communications satellites, rather than relying on working through the Intelsat framework. Eutelsat provides capacity for telephoning, the European Broadcasting Union and *ad hoc* services, and also leases transponders to its signatories. Unlike Intelsat, which has its own R&D facilities, Eutelsat relies for its R&D on ESA. Eutelsat operates ECS on lease from ESA and is now developing a second-generation system.

Major policy issues arise about the most appropriate means of determining producer and user requirements in the commercialization of all these services, especially with the moves afoot to deregulate the telecommunications sector and competing technologies. Satellite telecommunication services are operated by national PTT or government-licensed common carriers which have conflicting interests as members of Intelsat, national services providers and participants in regional systems. Already several US companies have begun to develop separate systems for business traffic in competition with Intelsat.

Recent advances in optical fibre technology currently make cable systems the cheapest form of wide-band transmission for most high capacity fixed routes, although they require a large initial investment. Satellites also involve large investments because of their technical complexity and the high cost of launching them into orbit. However, for telecommunication networks that cover a number of low capacity routes, multi-point operations, inhospitable terrain, or a requirement for rapid installation including temporary service, satellites are likely to be a better option.

Recently, specialized business services have been introduced which employ Very Small Aperture Terminal systems (VSAT or microterminals) with antenna sizes typically in the range of 1.2 to 1.8 metres. Applications include corporate data, stock control, credit-card verification, electronic mail, etc. The VSAT stations currently cost under $10,000 and are designed to be installed on each of the sites of a single corporate user and work to a larger central hub station. The growth of these corporate networks in North America is spectacular, with approximately 30,000 VSAT terminals in service and orders for 100,000 terminals expected to be placed in the next twelve months. A similar growth pattern is anticipated in Europe by 1990.

Current communication satellites have an operational life of between seven and ten years. So far they have been replaced by models incorporating newer technology and usually with a higher capacity. The driving force for new developments centres on efforts to increase capacity and to reduce costs per circuit. ESA programmes are currently exploring improvements in component reliability; higher capacities using new frequency bands; highly directional antennas providing spot beams; higher EIRP; on-board systems for circuit-switching; direct inter-satellite links between satellites in different orbit positions; and design life in excess of ten years (already a requirement for the most advanced satellites, though shorter lifetimes are acceptable in some cases).

Maritime telecommunication services

An international satellite service for communication to ships at sea has been available commercially since the first call made over the Marisat system in July 1976. Inmarsat came into being on 16 July 1979. By January 1987, the organization included 48 countries through their designated PTT signatories, with the US having the largest shareholding of 29 per cent, and the West Europeans collectively 48 per cent of the total.

Inmarsat provides the satellite capacity for a range of communications services between 'earth' stations on ships, provided by the ship owner, and 'fixed earth' or coast stations, provided by national telecommunications administrations. As of mid-1986 there were sixteen operational shore stations, with fourteen more due to be completed by 1990, and 4,479 operational ship stations. The system has no provision for direct ship-to-ship communications, though this could be established via a shore station with a 'double hop' through the satellite.

Services provided include telephone, telex and other data services. Voice and telex channels are available on a dial-up basis from ships, and other data services are being developed. Subscribers on terrestrial networks may have to go via a maritime operator for voice channels to ships, but direct dialling is widely available for telex. Group-call facilities are available in the shore-to-ship direction, permitting a common telex message to be sent to a particular fleet, to a national group, or to all ships in a defined geographical area, this last service being particularly useful for meteorological broadcasts and navigational hazard warnings. Following recent successful trials with the liner *Queen Elizabeth II* by British Telecom using Intelsat capacity, Inmarsat has approved (initially as a one-year pilot) a television service to be specially equipped for ships from Comsat's shore stations in the USA.

The Inmarsat service is provided by three operational geostationary spacecraft and in-orbit spares, servicing the Atlantic, Pacific and Indian Ocean regions and providing coverage between the latitude of 70° North and 70° South, with the exception of a small part of the eastern Pacific. There are plans to complete this coverage, initially by changing some of the operational satellite longitudes. Ways to extend the service to the polar regions are under study, although its economic viability will have to be evaluated carefully.

The Inmarsat space segment has until now been provided by leasing spacecraft from Comsat (Marisat), from ESA (Marecs), and by leasing a maritime facility carried on some of the Intelsat V spacecraft. The second-generation systems will be owned and operated by Inmarsat, and the industrial procurement of spacecraft and ground control facilities is under way. The new satellites are expected to be in service from the first half of 1989. Inmarsat's capacity is estimated to be sufficient for the Atlantic region into the mid-1990s and for the other regions up to the end of the century. Ways of increasing the capacity in the Atlantic region are being studied.

Land mobile

Radio communication to moving vehicles on land – the Land Mobile Service – is a business growth area. The annual growth rate in Europe of 12 per cent in the late 1970s led to demand for services outstripping capacity. The competitors for the available channels include: military requirements; public services (police, fire, ambulance, utilities); civil defence; private networks (taxi, delivery, haulage, public transport); mobile subscribers in the Public Switched Network; radio-paging services; and Citizens' Band radio. These users are currently catered for by terrestrial radio services using VHF and UHF frequencies. In recent years many countries have released new channels for these services, but even so there remains a severe shortage of channels. The new 'cellular' radio systems are designed to permit a much greater degree of frequency re-use, a development which will remove this constraint to growth. There is no worldwide frequency allocation, although Inmarsat signatories are seeking an allocation at the ITU World Administrative Radio Conference (WARC).

No commercial satellite systems yet serve land mobiles, for which disadvantages arise because the current technology does not match the benefits of cellular radio systems, and the operating costs are higher. Cellular radio is likely to remain the preferred technology, at least for the public correspondence services. However, satellite systems could provide a wide-area overlay network in order to cover remote areas with no local terrestrial systems; serve long-haul vehicles that otherwise would need to be equipped for different local networks; offer a vehicle and cargo location system; and provide wide-area paging and message systems. This last is the most likely to emerge as the first land mobile service. ESA's Prosat programme includes experimental trials designed to solve several of the technical problems.

Aeronautical services

Proposals for aeronautical systems have concentrated on ground-to-air and air-to-ground links – for air traffic control, operational traffic and public correspondence. No significant requirement is evident for air-to-air communications circuits via satellite. A system designed for air-to-ground links could, of course, accommodate the occasional air-to-air circuit by 'double hop' via a ground station; or, if there is sufficient demand, by incorporating switching in the satellite. No such system is so far operational.

There is a resurgent interest in aeronautical satellite systems. Trials with Boeing 747 aircraft, equipped with a modified Inmarsat terminal, have demonstrated both voice and data communications. BTI, British Airways and Racal Decca also plan trials with a view to a commercial service. In October 1985 the Inmarsat Convention was amended to allow the provision of aeronautical services. The Inmarsat Council is committed to providing a full range of commercial aeronautical services from 1988/9, and has authorized investments in the development and adaptation of equipment. The International Civil Aeronautical Organization (ICAO) is studying the possible use of satellite systems for air traffic control.

Search and rescue

The elements of a search and rescue operation are emergency alerts; position data; identifying units that can provide assistance; and the coordination of the rescue attempt. Satellite techniques can play a part in all of these functions. For example, the 'alerting' function can be performed using automatic call processing through the Inmarsat system. The operations from the appropriate rescue coordination centre and subsequent communications could also be handled through Inmarsat. As a back-up, radio beacons to indicate the emergency position can operate through the polar orbiting Cospas-Sarsat system, or possibly through the Inmarsat system. Inmarsat is currently carrying out trials for non-polar regions.

Gradually from 1991 to 1997 new maritime techniques will be introduced in the Future Global Maritime Distress and Safety System. The essence of this system, in which Inmarsat will have a significant role to play, will be automated techniques for communication.

Direct broadcasting satellites (DBS)

The 1977 WARC reached agreement on the parameters for satellite systems to broadcast television programmes from the geostationary orbit for regions other than the Americas. Each country was allocated five channels for its national use in the band 12–12.5 Ghz, with a satellite-radiated power level high enough to enable a high-quality signal to be received on individual home receivers with antennas of some 60 cm in diameter. The satellites are spaced in orbit at 6° apart. The coverage of each country – 'footprint' – is closely defined to reduce interference in other countries in the same area. To minimize interference, use is made of spatial separation (orbit and ground), frequency allocation and orthogonal circular polarization.

The allocation of channels and orbit positions for the Americas was made in 1983. The different criteria for levels of interference and the involvement of fewer countries have permitted a larger number of channel allocations per country. All countries have a minimum of eight channels and the USA as many as 32. However, not all countries, particularly the less developed, will take up their allocation. At present, only those countries outside the Americas with a need to provide full national coverage (e.g. Australia, India, Scandinavia) or with governmental backing (e.g. France, West Germany) are initiating a DBS service. There are commercial doubts about the viability of a TV service that will restrict viewing subscribers to a nominal choice of only five channels, though in Central

Europe combined coverage from French and German satellites will give ten channels. In the USA and Canada the greater number of channels will enable a larger subscriber growth to be achieved and thereby alleviate the commercial risks.

Within Europe, the French and Germans have been especially quick to develop DBS under the WARC arrangements, and the British are now close behind. The interesting option for Europe is to establish pan-European channels. This involves the technical problems of arranging suitable frequency allocations and orbit positions within the existing plan format. But it also raises social, commercial and political issues, if multilingual programmes are envisaged and if costs have to be recovered for the provision of the service. Financing from advertising revenue is a further complication, since the advertising regulations and copyright rules vary significantly among European countries. Olympus (the large communication satellite being developed by ESA) will be used for widespread experiments in broadcasting.

Television distribution

The distribution of programme material for television to broadcast sites and to cable distributors is classified internationally as a fixed service. It is thus transmitted in the frequency bands allocated for operation by common carriers. Antennas with diameters of 1–2 metres are required to receive these signals. Satellite transmission is the most cost-effective medium for the distribution of programmes to multiple sites, and for outside broadcast events where a temporary link is required. Hence they are regularly used for European and indeed international events, whether for news coverage or for spectacles such as the Eurovision Song Contest. The satellite capacity available has prompted the emergence of a growing industry to provide television programmes. In Europe some 18 channels are in use with schedule times ranging from 1 to 24 hours a day. The Société Européenne des Satellites is planning to introduce a 16-channel Europe-wide service.

The cost of a receiver for satellite broadcasts has now come down to £1,000-£1,500, and is still falling. It is therefore within the purchasing power of a high proportion of the population of the developed world. An increasing number of individuals are equipping their houses with receivers. Their legal entitlement to do so is a regulatory issue in many countries, and in some it raises considerable problems. The operator of TV services has to generate demand and collect revenue either by subscription or by paid advertisements. The regulatory licensing and advertising issues make for lively political debate. Commercial considerations also probably require that TV distribution will ultimately have to be encrypted to prevent unauthorized access. Beyond these issues lies the crucial question of what kind of service the customer will actually want to use.

The prospects

Western Europe has demonstrated an excellent technical capability across the full spectrum of telecommunications satellites and has further potential to be exploited. Europe has built the foundations for a full involvement in all types of communications system and ground station. Good though the industrial skills in Europe are, however, the United States has had a much larger and more rapidly growing home market across the range of applications and has a volume demand within a protected environment. Some of the large US aerospace and electronics companies, with the considerable backing of large defence contracts, have not only learned good and reliable engineering, but have acquired practice in supplying spacecraft at competitive prices to world users. Aggressive sales techniques and strong government support from the outset have helped to establish operational systems within the US, wide entrepreneurial success in software as well as hardware supply, and a buoyant service industry. Interestingly the Canadian industry has also succeeded in winning major contracts for spacecraft in open international competition against both European and US tenders. And we must expect increasingly vigorous competition from Japan.

The European industry is increasingly active, and has been well supported by the technological base of ESA as well as by national expenditures. There is, however, as yet no overall European policy to improve the cohesiveness of complementary European companies, along the lines of Esprit in information technology. The reluctance of the European PTTs to develop operational systems on a continental scale is still a major constraint inhibiting investment in infrastructures (both private and public) and thereby limits market growth and international competitiveness. Attitudes are changing, but slowly, given the huge procurement power of the PTTs both directly and through bodies such as Intelsat and Eutelsat.

Deregulation may help considerably, and here Britain is some way ahead of the other Europeans. Equally some satellite producers have yet to develop a sensitivity to user needs and commercial viability.

It is not just a question of new technology to be gained and profit to be made. It is also a question of employment. A communication satellite is a new enabling tool and it has permitted a new global industry to emerge. The supply industries in Europe for satellites and launchers employ a few tens of thousands of people who are specialists in space. These industries in turn supply the communications industry, which serves business, entertainment, defence and other fields, which employ many hundreds of thousands of people in European countries, who in turn provide services for a combined population of over 250 million.

(b) REMOTE SENSING

Remote sensing is the second major application of space technology. Satellite-based Earth observation covers all activities relating to the acquisition from orbital altitudes of physical data concerning the terrestrial environment, i.e. land, seas and the atmosphere. Thus defined, Earth observation involves three main types of system. First, earth resources satellites allow the thematic mapping of exposed land masses and the return of useful data concerning topography, geology, hydrology, vegetation, habitats, pollution or, more generally, an inventory of a wide range of resources and the monitoring of changes. Second, weather satellites regularly monitor the atmosphere from either polar or geostationary orbit. Third, oceanographic satellites regularly monitor physical conditions on the sea's surface and at the interface of ocean and atmosphere.

Over the past decade, by initiating a series of important Earth observation programmes, Europe has become a major developer of technology for remote sensing. Of these Spot 1, launched in 1986, is the first European satellite designed for operational remote sensing of land masses. But it is not the first demonstration of Europe's technical capabilities in this area. As early as 1977, Meteosat 1, the first European meteorological satellite, started routine observations of the Earth's atmosphere and surface, thus inaugurating a service which has now become essential to weather stations in Europe and Africa, as well as to various agencies involved in oceanographic activities or global climatic research studies.

Experiments aboard the US Shuttle, such as the German MOMS (Modulator Opto-electronic Multispectral System) or the Metric camera tested by Spacelab 1 in 1983, have confirmed European technical expertise in high-resolution remote sensing. European ambitions in this area are further illustrated by the challenging development by ESA of ERS-1.

Current European programmes

In 1976 the common interest of ESA members was evident in their concern to gain access to data from the US Landsat satellite. ESA set up and consequently operated the Earthnet programme, consisting of receiving stations for Landsat data in Fucino (Italy) and Kiruna (Sweden), as well as for data from experimental US satellites (Seasat, Nimbus 7) in Oakhanger (UK) and Lannion (France).

Landsat data were used in many ways in Europe, from basic research to pollution monitoring, mapping, crop evaluation and so on. The potential economic and political relevance of these data led some ESA members, notably France and Sweden, to press for a European programme of remote-sensing satellites as soon as possible. The French proposed Spot, a system oriented towards high-resolution optical observations of the Earth's surface. Though some major countries, such as the Federal Republic of Germany, showed a lack of interest, Sweden and Belgium joined the French in their determination to go ahead with Spot 1.

After some soul-searching and redesign of its own strategy, ESA gradually became committed to an experimental mission, ERS-1, finally authorized in 1984. Meanwhile the French decided in October 1981 to start funding of Spot 2, identical to Spot 1, in order to operate Spot spacecraft on an operational and commercial basis. Sweden and Belgium again joined France and decided to participate in Spot Image, the entity set up to act as the commercial arm of the

Spot programme. The French followed with decisions to extend the series with Spots 3, 4 and 5.

Meteorological programmes
Since 1977 Meteosat satellites have provided satellite data for weather forecasting. The subsequent Meteorological Operational Programme of ESA provides further Meteosat satellites to give continuity of service to users until 1995. The new European Meteorological Satellite Organization, Eumetsat, stems directly from these programmes and is expected to cooperate closely with ESA on satellites, both polar and geostationary, for meteorology.

Spot programme
Spot 1 was put into orbit on 22 February 1986 by Ariane. Two more first-generation spacecraft, designated Spot 2 and Spot 3, have been ordered to provide continuity for the programme until the end of the 1980s. Spot 2 should be available for launch in mid-1987, and Spot 3 by August 1989.

Spot spacecraft carry two identical HRV sensors (high resolution visible), based on static solid-state arrays of detectors which operate in the visible and near infra-red part of the spectrum. The major features of Spot are the relatively high ground resolution of the imagery it will produce (ten metres in the panchromatic mode, twenty metres in the multispectral mode) and the ability of its sensors to point up to 27° East or West of the local vertical axis. (See Table 8.) This latter feature has the interesting potential of increasing the number of opportunities to obtain views of a given area. It also permits stereoscopic observations by combining views taken at different angles from the vertical, and therefore opens up the possibility of third dimension (or altitude) determination, an important requirement for cartographic applications.

The Spot programme was planned from the beginning as an operational and commercial system. CNES is in charge of spacecraft procurement, launch and operation, while Spot Image, a commercial corporation, is in charge of data distribution and all commercial relations with data users. Spot Image is developing a network of agents, distributors and subsidiaries to serve local markets.

ERS-1
ERS-1 is an experimental technology demonstration programme using active microwave, mostly aimed at oceanographic observations.

Land observations will also be carried out and will undoubtedly lead to major advances in mastering synthetic radar observation techniques. Its launch is planned for 1990 and it will have an expected life of 2–3 years. Canada has also joined this ESA programme.

ERS-1 will demonstrate in-orbit capabilities for all-weather radar observation, in both imaging (Synthetic Aperture Radar – SAR) and non-imaging modes (scatterometer, altimeter). It will operate at different frequencies and should constitute a major scientific and technological test of the operability of active microwave satellites for remote sensing.

The objectives of the ERS-1 programme are to define, develop and exploit remote-sensing data for coastal, ocean and ice applications, and to increase the scientific understanding of coastal zones and global ocean processes. Applications which will benefit from ERS-1 include off-shore oil activities, ship navigation, fisheries, oil pollution monitoring and such like.

Ground facilities and services

European industry has made great strides since the 1970s in developing ground facilities, such as receiving and processing equipment, digital image manipulation, film recorders and SAR processors. Whereas the first European stations for receiving Landsat data were for the most part made of US or Canadian equipment, European industry has built or is currently building five facilities outside Europe for receiving and processing Spot and Landsat data.

A similar trend can be seen further downstream in the chain from data acquisition to data interpretation. This area covers digital image analysis equipment and software as an aid to data interpretation, as well as associated services. European initiatives and developments in this field are numerous, with the result that European industry has become competitive in world markets.

With the preparation and launch of ERS-1 at the beginning of the next decade, further developments are expected in SAR data-processing and data interpretation and dissemination in near real time.* The requirements of the user communities in oceanographic and shipping will press ESA and its members to set up high-throughput, fast-turnaround facilities to process the enormous

*Converting data into useful pictures or maps is a complex and time-consuming process. The closer technology comes to instant or real-time processing, the more valuable the results, especially for military planning.

amount of data transmitted by ERS-1 and extract from them wave spectra, surface wind velocity and direction, ship positions and the like, all parameters whose usefulness is very short-lived.

Future European programmes

A second-generation Meteosat

This should provide data of improved quality as well as new data, such as profiles of temperature, water vapour and higher resolution data for regional applications. The launch is planned for late 1994 to ensure continuity with the present Meteosat Operational Programme, which runs until 1995. The operational system will be financed by Eumetsat, with government intervention in this field being limited to preoperational R&D.

Successor Spot satellites

Design work has now been completed on Spots 4 and 5. The preliminary industrial definition phase for the improved satellites began in early 1987. Production of Spot 4 is expected to begin in early 1988 for launch in mid-1992. Approval for Spot 5 is under consideration to allow its availability for launch in mid-1993.

Differences from the first-generation of Spot include the addition of a medium-infra-red band to the HRV instruments to measure vegetation humidity, and the installation of a new radiometer for large-scale monitoring of the Earth's vegetation and oceans. The new vegetation instrument, with five spectral bands, will be used for worldwide monitoring of crops and spontaneous vegetation, for forecasts of agricultural production, and for environmental studies. A secondary mission is the observation of oceans for scientific purposes or for specific applications such as fishing. The French also plan to develop a more efficient ground facility for image rectification with increased automation, so that more data can be processed at lower operational costs.

ERS-2

ESA plans ERS-2 for launch early in 1993. This would extend the ERS-1 mission, improve the benefit from the initial investment and provide users with 5–6 years of continuous data. The ERS-2 specifications are likely to be more or less identical to those of

ERS-1, in order to minimize modification costs, and to ensure continuity of data flows until the launch of the Columbus polar platform in 1995.

The European polar platform

The Columbus project, which includes the construction of a European polar platform, will permit a step-change in scope for remote sensing. Its increased power and load-bearing capabilities provide the opportunity to advance to the concept of an integrated multidisciplinary payload of instruments observing oceans, ice, land, meteorology and atmosphere, for both scientific and applied purposes. The project as a whole is discussed in more detail in Chapter 6. The programme requires integrated sets of instruments and should, with adjustment and replacement opportunities, permit long runs of observations.

Optimized versions of the instruments from ERS-1, together with new instruments, will allow the ocean and ice objectives of ERS-1 to continue to be addressed and to be improved upon. The major objectives for land observation would be to improve Europe's ability to manage its activities and resources in agriculture, forestry, land-use management, water resources, land surface processes, geology, cartography and environmental monitoring.

Similarly instruments on the platform would continue and improve upon the observations of the meteorological satellites currently in polar orbit. They would also provide regional and local data, profiles of atmospheric temperature and humidity, and research into and monitoring of atmospheric processes and constituents, particularly those which affect our climate.

The commercialization of remote sensing

So far this is the only sector, apart from space communications, to be exploited commercially, but still only to a limited extent. Many issues need to be addressed if successful commercial operations are to follow. The market for remote-sensing data is still difficult to predict in the short or long term. Its very diversity, as well as the need for continuing extensive investments, make it extremely difficult to estimate its future growth and potential size. Furthermore, political constraints on the distribution of high-resolution pictures of foreign countries may inhibit the viability of a remote-sensing system.

Users need a guarantee that satellite programmes for remote sensing will be able to provide a virtually continuous service over a long period of time. Otherwise they will be reluctant to rely on the data and to invest in the human and technical resources necessary to exploit them. Furthermore, the distribution of data to users has to be properly organized. Significant improvements are needed to meet the objectives of timeliness and reliability inherent in many applications of remote sensing. A sizeable 'value-added' industry is needed to extract the information needed by the users from the raw images provided by the satellites.

These points are interconnected. The market can develop to the point where it can sustain the cost of remote-sensing satellite systems only if the required continuity of service is guaranteed. However, governments are reluctant to subsidize such systems for too long, fearing that users may expect subsidies to continue indefinitely.

Some applications of remote sensing can be argued to be related to weather forecasting, traditionally accepted as a government responsibility, although some equate it rather with surveys of areas in which industry usually plays a direct role. This question can be debated at length, but existing institutional arrangements may condition decisions. Thus, weather forecasting as an accepted government domain already has a clearly identified customer for the collection by satellite of weather data; but there is not an established and structured market for surveying from space. The history of Landsat and early Spot operations demonstrate that the market for remote-sensing services is very diversified.

In spite of this situation, the United States and France have separately taken the decision to operate remote-sensing satellite systems on a more commercial basis. Their approaches, however, differ: the US government would like industry to take over and operate the whole system after a very short transition phase, whereas the French government has agreed to underwrite the initial capital costs of the satellites and has established Spot Image as a commercial corporation with data-marketing responsibility.

In both the French and American cases pricing policy is based on complete cost recovery and therefore should not differ significantly. However, the commercial risks involved in the business of remote sensing are very high, which explains the reluctance of US industry to make firm commitments to take over of the Landsat programme without a solid government guarantee to reduce those risks. The recent cancellation by the EOSAT corporation of the contract for Landsat 7 and 8 satellites, until it gets such a guarantee, aptly illustrates the limits of the US approach. The recent difficulties encountered in the US efforts to promote commercialization suggest that it is not yet possible to operate a self-sustaining and profitable satellite system. Interestingly, the Soviet Union has recently indicated a willingness to make available commercially images from their satellites to a resolution of 30 metres and perhaps subsequently 10 metres.

These issues have to be seen in the context of the market-place, and the market is as yet in its infancy. Applications of space imagery to geological exploration, for example, are already well developed and widely used by oil and mining industries. This is not the case for many mapping applications, which require high-resolution data and stereoscopic capabilities, or for crop conditions and pollution monitoring, which require frequent observations during the growing season. In addition, the operational use of such data requires technical equipment and training which are not usually available either in most government administrations or in private corporations (with the notable exception of mapping agencies).

The routine use of remote sensing will come about only if service industries bridge the gap between image producers and users. It is vital that a strong and efficient relationship develops between space imagery producers, distributors and the value-added image-processing industry. The development of the European market therefore requires producers who are responsive to market requirements.

(c) BASIC SPACE SCIENCE

For the purposes of convenience the following sections distinguish basic from applied science, even though the two shade into each other. Under basic science we include those activities which have an intrinsic intellectual value and which have been so important in stimulating European interest in space. The applied science section then focuses on activities with further, perhaps eventually commercial, applications.

Space flight has brought about major advances in several scientific disciplines, notably astronomy and astrophysics, solar physics, lunar and planetary science, and in the understanding of the sun/earth system, commonly referred to as solar terrestrial physics. Observations from space were bound to be highly significant for these areas of fundamental research, since the elimination of the blanketing by the Earth's atmosphere made the whole electromagnetic radiation spectrum accessible for the remote sensing of the physical and chemical properties of the sun, the stars and the galaxies.

Exploration of the Earth's radiation and magnetized plasma environment, and of the Moon, the planets and interplanetary space gave a totally new dimension to the study of the origin and evolution of our solar system. Recent spectacular, and extremely successful, examples of these endeavours were the encounter of the Nasa-Voyager space probe on its trajectory along the outer planets with Uranus and its moons in January 1986 and the encounter of ESA's Giotto probe with Halley's Comet in March 1986. Both missions have provided a wealth of new data which necessitate substantial revisions of our assumptions.

Traditional space science. The topics mentioned above belong to what one could nowadays call traditional space science. Scientists were the first users of the pioneering spacecraft and have ever since formed a large user group. The investigation of the origin and evolution of the universe still presents one of the largest scientific and intellectual challenges for mankind. Space-derived research has provided a quantum jump in the furthering of our knowledge, and space-borne instruments have opened up new wavelength windows on the universe in the infra-red, ultra-violet, X-ray and gamma-ray regimes. This has led to a drastic change in our perceptions, and the exploration of the universe from space will continue to play a dominant role in any further progress in these areas of basic science.

Microgravity science. Only a few years ago, the first space laboratory, Spacelab, brought a new category of experiments in fundamental science within reach: those which make use of the near absence of gravity within a space vehicle in continuous free-fall. This microgravity research entails the investigation of gravitational effects, or of effects that are normally completely masked by the influence of the Earth's gravity in a ground-based laboratory, in a number of physical, chemical or biological phenomena. Although very low gravity is the most obvious characteristic of an orbiter's space environment, other special environmental conditions can also be employed. These include energetic cosmic-ray and trapped particle fluxes, irradiation by the full solar spectrum and ultra-high vacuum conditions with practically unlimited pumping capacity.

Earth science from space. Observations from space provide a unique and powerful way of studying the Earth in a global sense. A coordinated programme, the International Geosphere Biosphere Programme (IGBP) is currently being formulated for a worldwide study of global change. Remote sensing of the Earth from space is potentially of great importance and will have a major impact on a number of established branches of fundamental science, namely, meteorology, oceanography, climatology and solid-earth sciences such as geokinematics and the study of the geopotential field.

Achievements and prospects

Traditional space science

In space astronomy, the era of exploratory survey missions is almost over. The latest, and remarkably successful, mission was the Iras satellite. A series of 'second-generation' projects have been carried out or are now in a preparatory stage. Europe has made a significant contribution in these areas, except in planetary surveys, which have been deemed too costly.

In the future the emphasis in astronomy will shift towards the development of the large semi-permanent observatories in space that are necessary for the next breakthroughs in astrophysics. The first such mission is Nasa's Hubble space telescope, scheduled for launch in 1988, with a small European contribution. In planetary science the next major step will be prolonged and in-depth exploration of topography, atmospheres and plasmaspheres with the aid of planetary orbiters and rendezvous of probes with 'primitive' bodies in our solar system (comets and asteroids). Such major scientific endeavours depend on international cooperation, in some cases on a worldwide scale. Smaller-scale missions are dedicated to specific scientific objectives and to the verification of new instrumental and operational concepts. A programme for traditional space science requires a mix of large- and small-scale projects.

The backbone of European space science over the past twenty years has been the mandatory science programme of ESA. Although much less ambitious than Nasa, ESA has built up an impressive series of 14 successful science missions in a row, without any failure. The scientific programme is so far the only mandatory ESA programme to which the member states contribute on the basis of their

GNP, and scientific merit has always been the paramount criterion. This has led to high-quality science products. In addition, national space science projects in some European countries, notably the United Kingdom, Germany, Sweden and the Netherlands, some associated with Nasa programmes, have further helped to build up Europe's reputation. A supranational effort is crucial to enabling Europe to take part in at least some of the main scientific space ventures of the future. The limited financial resources available within Europe and the necessity for a timely development of the enabling technologies demand a selective approach.

A long-term plan, covering at least two decades, was defined by a Survey Committee of leading European scientists in 1984. Horizon 2000 comprises four main elements, or 'cornerstones', for space science in Europe: two large-scale missions in X-ray and sub-millimetre astronomy; a coherent approach to solar terrestrial physics, comprising an upstream solar observatory and a multi-probe space plasma mission; and a cometary science project to return pristine material to earth. The plan is flexible enough to incorporate smaller-scale projects. Horizon 2000 meets the requirements of timely identification of areas of research in which Europe can claim a leading role or can make a substantial contribution vis-à-vis the other space powers. It possesses a high level of technological sophistication and thus acts as a catalyst for innovative technological developments in European industry. This technology-pull has been a unique feature of scientific satellites from the beginning and is likely so to remain, since it is the very nature of the scientific quest to strive for the nearly impossible. Horizon 2000 strikes a proper balance, albeit as a minimum programme, among the main areas of interest in the European scientific community. It does not exist in a vacuum but involves cooperation on a worldwide scale without any major loss of European autonomy and independence.

Apart from the science programme of ESA, national and multilateral projects can be made largely complementary and indeed can add scope and versatility. Moreover, a European science programme requires the national development of scientific instruments and their enabling technologies.

The programme for traditional space sciences is not contingent on the existence of a manned space station. But a space station could bring technical advantage and facilitate experimental techniques. Preliminary analysis of the potential of a station indicates that its usefulness as a payload carrier for large astronomy missions is limited by the disturbances it generates. It is technically useful as a service, assembly and staging base, although the cost-effectiveness is unclear, since a reliable cost estimate is not yet available. For many purposes a free-flying platform is a better solution.

Microgravity science

This branch of space science covers a large variety of research topics, including solidification and fluid physics, physical chemistry, biology and biotechnology, animal and human physiology, and medicine. Absence of gravity prevents quick segregation in heterogeneous mixtures, avoids gravity-induced convection arising from temperature or concentration gradients, eliminates hydrostatic pressure and provides the possibilities of containerless experiments. Some of these issues are considered in the section on applied science.

In the field of gravitational biology, the mechanisms of gravity sensing, the threshold of sensitivity and the mechanisms of response in living systems are not understood. The few experiments conducted in this field under microgravity indicate pronounced effects on replication and differentiation during culture owing to weightlessness. These results cannot be explained by the current biological theories and therefore constitute basic discoveries.

It is as yet premature to make well-founded statements about the potential breadth in scientific significance and rate of development of the microgravity sciences. Also, since the space-based research efforts are predominantly of an exploratory nature, basic and applied research are intertwined. Many of the current efforts can be considered to lie in the realm of basic science. Relevant microgravity investigations at present include tests of hypotheses which predict what should happen in the absence of a gravitational field, particularly in the material and fluid sciences; the detection of the effects resulting from the absence of a gravitational field and subsequent formulation of explanations, particularly in the life sciences; and the use of the results obtained under microgravity to improve and optimize the related research efforts in a terrestrial laboratory environment.

Earth science from space

Essential to the understanding of the Earth's history, behaviour and evolution is the observation and study of the interplay between its many different constituents, namely, oceans and ice, atmosphere, land and solid earth. Investigations of these phenomena over the past decades have delineated the profound effects, arising from interaction between these components, on the evolution of our planet. The exchange of energy and momentum between the land, the ice and oceans, and the atmosphere determine the thermodynamic equilibrium of the Earth. These interactions are controlled by many factors, such as the transport of heat by ocean currents, the distribution of atmospheric trace gases and pollutants, and the hydrological and biochemical cycles.

The significance of space-based observations lies in their global view of the planet and, most importantly, in the simultaneous measurements of the interaction between the different components of, for example, the climate system, from the same vantage points. An example is the measurement of the anomalies in the temperature of the sea's surface in the tropical Pacific, which have been linked with the observation of large-scale anomalies in the atmospheric circulation. Another example is the influence of major volcanic eruptions on the climate.

The effects of human activity on the behaviour of the Earth system are also rapidly becoming a major issue, and the potential changes induced by this activity need to be assessed. This can be done only if reliable models are available that describe the evolutionary behaviour of the global Earth system. A well-known example of human-induced interaction is the burning of fossil fuel at unprecedented rates, which injects enormous amounts of carbon dioxide into the atmosphere. A steady increase of carbon dioxide in the atmosphere can introduce global climatic changes as a result of the 'greenhouse' effect.

Although limited programmes for global observations of the Earth have already been carried out, the crucial elements for fundamental progress in Earth science will be continuity in observations and permanent monitoring of the Earth, both of which are essential for establishing a firm and coherent data base. In most cases it is necessary to have global coverage, which points to the need for space observations from polar orbits. A major problem is adequate sampling in space and in time. This certainly requires more than a single spacecraft. In other words, international coordination and collaboration are key elements.

An overview was prepared in May 1986 by an Earth System Science Committee, established by the Advisory Council of Nasa. This committee recommended that two programme paths for Earth system science be pursued in the coming decades. First, the study of the solid earth, including measurements of fundamental characteristics, would yield insights into long-term planetary evolution. This would encompass, among other things, investigations of plate tectonic motions, continental deformation and evolution, mantle structure, the Earth's gravity and magnetic fields. These studies would provide input also for the assessment of processes operating on a shorter time-scale as a result of coupling between atmosphere, hydrosphere, crust, mantle and core.

Second, the study of the fluid and biological Earth is a prerequisite for the understanding of global change into the next century. It involves the study both of processes directly relevant to global change (e.g., the physical climate system, the biogeochemical cycles and global moisture) and of the processes playing a significant indirect role, such as local weather patterns, sea-ice distribution and solar variations.

Up to now, Europe's role in this field of Earth system science has been very minor. Its main programmes in Earth observations have been mainly application-driven (e.g. Spot, ERS-1). A balanced European programme is feasible only in the context of a supranational commitment, in which ESA could be instrumental, and it depends on the availability of polar-orbiting platforms as the most advantageous and cost-effective means for global Earth observations in the 1990s. Multidisciplinary payloads provided by the United States and Europe can provide a coherent observational approach to the global study of oceans, ice, land and atmosphere, and need to be operated in a coordinated fashion. Using this opportunity as a stepping-stone, Europe could rapidly catch up with the developments in this field. Dedicated satellites in special orbits are still required for solid earth studies (crystal dynamics, gravity and magnetic field studies) and some atmospheric topics.

(d) APPLIED SPACE SCIENCE

State of the art

Microgravity conditions permit experiments or processes to be conducted in orbit which may subsequently have applications on

Earth. It is here that we encounter the ill-marked boundary between basic and applied science. For example, with regard to crystal growth, weightlessness permits scientists to grow large, near-perfect crystals. This is possible because, in the absence of gravity, little or no distortion of the crystal occurs and there is no contamination. The industrial applications of pure and near-perfect crystals are many. They are required in computers, lasers and numerous other optical and electronic devices. Microgravity conditions offer scientists an opportunity to investigate and improve methods for creating advanced metals, glass and ceramics. One benefit may be the development of lower-attenuation glass fibre for use in optical communication. Another important process that can be studied extensively in space is rapid cooling, which may give materials new properties and therefore contribute to advanced casting technology on Earth.

In the processing of biological material a widely used analytical technology is electrophoresis, in which a gel or another supporting medium is used to suppress convective flows. To apply this process to cells, cell components or other particles in the supporting medium must be eliminated, which becomes possible in microgravity. New medicines may then be produced.

There is, nevertheless, a wide gap between scientific exploration and possible industrial application. The first step in bridging this gap is experimentation and verification. This activity can be conducted on Earth, but it is expensive and available methods produce a very restricted time limit of from 1.7 to a maximum of 20 seconds. One alternative is to use sounding rockets, which launch a small payload into space. As the payload coasts upwards and falls back to Earth, a low gravity condition can be achieved for three to five minutes, permitting scientists to explore a wider range of phenomena. The Spar sounding rockets, for example, provided a large data base which served as the foundation of the microgravity programme aboard the Shuttle.

The second development stage requires the use of a space infrastructure and of the hardware necessary to conduct experiments of long duration. The third stage of the move to commercialization is demonstrating that the processing concept can work on a larger scale, is economically attractive and has a market. The routine production stage would normally follow, but at the moment it seems to be very far away. Currently the research stage is under way, but we have not yet reached the stage of commercial demonstration. The prospects of such commercial demonstration seem to depend primarily on the cost of space transportation and on the reliability of the space vehicles and all of the required infrastructures.

The Shuttle is at the moment the only vehicle in the West which enables experiments of long duration to be conducted in space. Experiments in microgravity using the Shuttle/Spacelab combination, which can accommodate a team of four research scientists, have so far yielded the best results. But there are three important limits. First, the movements of the members of the crew cause micro-accelerations which can compromise the results of certain experiments. Second, the length of the stay in space is about ten days, and many experiments require a significantly longer time. Third, the Shuttle does not produce enough energy for some applications of microgravity. Some of these inconveniences can be avoided by utilizing free-flying platforms, such as the Eureca, which will permit precise microgravity experiments to be conducted without disturbance.

Some American space companies are already thinking of beginning to market an industrial module which would be launched unmanned by the Shuttle. This launch could take place two or three years before the space station is ready and would carry a pressurized workroom in which astronauts from the space station could eventually work in a 'shirtsleeve' environment during the two or three days it would take to service the module.

The space structure which best provides for microgravity activities is, without a doubt, a manned space station.

This would permit experiments of a long duration to be performed directly by a team of scientists who would have the possibility of working in an environment with a microgravity level which is certainly of a higher quality than that of the Shuttle/Spacelab. The space station would also be the ideal structure within which routine production could be initiated. Nasa has begun a project to build a structure of this type which, if current plans and funding are maintained, should be operational some time in the 1990s.

The costs

By the end of the 1990s, if everything proceeds as planned, the Western space industry will have built all of the basic infrastructure necessary to begin the process of the industrialization of space. But what are the costs of the infrastructures, and will they be reliable? Today the cost of Shuttle transportation is very high. This sum must be reduced to approximately a tenth of its current level if it is going to be commercially feasible to produce new materials in space. In effect, the investments which industry must make in order to operate in space are too high at the moment, when compared to the amount industry spends on related research on Earth. A report from the American Office of Technology Assessment concluded that a commercial space venture would have to be assured of very high revenue before it became an attractive investment. Furthermore, there is always the risk that some activities which are now believed to be possible only in a space environment may one day become feasible on Earth at a much lower cost. A significant example of economic prospects discouraging the investor was Johnson & Johnson's cancellation of its proposed collaboration with McDonnell Douglas in the production of the first pharmaceutical products in space. Another factor of uncertainty is that the investors cannot count on a stable and predictable transport system.

In the wake of the Challenger tragedy, Nasa cancelled 15–18 Spacelab missions that were planned to fly during the next five years, greatly reducing the frequency of space experiment opportunities for scientists from the US, Europe and Japan. Nasa is likely to fly only three more Spacelab missions before the end of the decade, only one of which will use a pressurized module. These changes are likely to convince many scientists that they are better off flying their experiments on an unmanned launch vehicle. In discussions on the Hermes and the Columbus projects, many scientists argued strongly in favour of unmanned and cheaper projects, fearing that Columbus would absorb too much of the space budget.

Profitable products

Because of the high cost of space transportation, the conditions necessary for the commercialization of products and profitability are twofold: first, the product or the service rendered must have a sufficiently high intrinsic value; and, second, there needs to be a large enough market. As far as the first condition is concerned one must take into account the value-to-weight ratio. It is obvious that candidate materials for commercial manufacturing in space should be sufficiently light to minimize transportation costs, while being valuable enough to ensure that the market price offsets the costs attributable to transportation.

An example of such a product is pharmaceuticals, whose prices can be very high. The McDonnell Douglas and Johnson & Johnson pharmaceutical venture planned to use space processing for the production of new medicines and was expected to generate one billion dollars in annual sales by the early to mid-1990s. The venture focused on the use of the electrophoresis separation process in space to obtain mass quantities of a hormone. The Ortho pharmaceutical division of Johnson & Johnson expected to begin human patient testing in early 1985 having produced the material on Shuttle mission 41D. McDonnell Douglas astronautics, however, had encountered problems in making the product in the quantity required for clinical testing. At that point Ortho decided to cancel the agreement with McDonnell Douglas. This demonstrates that technical difficulties have not been successfully resolved, even in a type of microgravity activity which is more advanced than others.

So far only one product has been obtained, the monodispersed latex spheres. The spheres are used as tiny rulers to determine relative sizes of objects under microscopes and to calibrate filters, particle counters and porous membranes. Spheres smaller than one micron and up to three microns can be produced successfully in ground laboratories. Producing spheres of a uniform diameter larger than this is very difficult because of adverse gravitational effects. The spheres which have been produced in space by seeded emulsion polymerization are 10 microns (10 thousandths of a millimetre) in diameter. In spite of this good track record, the production of monodispersed latex spheres on the Shuttle stopped in 1985 because of lack of demand.

Another sector of interest to private companies is that of crystal growth. Microgravity Research Associates, Inc., together with Grumman Space, has planned to manufacture gallium arsenide semiconductor crystals in space. Gallium arsenide has properties far superior to silicon, which has been the basic electronic industry semiconductor material for several decades. New super-computers that will perform billions of computations every second, vital for strategic defence systems and advanced satellite communication systems, will have requirements that will surpass silicon technology and open the market for a new semiconductor material. Raw material on Earth is able to yield only 2 per cent of gallium arsenide as an end product, whereas in space it is possible to obtain a much purer product at 10 per cent. The cost of the production of four hundred chips on Earth with a yield of eight good gallium arsenide chips (2 per cent yield) is approximately $300. In space there is a yield of 10 per cent, so that from 400 chips we obtain 40 good chips. The processing costs are very large because of transportation prices. Even though the total cost is higher in space, the potential profits greatly exceed those available from earthbound production. But profits will flow only if there is a market ready to absorb the growing number of microchips.

Some marketing forecasts are decidedly optimistic about the future. The Centre for Space Policy, an American organization which specializes in estimating commercial or industrial opportunities in space, has predicted that by the year 2000 the annual revenue produced by the processing of material in microgravity will be roughly $41.5 billion. It is, however, difficult to make judgments from such assessments, because of the high number of variables involved and the lack of substantial reliability or applicability. Indeed, the commercialization of space may not occur until the twenty-first century, when cheaper transportation may be available.

Organization

In most of the industrialized world there is a marked and growing interest in microgravitational experimentation. These activities are mainly undertaken by governments and by space agencies. Only in the US has the private sector become involved to a relevant extent. Despite considerable promotion by Nasa of the potential commercial benefits from microgravity applications, the results of its own studies so far have not been particularly encouraging.

A European Low Gravity Research Association (ELGRA) has been set up with the sponsorship support of ESA and the Council of Europe in order to coordinate national activities in this sector. In 1982 ESA established the Microgravity Programme for basic research, with modest resources. The main programme involves the launching of sounding rockets for experimentation in fluid physics and material science. A series of experiments have been planned for execution on the Spacelab and Eureca. Within Europe the greatest interest in microgravity experimentation has been evident in Germany, where the Ministry of Scientific Research and Technology spent approximately $150 million between 1978 and 1985 on microgravity activities. The German programme for material processing is not purely scientific in orientation, but also seeks to encourage the industrial sector to explore the potential applications of space-processed metals, composite metals, chemicals and crystals. France is also carrying out a research programme to evaluate material processing applications. Some years ago, CNES designed a specialized automated 'manufacturing-in-space' system, called Solaris. The effort to promote interest in Solaris among other ESA member states has not been particularly successful. British interest in microgravity has been limited. As for the participation of private companies, a new organization called Intospace has been formed by the German MBB/ERNO and Italy's Aeritalia. This multinational marketing organization is designed to bring potential microgravity users together with the producers of European space hardware and systems. So far, however, the involvement of the private sector in Europe remains small.

The prospects for Europe

The industrialization of space, should it occur, would provide a number of important opportunities for those involved. The development of new materials, whose production is possible only under microgravity conditions, could prove to be an important factor, not only commercially but strategically as well (e.g., high-speed microchips for ultra-sophisticated computer systems). It is still far from certain, however, that microgravity activities can be made commercially sound, whatever the technical, economic and institutional framework. If the potential of these activities nevertheless remains attractive, international cooperation appears to be the best way to share the risks inherent in such an endeavour.

The most important decision currently outstanding is over the space station. Among the major divergences between Nasa and ESA, two are especially relevant to microgravity research: the technology transfer issue, and the right to the patents and exploitation of discoveries made through the space station. The German government wants to equip the permanent attached module as an advanced space laboratory for microgravity experiments. Nasa has not yet agreed, and its officials have discussed using it primarily for life sciences and related activities. The question of proprietary rights to exploit discoveries has not yet been resolved in negotiations. One of the objectives of Nasa has always been to channel funds and technical capabilities away from activities which are competitive or not compatible with US interests and to dominate as far as possible the definition of the missions of collaborative programmes .

To proceed with the immediate objective of establishing an independent European capability in the field of space industrialization would appear to be very difficult, unless Europe is ready to act on its own by developing its own infrastructure to which it can control access. Europe is technically capable of achieving such a goal, but the costs would be enormous and in microgravity the commercial prospects are unproven. But Europeans may have to consider whether to acquire the experience which would enable eventual commercial applications to be exploited.

(e) SECURITY

Current military uses of space

For the thirty years of the space age, military space activities have been divided into five traditional missions: communications, reconnaissance and surveillance, navigation, meteorology and geodesy. This section surveys these current space missions. The general characteristics of military satellites and their orbits are governed by basic technical considerations. These are set out in detail in the Annex and Figures 5, 6 and 7.

Communications

Most operational communications satellites (Comsats) today use ultra-high frequencies (UHF) and super-high frequencies (SHF), but extremely high frequency systems are under development. The move to higher frequencies for military satellite communication (Satcom) is motivated by two major factors. First, higher-frequency radio waves have a higher limit to their data-carrying capacity than lower frequencies. Second, transmitting antennas for higher frequencies can be made smaller without sacrificing performance, since the effectiveness of a transmitter dish is determined by the ratio of its size to the wavelength of the radio waves it is transmitting. There are three additional reasons for high frequencies (accompanied by wide bandwidths for some particular needs of Satcom). First, it is easier to protect higher-frequency links against countermeasures. Second, higher frequencies suffer less distortion in passing through an ionosphere disturbed by nuclear detonations. Third, although laser communication is also coming into use for satellite-to-satellite and satellite-to-aircraft links, ground-to-space laser communication links could obviously be frustrated by clouds. Covert 'low probability of intercept' (or LPI) communication, which does not betray the location of the transmitting ground terminal, is easier with wide bandwidths.

Military Comsats are deployed in a variety of orbits. Geostationary is high enough to allow widely separated ground stations to communicate through a single satellite, and a stationary satellite makes it easy for users to point their antennas. But the polar regions are invisible from geostationary equatorial antennas. The Soviet Union, which has many military installations at high latitudes, deploys Satcoms in Molniya orbits (see Annex). A communications satellite in LEO is visible at any given time from a relatively small 'footprint' of Earth below. Two terminals within the print can communicate directly, but widely separated users must store messages on board the satellite when it is overhead, ordering the satellite to 'dump' the message when it passes over the recipient. The Soviets deploy large numbers of such store-and-dump satellites.

Users of military Satcom fall into three categories: high-data-rate peacetime users, including intelligence and diplomatic terminals; tactical forces, which need moderate data-rates but worldwide coverage, small mobile terminals and resilience to disruption; and nuclear forces and their commanders, needing low data-rates but performance under severe stress.

Today's US Defense Satellite Communications System (DSCS), Fleet Satellite Communications (FleetSatCom) and Air Force Satellite Communications (AfSatCom) systems broadly represent this tripartite division. The DSCS provides the US government with worldwide (except the polar regions) high-data-rate voice and data communications.

The FleetSatCom (or FLTSAT) constellation consists of four synchronous satellites distributed about the equator in almost the same positions as the four DSCS spacecraft. The FLTSATs relay a fleetwide broadcast, transmitted to the satellites from ground stations, which almost all navy ships can receive. Surface ships normally transmit messages back to shore stations via the satellite link. Submarines, which can only receive and transmit at certain times, are provided with special facilities. All channels in the FLTSAT system operate in the military UHF band, except for an SHF uplink that carries the fleet broadcast up to the satellites.

The AfSatCom programme does not consist of a particular satellite constellation, but rather of communications packages on spacecraft sometimes designed for entirely other purposes. In addition to channels on the FLTSATs, the AfSatCom system includes communications packages on the DSCS spacecraft in Molniya orbits, and, in the future, on the 18 satellites of the Navstar Global Positioning System (GPS) constellation, providing worldwide coverage. Obviously, almost any military spacecraft would make a convenient 'host' for a small AfSatCom transponder, and it would be possible in principle for the Department of Defense to put simple transponders on civilian satellites as well. The array of Comsats available to the US military is completed by certain Nato systems and various experimental spacecraft.

The control of complex spacecraft that require frequent ground commands depends on a worldwide network of ground stations. Suitably located ground stations in areas resistant to political change, not to mention military conflict, are hard to provide. Direct satellite-to-satellite relay links avoid all these problems and obviate the need to store data on board, when the satellite is not in direct view of a control station. Nasa's Tracking and Data Relay Satellite System (TDRSS), consisting of a pair of spacecraft in synchronous orbit, will provide essentially uninterrupted relay between satellites at all altitudes with one ground station at White Sands, New Mexico.

Reconnaissance and surveillance

Electromagnetic radiation emitted or reflected from terrestrial objects can be detected from space in any of the three wavelength bands to which the atmosphere is transparent, i.e., the visible band, certain infra-red bands, and the microwave radio band. It follows that these are the bands used for military surveillance. In peacetime, these remote-sensing techniques are used for both tactical and strategic purposes. These include the collection of communications intelligence, the identification of the characteristics of new and deployed weapon-systems, and the gathering of tactical intelligence, such as tracking fleet movements, locating land unit headquarters and monitoring activities at air bases.

Although many of the same remote-sensing technologies apply to both tactical and strategic intelligence, there are three particular requirements for tactical missions. First, battlefield intelligence must be acquired, processed and disseminated rapidly, if it is to be useful. Therefore, the orbit and number of satellites should be chosen to allow continuous or very frequent survey of the battlefield: geostationary, Molniya or harmonic orbit, and a large number of satellites. Transmission time should be shortened. Data Relay Satellites and highly secure communications become very important. Second, tactical sensors of genuine military value must expect to come under attack, whereas peacetime intelligence collection is not likely to be directly impeded. So they must be well protected. Third, space-based sensors – a necessarily global capability – must compete in cost-effectiveness and survivability with other means of collecting tactical intelligence, such as aircraft and remotely piloted vehicles.

As for nuclear operations, space can be used to detect missile launches and nuclear detonations. Data that warn of missile launches permit the safe escape of bombers, tankers, cruise missile carriers, airborne command posts and, for launch under attack (LUA), ICBMs. Confirmation of detonations might also serve as a last check on an LUA decision. But the most important use of missile launch and nuclear detonation data would probably be to give decision-makers a clear assessment of what had happened – information crucial to responsible action and, under the likely chaotic circumstances, otherwise hard to come by.

Imagery

The resolution of a spaceborne optical camera is proportional to its altitude (See Table 8). Thus a photo-reconnaissance satellite orbiting at an altitude of 200 km and yielding imagery with one-foot resolution would at 5,000 km yield Landsat-type images that would be useful for forestry, but useless for most intelligence purposes. Photo-reconnaissance satellites are therefore confined to low earth orbit. Coverage at all latitudes requires polar orbits for these satellites. Furthermore, if the satellite has an on-orbit lifetime of longer than a month, it should make use of the sun-synchronous property of certain near-polar orbits, which maintain the same orientation with respect to the sun as the season change, always taking pictures at the same local time on the Earth below regardless of season. Low-altitude, polar, sun-synchronous orbit is therefore the home of long-life photo-reconnaissance satellites.

Infra-red cameras collect information about the surface temperature of objects on the Earth, potentially revealing features obscured at visible wavelengths. Radar images can be formed by illuminating the Earth with microwaves and processing the reflected signals. Active satellites provide night-time and all-weather imagery.

Signal detection

Satellites can also detect signals in the visible, infra-red and radio bands, including microwave pulses from the radars on a ship, telemetry from a cruise missile test vehicle, the visible flash of a nuclear detonation, or the infra-red plume of an ICBM launch. If the signal is sharply structured in time – like the flash of a nuclear burst or the pulses of a radar – the emitter's location can be deduced from the differences among the signal's arrival times at several well-separated satellites.

Intelligence satellites designed to operate at radio and radar frequencies are know as 'electronic ferrets' or 'electronic ears'. Their functions include eavesdropping on radio communications; locating sites with particular 'radio' characteristics; monitoring the intensity (or changes in intensity) of radio emissions (as an indication of new military activity); mapping the coverage and characteristics of radar installations (early warning; ground-to-air missile control); and intercepting telemetry transmissions from weapons under test.

One particular benefit of electronic reconnaissance is that it adds a dimension to photo-reconnaissance data. An electronic signature can convert a puzzling photographic 'blot' into a completely identified object. Ferret packages may be operated on their own or used 'piggyback' on a photo-reconnaissance satellite.

Orbits for signals detection should be chosen to provide continuous coverage of target areas, thereby preventing the opponent from concealing information by performing tests, sending messages, moving mobile radars or launching missiles during coverage gaps. Geostationary orbits offer continuous dwell over mid-latitudes; the US acknowledges that it stations warning satellites there. Long dwell times (and coverage of northern latitudes) are also possible from Molniya orbits; the Soviet Union deploys warning satellites in this way.

Continuous coverage by several widely separated satellites, permitting emitter location by the time-difference-of-arrival techniques, requires a 'birdcage' constellation; the US Nuclear Detection System (NDS) aboard the Navstar GPS satellite is in this kind of orbit.

Apart from geostationary missile warning and birdcage NDS deployment, the US has not revealed the locations of its other signal detection satellites. They could make use of all three possibilities: that is, geostationary, Molniya, and low and mid-altitude birdcage constellations.

Navigation

Accurate navigation is essential for supporting reconnaissance, weapon delivery (including sea-launched ballistic missiles), battle management, the precision emplacement of sensors and mines, and rendezvous. Terrestrial navigation systems have either restricted coverage or poor accuracy. In one satellite navigation method, used by the US Navy's Transit system and its Soviet equivalent, the user listens to how the received frequency of a radio signal changes as the transmitting satellite passes from horizon to horizon (Doppler shift). By knowing the satellite's orbit and the pattern of frequency change, the receiver can deduce its position on the Earth's surface. The need for global coverage makes polar orbits best for these satellites.

In a second navigation method, the user measures the arrival times of signals from several well-separated satellites, and then uses the inverse of the time-difference-of-arrival emitter location technique to deduce its position. The Navstar GPS provides just such a constellation.

Meteorology

Military operations, which are increasingly wide-ranging, require knowledge of the weather pattern in distant parts of the globe. The US Defense Meteorological Support Program (DMSP) satellites are in near-polar sun-synchronous orbits at 850 km. They orbit the earth 14 times per day at approximately 100 minutes per orbit. From an altitude of 850 km, the width of the swath of Earth visible below is almost 3,000 km – one fourteenth of the Earth's circumference. Thus, on its 28 passes over the equator each day, a DMSP satellite views nearly every point on the equator twice, once on an ascending pass and once on a descending pass. At other latitudes the swaths overlap. Data for military use can of course also be extracted from civilian weather satellites.

Geodesy

A precise knowledge of positions on Earth, and of Earth gravity on the various parts of a trajectory, is essential to the guidance and targeting of any vehicle that relies on inertial navigation, such as a submarine, aircraft or missile. Many of the well-publicized 'scientific successes' of space exploration and continuing work in that area are of military origin. For the development of ICBMs it was necessary to obtain precise measurements of the relative position of the planned missile launching points and the missile's targets. Such information could only be obtained from space. The accuracy of ballistic missile guidance systems was also critically dependent upon knowledge of the very small perturbations in the Earth's gravitational field. This too could only be explored effectively with the assistance of space-based measurements. Today, the development of effective cruise missile guidance systems also requires the use of space. Such guidance systems work on the principle of comparing a 'digitized map' of the Earth's surface held inside the missile with the picture of the ground being 'seen' by the missile's sensors as it flies to the target. The 'digitized map' has to be produced from space observations.

The basic operational mode of a geodetic satellite system consists of an ultra-precise measurement of orbital movements of special satellites. Since these satellites are designed to allow a precise prediction of their orbital parameters, any deviation from these values can be related to variations of the Earth's gravity. Conversely, knowledge of the orbital position of the satellite permits positioning in relation to it.

New military uses of space

Besides these traditional military uses of space, some more exotic ones are emerging.

Asat and Dsat

Asats (satellite attack systems) consist of capabilities to destroy, incapacitate or interfere with a satellite mission. They are a response to the growing military and political importance of satellites. They can be of many types ranging from ground-, air- or space-launched missiles, to lasers and high-power microwave transmitters. Studies have shown that means to destroy, incapacitate or interfere with satellite systems are so diverse, and so difficult to monitor, that it is difficult to imagine an effective and verifiable ban on Asat systems. Similarly, an attempt to segregate various kinds of satellite so that some of them will not be targets does not seem realistic, because it would significantly reduce the protection for the others. Last but not the least, some protection does exist for US and Soviet satellites that can be defined as 'national means of verification'.

The Soviet Asat system already has a ground-launched interceptor, which is sent into the same orbit as the target. This is attacked, after one or two orbits, by a radar-guided vehicle with an explosive warhead which is detonated when the two vehicles are close enough. The current Soviet system can reach satellites with altitudes below 2,000 km for polar orbits and slightly higher for orbits with lesser inclinations. Such a system has a built-in lack of flexibility, because co-orbital attack requires delay until the target orbital plane is over the launch site. The ability to strike a full constellation in a short time is limited. Furthermore the system's dependence on active radar makes it vulnerable to jamming.

The US system, still in development, is significantly different. An air-launched missile, using infra-red guidance, scores a direct hit on the target. This design allows much greater attack flexibility than the Soviet system, although its altitude capability is limited to around 1,000 km.

Dsat systems (satellite defence) are under discussion as a set of means and actions that could be used to defend satellites against Asat attacks, including electronic countermeasures. They include passive methods (orbital manoeuvres, decoys and hardening) and active methods (jamming, firing projectiles at the attacker, and so on).

Both Asat and Dsat systems rely heavily on a satellite tracking and identification network. This consists of radars and optical systems positioned around the world and linked to a central system for data management. Radars are used for trajectory and gross measurement of the objects in orbit, whereas optical telescopes, located in relatively cloud-free areas or airborne, provide identification. The comparison of orbital tracks with the predicted tracks of existing satellites provides real-time information on launches of new satellites or manoeuvres of existing ones. Such a system provides an early-warning function together with the information necessary, first, for the safe use of space, since it monitors all the debris that could be dangerous to manned or unmanned satellites, and, eventually, for the targeting of an Asat system or a Dsat system.

ABM (anti-ballistic missile) system

Since President Reagan's speech of March 1983, the world has realized that research had already been going on in the US and USSR to study the feasibility of using both space- and ground-based assets to build an ABM system. Any system of that kind would necessarily involve a detection and discrimination capability, ground- and/or space-based weapons and a battle management system. Space systems would be placed in different orbits: those directed at early warning and the tracking of a boosted vehicle would be in geostationary or Molniya orbits. Systems of discrimination and tracking at the ballistic phase would be on altitude orbits of 4,000–10,000 km in order to observe more closely the re-entry vehicles and the decoys, while being able to defend themselves against Asats. Space-based weapons would be in low altitude around 4,000 km, allowing a short time for the weapons to target, while being able to counter Asat attacks.

The implications for Europe

The profiles of national space policies set out earlier in this report drew attention to the considerable military space capabilities of the USA and the USSR, and to an emerging Chinese programme. Within Europe only France and the UK have any significant capabilities, both selectively focused on specific tasks. Italy is developing a military communications system. Europe, as such, has no collective system of its own, although members of Nato's integrated structure share in its collective satellite communications systems. Although the necessary technology and overall economic capability exist to go beyond this, Europe has been unable to resolve its military and political differences up to now, or to define specific and agreed collective requirements. However, some national requirements and interests can be identified which might form the elements of a collective approach.

Reconnaissance and surveillance satellites

French interest in an independent system is linked to nuclear deterrence (better knowledge of targets and ABM defences in the

Soviet Union, etc.), to the overseas operations (mainly in Africa) of the Force d'Action Rapide (FAR), and to a desire for independent intelligence sources to support French diplomacy. These concerns have been met by an optical reconnaissance satellite with a non-harmonic sun-synchronous orbit, in order to allow a periodic full scanning of the Earth, with non-real-time image availability.

The Federal Republic of Germany is interested in monitoring its eastern border zone, which is about 1,000 km North-South and 100 km East-West. This requires an all-weather capability to meet local conditions. A radar satellite has the advantage of overcoming the weather conditions, but it is relatively easy to foil when monitoring a land area, and in any case it would not meet the need for real-time imaging of a narrow area, such as the Central Front in Europe.

The UK has a keen interest in strategic information about targets for its nuclear forces and ABM defences, and in intelligence to support diplomacy. Under bilateral agreements the UK has access to wide-ranging US intelligence sources, which produce a quantity and quality of information which neither the UK alone nor Europe collectively could replace in the short-to-medium term. But British concerns are evolving and might begin to encompass a search for complementary capabilities within Europe. The Italians have a growing interest in access to a collective system, and the Spanish have signalled a similar concern; hence the decision by both to associate themselves with the French Helios programme.

Because military doctrines differ significantly among the four largest countries in Western Europe, it is difficult to reach a consensus on the military use of a single joint reconnaissance satellite. That situation is made even more complicated by domestic political issues: it would be difficult for example for the Federal Republic of Germany to be part of a satellite system that supported significantly British or French nuclear forces. Nevertheless, there may be scope for bilateral projects: the United Kingdom and France have nuclear forces with similar targeting and penetration problems. Similarly, Italian and French interests in the Mediterranean and in Africa could be rendered compatible.

A joint European reconnaissance system could have great political significance. It would enable Europe to monitor treaty compliance and crisis behaviour, and it would also give Europe a voice in any pertinent discussions on space law. European nations cannot expect to be involved in any East-West discussions, or to be signatories of a treaty, without an independent capability for monitoring treaty compliance. And, of course, such a reconnaissance system would permit crisis monitoring within Europe, without having to rely on indirectly received evidence. It should be underlined that for both uses – treaty compliance and crisis monitoring – every government would keep its independence of decision while benefiting from its shared source of information. Independent European analysis could well help rather than hinder transatlantic cooperation.

A reconnaissance system would also provide the military with data on the readiness, equipment and organization of enemy forces. Europeans would have the option to 'piggyback' an electric intelligence package.

Communication satellites

European cooperation would be simpler to set up in this field. By definition Comsats can be made transparent, so that every country could use its part of such a satellite. The service could include a worldwide coverage: one spot beam over Western Europe and one or two movable spot beams for overseas operations. Such a system would be a significant step forward in interoperability and could maintain each country's freedom by the allocation of separate but identical transponders. But the case for a European system depends on a judgment about what this would add to the mix of Nato and national systems already in operation or in prospect.

Nato's involvement in the field of satellite communications began in the mid-1960s with a technical group study of how a Comsat system might be used both to assist communication between the Nato Council and its member governments, and to provide means for exercising the commad and control of Nato ground, sea and air forces. In 1971, the North Atlantic Council agreed a policy statement which set out in definitive terms the role to be played by satellite communications in Nato. The implementation of this policy was entrusted to the Nato Integrated Communications Management Agency – now renamed the Nato Command Information Systems Agency (NACISA). The result of this policy today is the Nato Integrated Communications System (NICS), the third phase of which has recently been completed. It provides a sophisticated, flexible, survivable, high-capacity and complex network of ground- and space-based elements for mainly fixed telegraph and voice communication circuits, and it supplements appropriate national systems. It is interoperable with the US DSCS and used by the European members of Nato's integrated military structure.

When operated together with appropriate national space- and ground-based systems, NICS should allow the full military communication requirement within the North Atlantic Treaty area to be met. Technical and operational improvements, particularly in the field of signal-processing, are of course continuously under consideration. The basic principle, however, of a mix of national and Nato systems, including a diversity of space- and ground-based elements, provides a great deal of versatility and robustness. In a more narrowly defined European context, there is clearly room for cooperation between the two European powers which retain residual worldwide military commitments – France and the United Kingdom – in ensuring that there is not wasteful duplication in meeting their national global communication requirements. But there is also a case for wider European cooperation in ensuring that the architecture of the various developing military and civil communication systems, together with their system of operational management, provides the users with the maximum possible degree of operational flexibility for military use, particularly in the event of unforeseen circumstances. Such cooperation does exist but needs to be strengthened within the general framework of European military cooperative programmes. This European cooperation must take account of US national developments in military communication, but needs to recognize that some US national requirements may lead the US down paths which the Europeans may neither wish nor need to follow.

Asats

With the advent of Asats and space-based defence systems, the survivability of satellites is no longer assured. No protection exists today for European satellites, civilian or military. Two approaches to this problem can be envisaged. Europe could develop a full Asat system to deter any attack on its satellites by threatening to reply in kind. Such an approach would probably be effective but expensive. The other approach would involve strengthening space law to ensure the survivability of space-based assets. One proposal is to define 'keep-out zones' in space, which satellites from adversary countries would not penetrate except for a short period of time and with advance notice.

Without a military satellite of its own, Europe is not well placed to demand inclusion in any treaty to protect satellites or to define proprietary keep-out zones in space. Obviously such a move would imply the development of some limited Asat/Dsat capability.

Ground tracking and identification system
Whether or not Europeans decide to develop Asats or to participate in a treaty about the use of space, Europe will need a ground tracking and identification system in order to acquire an independent knowledge of satellites orbited by other nations, and to ensure that none of them is threatening European space assets. Such a facility is an obvious candidate for collaborative European development and operation.

6

MEANS

Access to space and the opportunities which are there to be seized demand a sophisticated technological and industrial infrastructure, as well as the capability to manage very large programmes coherently and cost-effectively. This chapter identifies the elements needed to give Europe the chance of turning its potential across the range of space applications into solid and sustained achievement.

Space transportation systems

The exploration and use of outer space require capabilities for lifting objects outside the Earth's atmosphere. Powerful launchers are required, whether to place heavy payloads into low orbits or to place smaller payloads into distant orbits, particularly the geostationary orbit located some 36,000 kilometres from the Earth's surface. Only a few countries – the Soviet Union, the United States, China, Japan and the European Space Agency – have met these requirements, though more have placed small payloads in low orbit. So far only the Soviet Union has achieved launches on a routine operational basis. (See Table 6.)

Launch vehicles have in the main been developed from ballistic missiles (the Indian and Japanese vehicles are exceptions), thus making the expendable launch vehicle (ELV) the primary means for obtaining access to outer space. The projected increase in the use of space led the Americans to perceive ELVs as inefficient, and encouraged them to develop the Shuttle as a more efficient and cost-effective system. The Shuttle is a partially re-usable and manned vehicle capable of carrying and returning cargo to and from space. The USSR continues to rely on ELVs, but it too is developing a shuttle system. There is also an increasing requirement for mobility within space, to reach satellites or platforms in close proximity to a large staging post such as a space station or shuttle. In the future an orbital transfer vehicle will be needed to move payloads from one orbit to another, well-separated orbit: for example, to bring a payload from GEO to a space station in LEO for refurbishment. Recently there has been growing interest in new launch systems, reflected in the rash of proposals for horizontal take-off and landing vehicles as possible replacements for the traditional vertically launched vehicle.

Shuttle

The first partially re-usable manned space vehicle was incorporated in the Space Transportation System introduced by the United States in 1981. This Shuttle system consists of an orbiter with three liquid-fuelled engines, two solid-rocket boosters and a large external fuel tank. Launch is achieved by the combined firing of the liquid-fuelled engines on the orbiter and the solid-rocket engines. The solid-rocket casings are parachuted back to Earth to be recovered and re-used, whereas the external tank is released just prior to orbital injection and burns up on re-entry into the atmosphere. The DC-9 orbiter carries a crew and payload of some 30 tons to LEO, and 15 tons can be returned to Earth; for higher orbits an additional stage is attached to the payload. Once in orbit, payloads can be lifted out or hauled into the cargo bay by a remote manipulator arm, currently built in Canada. A manned manoeuvring vehicle has been developed to allow access to satellites close to the Shuttle. The Shuttle is so far the only vehicle of its type.

In the event the Shuttle has not provided easy or low-cost access to space. It was envisaged in 1975 that by 1984 the price for a dedicated Shuttle launch would be $40 million, but in 1984 a Congressional estimate put the cost of a flight at some $375 million. Prices charged to customers have steadily increased from $80 million in 1984 to some $150 million (at 1984 values) in 1988. The American government has decided that prices will increase to reflect the real operating costs. The use of the Shuttle by Europeans for Spacelab, and eventually for transporting modules for the projected international space station, is expensive, even without the uncertainties resulting from the technical problems revealed by the Challenger tragedy. These factors are all the more significant because most of the American ELVs were phased out in the 1980s, when the Shuttle fleet became operational.

The main advantage of the Shuttle is its flexibility as a space system. This flexibility is based on its large payload capacity; its provision for the repair and maintenance of satellites and platforms in LEO; facilities for scientific and technological experiments over an eight-day period; the transport and assembly of space station modules; the servicing of a space station with crew and cargo; and the transport of cargo from space. Nevertheless, it should be noted that the Soviet Union has operated and routinely resupplied a space station for over a decade through the use of a heavy launcher (32 tonnes to LEO) with a space station as payload. This space station is, however, much smaller than that contemplated by the United States.

Ariane

Until Ariane was developed, launchers for heavy payloads, especially to GEO, were available only from the superpowers. This made Europe, and indeed other countries, highly dependent. Early European attempts to develop a launcher through ELDO were abortive, but reliance on the US subsequently proved unsatisfactory, for example in the difficulties over the launching of the Franco-German Symphonie satellite. The European decision to start the Ariane programme turned out to be a prudent one.

Ariane was developed at a cost of some 960 million EAU and had its first successful flight in 1979. It provided the Europeans with an independent launch capability, but early attention was also given to the scope for capturing a share of the market for launch services. Arianes 1, 2 and 3 are the original family; Ariane 4 has been up-rated from 1,750 kg to 4,300 kg for geostationary transfer orbit (GTO) in order to reduce the cost per kilogram in orbit. Since ESA could not direct its own commercial operation, Arianespace was established as a private concern, separate from ESA.

When Shuttle launches proved complex to manage and costly, and in the absence of other competing ELVs, Ariane became a successful commercial operation. It was capable of carrying two payloads on each flight at a cost for a dual launch of some $54 million in 1984 (cf. Shuttle costs of $80 million), and $75 million in

1985. An Ariane 4 launch, with a load factor of 100 per cent of the 4,200 kilograms, costs ESA customers around $95 million in 1987. The cost of a launch for other customers depends on market conditions. The international launch market is such that no launches are offered on the basis of full-cost recovery.

In 1985 the ESA Council decided that the Ariane 4 programme, though suited to current launch demands, would not be able to meet the future launch needs of Europeans and other users. They therefore approved an optional programme for the development of Ariane 5 as a heavy-lift vehicle (originally set at 15 tonnes to LEO), with estimated costs at the time of 2,600 million EAU. Ariane 5, which is to be ready by 1995,is intended to be 20 per cent more cost-effective than Ariane 4 for both LEO and GEO; capable of accommodating wide-diameter payloads comparable to the size of the cargo bay of the Shuttle; and more reliable. It is also to be man-rated, that is, capable of launching Hermes; and to carry modules that can be assembled into a space station.

Hermes

Several countries have plans to develop small manned orbiters, which would not have any role in the launch process, but would be attached as a payload to the launch vehicle. One such vehicle is currently under test in the Soviet Union and another – Hermes – was adopted by ESA in 1985 in a preparatory programme, and originates from a French proposal. The Hermes project's incorporation of the transport of both crew and cargo is potentially relevant for a future European space station. The capital costs of the project were estimated in 1985 by CNES at 2,000 million EAU, with annual operating costs of 220 million EAU for two flights per year. The 1987 ESA estimate is 4,534 million EAU for development, with operating costs of 276 million EAU. Hermes was originally judged to be admirably suited to the long-term ESA objectives of European autonomy. Recent assessments within ESA suggest, however, that the initial operational and budgetary forecasts were over-optimistic, and that the cargo-carrying capabilities of Hermes will be limited. Initially designed to weigh 16 tonnes with cargo, it will now weigh considerably more. Configured at 21 tonnes, Hermes could carry 3 astronauts and 3 tonnes of payload.

Ariane 5 and Hermes will be key and interdependent elements in the ESA plan to enhance European autonomy. A manned presence in space will require both. A European space station will require Ariane 5 and Hermes, with an appropriate cargo capacity. Both projects are technically and managerially demanding, as recent revisions of some of the design parameters and the timetable indicate.

Launch service

The provision of a launch vehicle is only one element of a launch service. Launch-pads must be built; special facilities provided for the integration of the payload and the launch vehicle; and equipment and personnel made available for tracking and control of the vehicle after launch. Ariane launches take place at the Centre Spatial Guyanais (CSG) in Kourou (French Guiana), close to the Equator and thus favourable for launch into GEO. The CSG was made available to ESA in 1979, after operating initially for the French national programme. ESA *and* its members are guaranteed access to the CSG facilities, and ESA has priority of use.

The main operations at the CSG are payload integration; launch facilities; and tracking and telemetry functions during launch. Two launch-pads are available, allowing a maximum of ten launches per year. The second launch-pad was completed in 1985 after four years' development and at a cost of 240 million EAU. It is the property of ESA and has been put at the disposal of Arianespace. Even these facilities for a rapid turn-around or launch-on-demand are limited, and any serious accident at the CSG would be a severe setback. It may be desirable to have additional facilities, but locations as suitable for GEO launches are not plentiful. One possibility would be the Italian site at San Marco, Kenya. Launches into polar orbit and orbits for many military payloads gain less advantage from an equatorial launch site, and alternatives may be available in Europe. In the future a European spaceplane might utilize conventional airfields and need less complex facilities.

The CSG tracking and telemetry facilities provide accurate orbit determination and allow launcher performance to be checked, using facilities in Brazil, Ivory Coast and the Nasa/DoD facility on Ascension Island. The status of the payload is monitored by ESOC at Darmstadt. ESOC's task is to monitor launch and early-orbit-phase operations so as to place the payload into the required orbit and perform in-flight commissioning and testing prior to putting the payload into service. For these purposes ESOC operates a dedicated ground system, including control and computing facilities and a terrestrial tracking network (Estrack) with stations located in Belgium, Spain, Germany, Gabon, Australia, Kenya, and French Guiana. ESOC is capable of controlling the complete range of spacecraft missions from near-earth orbit to deep space. Mission, spacecraft and ground station control are integrated into a single facility. However, this facility was not designed for manned missions, nor is it capable of tracking the full complement of objects in space.

Launch market

The demand for launch services is not precisely predictable. Forecasts have suggested a market of 120–160 payloads to the year 2000. But rapid developments in fibre optics complicate forecasts for communication satellites, and the expected demand for DBSs has been slow to materialize. The extent of the demand will also depend on other factors, such as the building of a space station, the promotion of other applications satellites and military activities.

A customer's choice of a launcher depends on price, availability, the perceived reliability of a launch vehicle and the insurance requirements. Offers from the Soviet Union and China raise further issues about technology transfers and foreign policy. The recent spate of launch failures has vastly increased insurance costs, to the extent that in some cases launch and insurance costs together reach the cost of the payload. Reliability and insurance arrangements could therefore be crucial factors in the future, if launcher supplies outstrip demand.

Ariane has been able to compete with the Shuttle because of its precision, its less complex procedure for planning and integration of payloads and its lower prices, together with an aggressive market strategy. However, there used to be no third competitor, a situation that has dramatically changed. New ELVs are under development in the United States; the USSR and China have entered the launch market; and Japan plans to produce a competitive launcher. Customers will no doubt be faced with an array of tempting terms for launch and insurance. In this milieu the competitiveness of European launchers will be of paramount importance, and the ability to attract foreign customers as well as to keep European loyalties will be sorely tested. To be cost-effective Ariane 5 almost certainly needs a significant export market and, on ESA estimates, a minimum of six launches per year.

New transportation vehicles
The forecast increase in space activities and long-term launch requirements, and the possible shift from partially to fully re-usable vehicles, present a case for new launchers to LEO (and perhaps from LEO to GEO) with a very fast turn-around time and little complexity in the preparation of payloads. Such vehicles might combine a lower cost per kilogram in orbit; a potential for cargo recovery; and manned capability. Several designs are under investigation in France, Germany, Japan, the United States and the United Kingdom. Preliminary work has commenced in Europe on Sänger, a German project, and Hotol, a British project. These vehicles are intended to be re-usable; to operate like an air liner; to contain no expendable parts (apart from fuel); and to be capable of extended operation with minimal ground support and facilities. They should be able to take off from a conventional runway.

Such vehicles would have many advantages, apart from the projected low cost of access to outer space. They would allow routine access into and out of the atmosphere, and thus rapidity and flexibility for low orbit missions. Some people have gone further and suggested that they may also provide hypersonic air services between far-flung destinations on Earth. For military purposes there is the possibility of reconnaissance and other missions. In the United States the spaceplane is viewed as potentially offering both low-cost access to space and a superior vehicle for all long-haul transportation.

No design for a spaceplane can be achieved without major advances in the propulsion systems, materials structures, computer hardware and software, and other technologies. These developments straddle traditional disciplines and require new skills, since such vehicles are neither aircraft nor spacecraft. Their development will be technically demanding, and initial costs may be very high, perhaps 4–6 billion EAU over 10 years; but the potential long-term benefits are too significant to ignore. Hermes will provide some knowledge on hypersonic technology, but it will not help with the horizontal take-off and air-breathing engine technologies that are essential to the next generation of launchers.

Satellites
Increased interest in the potential of space has stimulated the

development of large numbers of different types of satellite. Since the first satellite was launched in 1957, over 3,500 have been placed in orbit. Technological developments, as well as experience in their use, have generated great variations in the complexity and size of satellites, not least in those developed by European industry.

The necessarily long lead-times mean that many satellites that will be deployed over the next decade are already in the design or production phase. For some satellite systems there will be just minor changes to versions already developed. For other applications new types of satellite will be introduced, particularly for mobile communications. Of great importance will be the development of a data-relay satellite system (ideally three satellites) capable of relaying data in a permanent or semi-permanent mode to and from stations, vehicles and platforms orbiting at altitudes below GEO. This will allow continuous contact with a space station or manned vehicle and allow data from Earth observation satellites to be received on a more timely and secure basis.

The costs of a data-relay system for Europe are a matter for speculation. ESA's estimate is 700 million EAU for DRS-1 at an operational minimum of two satellites for 1996–7. However, European industry's estimate is in the order of 900 million EAU. It is not yet clear that the traffic demand would warrant a wholly owned European system. A possible option, which might be more cost-effective, would be to join Japan and the United States in developing a global system.

For some operations it is more cost-effective to use a single large satellite or platform – instead of a number of smaller satellites – which might also carry multi-mission platforms. Such a platform can, for example, combine into a single polar orbiting platform, with sensors associated with different small Earth observation satellites. Eurospace has costed this option at some 700 million EAU for a ten-year operating lifetime, with servicing by an orbiter such as the Shuttle or Hermes. There are many technical and economic advantages to be derived from such a polar platform.

Over the next decade some communications satellites will be larger and more complex and have significant increases in radiated power, thus allowing smaller receiving antennas to be used. Olympus will be the first such European satellite (built at a cost of some 600 million EAU) and will reach much of Europe with its powerful beam, thereby making possible a truly pan-European television service. Intelsat 6 and Eutelsat 2 satellites will follow this trend. Smaller antennas and lower costs should stimulate demand for further satellite communication services.

ESA has allocated some 1,660 million EAU over the next decade towards research and development in advanced techniques to keep Europe in the forefront of this technology. Expected developments include on-board switching and satellite clusters with optical links integrating the fixed, broadcast and mobile services. However, not all of these developments will necessarily have commercial application. The emphasis is to be focused on the needs of the users through improved integration of space and terrestrial systems. It should also be noted that subsequent generations of Comsats may be smaller and less complex.

Satellites for security purposes would use many of the same technologies, as is the case with those few military satellites already developed in Europe. However, any moves to enhance European capabilities in this domain would require further investment in technologies and systems to perform precise security tasks, for example with photographic, microwave and electronic reconnaissance satellites. For many of these technologies Europe is currently dependent on US suppliers.

Space station

A space station is a durable infrastructure providing power, storage, docking capabilities and, if manned, life support, as well as residential and working space. This can be achieved in several different ways. The USSR has operated space stations with human crews for over a decade.

A space station allows sophisticated experiments in life and material sciences; storage facilities for fuel and other supplies; repair and maintenance of satellites and platforms; and more efficient staging of voyages to higher orbits and to the Moon, planets and deep space. In conjunction with other existing and projected facilities, such as a cargo-recovery vehicle or a data-relay satellite, new space services become possible.

As indicated in an earlier section of this report, space stations can be operated by various combinations of robotics and human crew. The necessary range of automated systems is not yet available, so at least initially some type of human presence is required. And for some tasks human crews are essential, albeit costly.

The decision to acquire new space assets of this kind represents a quantum jump within a space programme and necessarily involves the commitment of major resources, technological as well as financial. It would also have a big impact on the overall direction of future space activities. Europe has responded favourably to the American invitation to participate in an international space station, along with Japan. Indeed, Europe has already acquired some relevant experience with Spacelab. This pressurized module was an ESA programme designed, funded and developed as a European manned element in the American STS programme at a cost of 1,000 million EAU over a period of ten years. Spacelab's performance and its use as a tool for experimentation in a variety of science and technology applications have been demonstrated in the three flights of the first module since 1983. Spacelab is totally dependent on the Shuttle for transport to and from space. The second module, delivered in 1985, has not yet flown. In September 1986 Nasa announced that over the next ten years there would be only three, not fifteen, Spacelab flights, a great disappointment to the Europeans. This decision resulted from changing American priorities in favour of military missions, and clearly demonstrated the penalties of dependence on the US.

Experience with Spacelab, though limited, has shown the usefulness of deploying an unmanned platform for certain types of experimentation. This in turn has spawned the Eureca free-flier programme, whereby a platform carrying experiments can be placed into orbit and, after a period of about six months, recovered and returned to Earth. It is then refurbished and re-used. Eureca is dependent on the Shuttle for launch and retrieval services, a dependence which Hermes would remove only to the extent that it can take over Eureca's functions.

The Columbus programme is directed at European participation in the US-initiated international space station, but would pave the way for an independent European capability. (See Figure 8.) The structure of Columbus draws on Spacelab, but is not yet fully established. The ESA ministerial meeting in 1985 approved the outline programme and set a budget of 2,600 million EAU up to 1995, including a three-year period of operation. A new estimate, based on industrial studies, now puts the development of the Columbus programme at 3,611 million EAU, at 1986 exchange rates. The elements of this programme are a pressurized attached module; a man-tended free flyer (MTFF); a polar platform; and an enhanced Eureca. The name Columbus was chosen at a time of optimistic assessments that construction in space would start in 1992, the quincentenary of Columbus' voyage.

Quite what the European components and functions within this international space station will be depends on the outcome of negotiations currently under way. ESA and its members are keen to operate a space laboratory, whether attached to the space station or in a free-flying mode, for the conduct of material and life science experiments; and to include a European polar platform with a co-orbiting unmanned platform (the enhanced Eureca). Negotiations are in train with the United States over the jurisdiction, ownership and control of the space station. Until these issues have been resolved, the level and status of European involvement is uncertain, since European participation will need to reflect European interests. In so large a venture asymmetric financial contributions are bound to generate keen bargaining over the relative shares of material benefits and control.

Europe does not currently have the all-round capability to develop an independent space station, nor will it have such a capability for some time to come, without Ariane 5. Europe lacks a launcher capable of carrying space station modules; a manned vehicle to assist in construction; supporting automata; and a cargo-recovery system. As long as these are not available, the Europeans will be dependent on the United States. The compensating benefits would be of two kinds. First, the Europeans would acquire experience and know-how which could then be drawn on if the decision were taken to develop a European space station. Second, there would be European access to facilities for the conduct of life and material sciences experiments, as well as the use of the programme for various other applications. These policy issues are discussed in Chapter 8.

A space station is expensive. The original American estimate of about $8 billion is already much too low; it will cost a good deal more. Apart from the considerable capital costs, the operating costs will be very high. The additional costs of the Shuttle might be as much as $350 million per flight, if American policy to recover a return closer to the full costs is implemented.

The investment costs will be incurred well before any economic returns can be reaped, and will have to be borne by governments. But early involvement of users in space station activities may be a prerequisite for balancing the infrastructure with the capacity to use it. This may require the inclusion of special provisions oriented towards the private sector.

People and robotics

In planning a new generation of space programmes, Europeans must address the question of what exactly is involved in seeking autonomy in manned space flight. The answer is crucial in determining the level and distribution of resources, and also in setting the performance and safety standards for space systems. Europe has already developed substantial know-how in manned space flight through collaboration with Nasa in developing Spacelab, still the only manned payload for the US Shuttle. The development of Spacelab has helped to build up a European ground infrastructure to train European astronauts and to control missions. The first European missions, involving European astronauts – still in cooperation with Nasa – have shown the public, politicians and policy-makers that manned space flight is a key element of the space capabilities of a nation or, in our case, of Europe.

But it is not only that people in space have a symbolic and a political value; human crews can perform operational tasks, and thus provide an important capability that is necessary for the effective utilization of space. As other sections in this report show, space provides a large potential both for the application of many technologies and for scientific research. The opportunities to exploit this potential strongly depend on two factors which will drive the concepts of future space systems: first, the reduction of transportation costs and, second, the reduction of operational costs.

One way to achieve the first is to acquire fully re-usable manned and unmanned transportation systems. Achieving the second requires the availability of in-orbit facilities for repair, maintenance, servicing and payload exchange, as well as in-orbit construction. Such operations require an infrastructure that can carry permanent or visiting human crews. The economic viability of both will largely depend on an optimal sharing of operational tasks between people and robots. (See Table 9.)

The capabilities of people and robotics

In industrial operations on Earth, there is a developing trend towards replacing humans with robotic systems whenever the latter can perform tasks more economically or to a better quality. Such tasks consist of simple generic manipulation in a predefined sequence. A robotic system is able to adapt, even improve on, the abilities of a worker doing repetitive tasks, while more delicate tasks, such as reasoning, planning and trouble-shooting, are performed by people. The crucial advantages of people are their flexibility in adapting to new tasks or unknown situations, their intelligence and innovative capability in solving very different problems, their mobility and excellent perception, and their wide-ranging physical dexterity. Humans are capable of integrating new and diverse information so as to arrive at new or alternative solutions to any problems which arise. A routine operational sequence may be projected in detail, or the result of scientific experiments may be expected in advance, but not all occurrences, opportunities and even findings can be anticipated.

Hence people in space can recognize and analyse problems as they arise and, if necessary, redefine an operational procedure or experiment to obtain a controlled influence on the results. A human in space may perform a wide variety of tasks with very different objectives; a mission specialist trained to perform or operate specific experiments may also be able to perform maintenance, repair or assembly tasks. Any limitations do not depend on human characteristics in general, but flow from the individual's personal training and assigned task allocation. People operating in space can interact and discuss with the scientists or mission specialists on ground, and thus do more than act as a routine operator, who can be replaced effectively by a robotic system. Tasks which often change their sequence or character or are hard to predefine are an obvious domain for human crew.

Another major advantage is that people have a unique capability to perform diagnoses, to learn, and to acquire and interpret multisensory information. People can recognize complex patterns and extract relevant information from scenes observed from new viewing angles or distorted by a noisy background. They generally also have the capability to assess the likely overall results of an operation. This unique feature makes it impossible to dispense with people in operating space systems, if we take into account the current state-of-the-art of robotic systems.

But of course human crews have some disadvantages and impose constraints which have to be taken fully into account. In short, these comprise the medical health issues (radiation, microgravity, environment); limited physical strength; the psychological dimension (fatigue, stress, attention, motivation); safety considerations; and, of course, the costs.

As for robotic systems, three major categories are relevant: teleoperated, hybrid and autonomous systems. These three categories represent an increasing order of versatility, capability and independence.

Teleoperator systems, such as the Shuttle RMS, represent the current state-of-the-art in robotics for space applications. They are usually multi-jointed, single-arm manipulator systems. The operation of these teleoperator systems hardly depends at all on the 'man-in-the-loop' for real-time analysis of the non-structured environment, decision-making and control of the manipulator. Teleoperator systems today have limited capabilities with regard to dexterity, versatility, perception and diagnosis systems. However, the enhancement of the perception systems and feedback of information to the human operator, as well as of the dexterity of the manipulator arm, will give the ground operator the feeling of being present at the worksite. This enhancement of the teleoperation mode is called telepresence.

Hybrid robot systems will provide increased autonomy wherever simple and repetitive subtasks can be preprogrammed and assigned to automatic operation. This will relieve the human operator of routine tasks so that he or she can concentrate on high-level tasks. The operator still has to control the total procedure and give high-level commands to the robotic systems, using an advanced teleoperator work-station as the interface.

The operation of fully autonomous robots will not require permanent supervision by a human operator. Autonomous robots will be able to adapt to a wide variety of tasks, since they will have at their disposal a broad range of embedded extendable expert systems and methods for artificial intelligence (AI) systems with which they will diagnose, decide and optimize operations in unfamiliar situations.

The problem today is the limited autonomy of robotic systems. Those we have are capable of reacting to an individual situation which is well predefined, but cannot adapt independently to unknown events. In this case a human operator has to analyse the new situation at the remote work-station, which is equipped with a multiplicity of information systems such as graphic and data displays. Robotic systems in the future will have at their disposal learning capabilities which will support the extension of a knowledge and diagnosis system.

A solution to the problem of the unknown will be the extensive use of data bases for operational planning and of more sophisticated computer data on the space elements. The use of these categories of data bases will enhance robots' capabilities and will provide an important basis for achieving systems autonomy. Robots will be self-adapting to unknown environments and eventually perform complex tasks, once they have the means for scene analysis, reasoning and mission planning.

Teleoperation will be one valuable means of performing operations in orbit, though the human factors in telerobotics operation have to be extensively investigated. Efforts are already under way to improve information feedback systems, such as predictive stereoscopic and graphic displays at the work-station, and simulators for planning and comparison with real operations in orbit. It will not be possible to separate completely the 'man-in-the-loop' from the teleoperator system (that is, with a human operator on the ground and the teleoperator on an unmanned space system), mainly because the transfer of information between space and ground is subject to delays.

Allocating tasks to people and robotics

In determining the allocation of tasks between people and robotics in the future we have to take the following into account: technological developments in robotics; robotic capabilities; the complex character of the tasks; the orbit location of the worksite; the availability of manned transport and launch vehicles; and the in-orbit infrastructure. People will also be involved in in-orbit operations if teleoperation modes are applied. It is not possible to identify quantitatively absolute figures to govern the choice, but we can make general statements about the allocation of tasks between people and robotics depending on operational modes, trends in the development of robotic technology, task categories and different orbits.

Table 9 illustrates the possible distribution of tasks between people and robotics. The involvement of people will shift from manual, planning, control and supervision tasks to supervision only, if robots can be developed as autonomous systems. Supervision may not even be needed continuously, in that routine tasks may be performed by robots with their own supervision systems.

Towards a European strategy

This analysis assumes that robotics will make remarkable progress in the future, especially in the area of artificial intelligence. In an optimistic scenario, it may be possible within three decades to have available autonomous robotic systems which could take over a number of tasks currently performed by human crews during both intravehicular activities (IVA) and extravehicular activities (EVA). But it has to be emphasized that people will remain of paramount importance to in-orbit operations. The efficiency of future space systems will depend on a close cooperation between people and task-oriented robotic systems, whether with people acting as decision-makers, supervisors or teleoperators, or with a human manual worker who is cooperatively supported by robotic systems.

In other words, if Europe is to engage in all those activities which are necessary for the effective use of space, it requires the skill and the special capabilities of people in space. Manned space flight is an essential part of an autonomy strategy. Without it, Europeans will always have just a fragment of the autonomous capabilities of the large space nations such as the USA and USSR. Moreover, Japan and China have already decided to develop in the long term their own manned space-flight capabilities.

ESA's long-term plan envisages two systems that will lead to autonomous manned space flight. One is Hermes, which can carry three or four astronauts to low earth orbits in order to join up with the international space station or one of its European elements, especially the MTFF. The MTFF is the second key element for achieving autonomy in orbit infrastructure, because it provides the working base for the astronauts to perform their tasks. In its first configuration the MTFF is not a permanently manned facility; it will be visited by humans only during specific servicing periods. This development strategy leaves open a European decision later on (in ten years) as to whether or not a permanently manned facility will be needed, since the technology of robotics may have developed so rapidly that the transfer of many more tasks to robots will make a permanent human role in space unnecessary. This development strategy is quite different from those of the USA and the USSR, and offers a unique way to develop European autonomy.

Ground segment

The development of the ground segment is crucial to any operations in space. Within the past decade, a number of large receiving stations have been established for Earth observation, originally under the European Earthnet programme for the reception of Landsat data. Earthnet acquires, pre-processes and distributes satellite remote-sensing images and data to receiving stations in other member states. Similar facilities have been established for other types of Earth observation satellite. To benefit from their own satellites, Europeans have had to conclude agreements with some foreign countries for the reception of data at ground stations within the latter's territory. The development of a Data Relay Satellite system would remove the need for foreign receiving stations and allow data to be received in a more timely and secure manner.

Antennas are used to receive communications from satellites. Developments in satellite technology have permitted the receiving antennas to become progressively smaller. These antennas can be located on the premises to which communications are to be sent, thus in principle reducing costs, since they obviate the need for land lines. This, coupled with the increasing range of communication services, has prompted a great increase in the ground segment market, so that it is now much larger in value terms than the space segment. For the period 1985–95 ESA estimates the total ground segment market to be in the region of 15,000–18,000 million EAU.

However, the price, character and performance of European designs have not been competitive with those from Japan and the United States. A very large part of the ground segment market in Europe has been captured by these two countries. The limitations of European industry in this sector stem partly from the fragmentation of the European market into many small markets separated by artificial barriers. The removal of these barriers, the further development of common specifications and standards and, most importantly, the opening up of public procurement would allow a single European market to be developed with the attendant benefits of large unit production. Some of these questions have long been addressed in the various ITU and satellite consortia and fora. More recently the European Commission has been instrumental in the promotion of common technical standards for the telecommunications sector, as well as in the development of an enlarged common European market.

It does not, however, follow that European industry will necessarily capture a larger share of the market either in Europe or globally. The performance capabilities of ground segment equipment manufactured by Europeans could certainly be improved, especially in relation to microelectronics and information technology. But over-sophisticated equipment is not profitable either; so a balance is required. The creation of a space infrastructure in communications is only one part of a long chain in which the multiplier effect is very significant. It would be ironical if Europe were to be independent in the construction of satellites and their launching, but did not have the independent means to use them.

The industrial infrastructure

Over a period of some 25 years or so Europe has acquired a solid industrial base in the space sector. Over 200 firms now have a primary interest in producing space systems and subsystems, with some hundreds more providing other subsystems and components. It has been estimated, for example, that 800 firms might eventually contribute to the Hermes programme. The major firms involved have solid foundations in the aeronautical and defence sectors – both traditional European strengths – and many have a role as national industrial champions, either directly through public ownership or indirectly through government contracts.

There is also an important and growing secondary industry, including the suppliers of equipment to end users; industries which are actual or potential users of the space segment; and commercial services which increasingly make use of space capabilities. ESA's activities are not the central focus for these groups, since their involvement is either with the organizations which operate space-based technologies (national PTTs, the international consortia – Intelsat, Eutelsat, Inmarsat, and so on) or with direct commercial and financial activities which happen to use space technologies.

European expenditure has been modest but also relatively cost-effective. No entirely satisfactory yardsticks exist for evaluating the return on investment, but all studies suggest that space R&D has had positive productivity effects and brought substantial benefits to a number of industries. The growing maturity of the European space industry is reflected in the increasing share of the commercial market (and not just government and ESA contracts) in the turnover of the industry, from an estimated 3 per cent in 1977 to 15 per cent in 1983. A 30 per cent share is forecast for 1988. Much of this has been due to launch contracts for Ariane and to earnings from communications satellites involving consortia with American manufacturers.

The future of these markets is not secure, given the intense, and subsidized, competition from launchers and rapid developments in fibre optic technology. Some markets have been slow to materialize: DBS and remote sensing are both examples. The ground segment market is subject to fierce competition, with the US and Japan taking 80 per cent of the international market. In addition, the European economies have won a return in the form of positive inflows on the balance of payments. Eurospace estimated these at 285 million EAU per annum over the period 1980–4, together with the tax revenue from the producers.

The personnel directly employed in the European space industry totalled some 21,000 in 1983, with a further 10,000 in institutions, consultancies and universities. Another 18,000 or so are employed in secondary industries associated with space technologies. The space industry employs highly qualified personnel; the proportion of engineers and university graduates is greater than 40 per cent of the total. The rate of growth in employment was some 7 per cent per annum between 1977 and 1983, but this is now tailing off. Indeed, delays in current ESA contracts are making Eurospace very anxious that the level of the workforce may drop if programmes are not brought forward.

The increased budgets agreed by ESA in 1985 had led analysts to suggest that there would eventually be a demand for 44,000 personnel in primary institutions and industries, and 29,000 in the secondary industries. Europe has many fewer space specialists than the United States; Eurospace suggests as few as 12 per cent of the US total. Surveys of European industry also indicate that there are serious shortages of some specialists. Expensive training schemes have had to be developed so that qualified engineers can acquire the further five years' training necessary.

Europe has not yet developed a space industry policy, although ESA has recognized that its programmes both depend and have an impact on the space industry. ESA's mandatory programmes helped to consolidate three industrial consortia – Mesh, Cosmos and Star – which emerged in the early 1960s as groupings of companies in the aerospace sector from different European countries. These consortia continue to function in contracting for ESA's scientific programmes, but the patterns of tendering for ESA's optional programmes, for international contracts and within individual European countries are quite different. The strengths and weaknesses of this pattern of industrial collaboration are discussed in Chapter 7.

ESA's second main impact on the industry has been through the rule of 'fair industrial returns' or 'juste retour', aimed at ensuring an equitable spread of national industrial participation across a range of ESA programmes. The results are set out in Table 5. Originally conceived as a necessary and valuable tool for distributing industrial benefits among ESA's members, this system has come under some criticism, and its consequences are also discussed in Chapter 7.

The third strand of ESA's approach has been to hand on the responsibility for the commercialization of space technologies. ESA has defined its role as providing the initial impetus from its R&D, which is then picked up by commercially oriented ventures, and either marketed as a particular product, for example by Arianespace, or operated as a specific service, for example by Eumetsat.

Finally we should note that Eurospace, the Paris-based representative grouping of European space companies, has played to some effect the two roles typical of comparable industrial organizations. It has built bridges among the companies and with ESA in order to channel views and test opinion; and it has developed considerable technical expertise and evaluative skills which help to ensure that industrial considerations are taken into account in ESA's planning and management processes.

Space law

Outer space is an international commons outside the sovereign control of any state. The laws determining its use are developed primarily in the UN by Copuos, which has a current membership of over 50 states. Within Copuos the status of ESA is restricted to that of observer, but ESA members are full and effective members of the Committee. Decisions in Copuos are made by consensus rather than by majority vote.

The principal instrument of space law is the Outer Space Treaty of 1967. This sets out the general principles for the use of outer space, but does not deal with specific applications of space technologies, most of which were not developed when the principles of the treaty were first agreed. The treaty stipulates that outer space, unlike air space, is not subject to national appropriation and is free for use by all states in accordance with international law. Three additional agreements cover the return and rescue of astronauts and objects launched into space, the liability for damage caused by space objects, and the registration of objects launched into space. This last agreement stipulates that states must register information on the space objects for which they are responsible, including their general function and orbital parameters. However, there have been many instances when the information provided by the launching state has been unsatisfactory with regard to the function of the space object, especially in the case of military satellites.

The Outer Space Treaty prohibits the stationing of nuclear weapons and other weapons of 'mass destruction' in space, but does not discuss the militarization of space or consider other types of weapon. Military activities have been carried out by some states and considered acceptable in so far as they have not involved the use of any form of weapon and do not breach international agreements on non-proliferation. They are therefore regarded as a 'peaceful' use of outer space. Some of these activities, such as the use of 'national technical means' (NTM) of verification, have been accorded a special status in bilateral arrangements between the superpowers. In 1981 and 1983 the Soviet Union proposed draft treaties prohibiting the stationing of all weapons in outer space, but these have met with several obstacles, among which is the problem of verification. A treaty of this kind would probably be multilateral, but Europe has not had an important role in the discussions to date.

It has been less easy to secure international agreement to regulate those activities that have significant economic and national security linkages. The European countries have refused to support the UN General Assembly resolution requiring the prior consent of the receiving state as a precondition for the use of direct broadcasting satellites. Europeans have considered this to be in violation of the principle of the free flow of information. There are also great variations among national laws pertaining to matters such as advertising and decency, and even in a European context some measure of harmonization and agreement is now considered necessary. Accordingly efforts to achieve this have been undertaken by a number of European institutions, including the European Community, the European Broadcasting Union and the Council of Europe. So far progress has been slow.

The expected increased participation of the private sector in space activities may raise some difficulties. The existing rules state that the activities of non-governmental entities require authorization and continuing supervision by the appropriate party to the treaty. Hence private unregulated activity in space is prohibited, and some measure of licensing and government regulation remains necessary. Three problems arise. First, where space activities involve non-governmental agencies from more than one country, some transnational regulation would be necessary. Second, the move towards privatization, so far more advanced in the UK than any in other European country, makes it harder to maintain regulation based on designated signatories who may have to choose whether and how to license a competitor. Third, the deregulation increasingly practised to enhance competition and entrepreneurship is a powerful constraint on international regulation.

The development of a multinational space station and the resulting space commerce raise legal issues not yet fully provided for by existing treaties. In the case of a national space station, it will be important to establish whether it would be desirable or viable to apply terrestrial laws to space activities or to introduce the required modifications and innovations necessary to ensure that individuals living and working in space are adequately protected. In a multinational venture such as the US suggestion for an international space station, there is the complication of the determination of jurisdiction or the right of a state to prescribe and enforce its rules of law. This is necessary to resolve such issues as intellectual property rights, product liability and export law. The question of jurisdiction will be determined by the terms of the relevant space station agreement, and there have been some divergences on this matter in negotiations between the United States and Europe. The ESA Council of Ministers declared in 1985 that a fundamental objective of European participation in the space station would be responsibility for the design, development and management of those modules built by Europe. On the other hand, the United States considers that its technological and economic leadership in the venture requires that it should have jurisdiction.

ESA members, in espousing the goal of autonomy, have embarked on a new phase of large, complex and expensive projects which may also be flanked by a military space programme. This new phase of activities will of necessity entail managerial and organizational systems that will be of much greater complexity than anything previously experienced. The international context, both political and economic, is also evolving rapidly. New international regimes will be necessary, and Europeans will need to consider carefully how to maximize their influence on them.

Part III
TOWARDS A COMMON SPACE POLICY

7

THE BALANCE-SHEET

Western Europe has managed, in a relatively short time and with limited means, to achieve a number of impressive results in space technology and the space industry. It ranks as the third presence in space. However, despite these notable achievements, essentially in the field of space science and in the area of launchers, European space efforts fall short of a truly effective joint policy. Nor are they commensurate with the kinds of technological, industrial and strategic stakes involved in space activities or with the human and economic potential available in Europe. This calls for a closer look at European strengths and weaknesses in this area, given that Europe is not held back by scientific obstacles or intrinsic inferiority. The problems are those of purpose and of the best use of resources.

In financial, technological, industrial and human terms, Western Europe's resources are on the same scale as those of the two largest space powers: the United States and the Soviet Union. And yet the gap between Europe's space programme and those of the two space giants remains considerable. Moreover, Europe is under increasing challenge from Japan. Significantly, the gap between European and American investments in space (around 1.8 billion EAU and nearly 20 billion EAU respectively in 1985) gives a ratio of less than 1 to 10.

Yet with this modest investment Europe has managed to master the key space technologies, and now possesses the modern industrial infrastructures required to design, construct and exploit most space systems. In addition, over the years European firms have gradually acquired substantial experience of working together. Organizational as well as personal relations have been built between many companies throughout Europe in the course of carrying out joint programmes. All this has contributed to the emergence of a vigorous European 'space lobby' at the industrial level.

ESA's contribution to the development of a collective European space capability has been fundamental. A unique example of a successful multinational space organization, ESA has provided the infrastructure for space collaboration among European states. It has fostered the emergence of a European 'space spirit' within the space community. Six European astronauts have been into space: two from France, three from Germany and one from the Netherlands. By formulating options jointly and exchanging knowledge and experience, the space science community in Europe has generated a momentum capable of persuading governments to adopt programmes at the European level. And by supervising the implementation of these programmes, ESA has also developed impressive managerial skills within a relatively efficient and integrated framework: it awards between 500 and 600 contracts per year to industrial firms in ESA countries and distributes the technological risks and benefits among member states.

Meanwhile, Europe's human resources engaged in the space industry and R&D are also impressive. European manpower is certainly comparable in quality to that of the other space countries. However, Europe still lags behind the US and the USSR in the overall number of qualified personnel. In the United States, there are some 250,000 people employed in space activities, whereas Europe, with around 30,000, has only about 12 per cent of the US number in spite of having a much larger total population.

Fragmentation persists

Europe's relative success in space from a limited financial and human base is, however, no cause for complacency. The resource shortage, compared with the dominant space powers, is in itself a fundamental weakness which has major implications in the long run for Europe's technological and economic strength, as well as for its security. Financial allocations, in a time of heavily constrained budgets and dependence on limited public support, tend to promote 'national' ventures and 'national' perceptions of what should be done in space. Differences in the absolute size of national space budgets are striking. These budgets are dispersed between various ministries and agencies, with military and civilian expenditures usually kept separate, and each with their own contracting terms. The unpredictability and slowness of commercial returns over the medium to long term makes it hard as yet to attract high levels of investment from private financial and industrial sources.

But this basic handicap is further aggravated by the persistent fragmentation of effort at both the political and the industrial level. The result is that Western Europe's stretched resources are deployed in a far from optimal fashion. While other space powers, such as the United States, the Soviet Union or Japan, have founded their space policies on an essentially national basis, European space activities have been carried out within a double framework. Most European countries have been involved in collaborative space endeavours, first in ELDO/ESRO, then, since the mid-1970s, within ESA, whose famous initial 'package deal' was most persuasive. Simultaneously, however, some European states have built up national space programmes to serve their specific national interests. ESA's programmes depend on the national facilities of its members. Decisions do not rest on a single and coherent approach within a supranational framework. European achievements in space are therefore the result of a compromise, not always an easy one, between national and collaborative options.

Disparities within Europe

A further complication is the unavoidable disparity between the larger and the smaller European countries. The former (i.e., France, the Federal Republic of Germany, Italy and the United Kingdom), with larger financial and economic capabilities, have chosen to develop their own national programmes, to an extent independently from the ESA framework. In each case attitudes towards space have been shaped by specific national and foreign policy ambitions or constraints. France, for example, has sought greater autonomy, while Germany and the UK have sought to maintain a close relationship with their American ally as a key dimension in their defence policies.

The smaller European partners may have an important capability in space exploration as well as an impressive industrial infrastructure (as in the Netherlands or Belgium), but they lack the budgetary and institutional means to succeed individually. With the sole exception of Sweden, they have therefore concentrated the bulk of their space effort on the collaborative option, by participating actively in ESA-sponsored programmes and by developing niche production. The result is a spectrum in which the national space expenditures of some countries, such as France, Sweden or, until recently, West Germany, are greater than their contributions to ESA, while Ireland has no national space programme at all. (See Figure 2.)

Burden-sharing through ESA

These important discrepancies have meant that ESA's attempts to harmonize national programmes and to guarantee as much equality as possible between member states have not always been successful. Two novel rules were developed within ESA to prevent this gap between the leading European countries and their less well-endowed partners from growing: namely, the distinction between mandatory and optional programmes, and the principle of fair industrial returns on investment. Despite these rules the gap, if anything, has actually widened.

Member states contribute to ESA's mandatory activities on the basis of their average GNP calculated over the past three years. This ensures both the stability of this part of the budget and a parity of decision for member states as regards the mandatory scientific projects. But many of ESA's programmes are optional: the countries participate and contribute according to their policy or industrial interests and their national priorities. Significantly, the major achievements of ESA in the field of launchers and operational systems belong to this category of 'à la carte' programmes. The mandatory programmes now account for only some 15 per cent of ESA's work.

These mechanisms have produced a situation in which the weightier members (in terms of industrial and technological capabilities) become the obvious 'project leaders' of crucial, but optional, programmes, thereby further increasing discrepancies among European countries. Indeed, the four major contributors to ESA (France, West Germany, Italy and the United Kingdom) together account for around 80 per cent of ESA's budget, while some of the other partners have difficulties on occasion in honouring their limited budgetary commitments. (See Figure 3.)

Fair returns

This feature should have been offset by the ESA rule of fair returns, whereby a country's percentage share of the total value of contracts placed under the mandatory programmes should correspond to its percentage financial contribution to a given programme. (See Table 5.) The industrial 'return coefficient', both as an average and individually, has succeeded in spreading the benefits of ESA contracts. But this outcome has been reached only by difficult and time-consuming negotiations that continue to prevent the smooth and harmonious integration of European and national space endeavours.

The fair returns policy is open to other criticisms. First, there is some inflexibility in that fair returns are calculated for each phase of a project rather than spread across projects, in spite of ESA's endeavours to compensate across 'packages'. Second, the cushion of guaranteed contract shares to some industrial participants removes some of the pressures for rationalization of the European space industry. Third, in practice the fair returns to smaller countries tend to be awarded through contracts to their smaller companies. Although this helps to encourage effective niche suppliers in those countries, it impedes access to contracts for smaller hi-tech companies as they emerge in the larger countries. The new CoSpace consortium is an attempt to remedy this.

A fourth problem relates to economies of scale. The smaller companies which can benefit in smaller countries are in practice more often suppliers of components than producers of subsystems, because the value of the latter's share (perhaps 15 per cent of a total contract) would generally exceed the fair return. In the Netherlands Philips has virtually left the space segment because there is not enough headroom for both it and Fokker, which draws in 60 to 70 per cent of the Dutch industrial return. All this impedes economies of scale for small companies. Finally, the large companies from the large countries to an extent win disproportionately high industrial returns as prime contractors, and the truth of the matter is that companies are sometimes chosen for political rather than commercial reasons, or because it is 'their turn'.

ESA's approach to contracts is a further complication. In its attempts to keep down the costs of already expensive projects, ESA is highly, but sometimes too, demanding in squeezing the profit margins of contractors. In their concern for value for money and exacting standards, ESA managers sometimes set very onerous and overspecific conditions and take too long to make decisions. The costs of tendering alone are sometimes a disincentive to bids. And of course the multilingual and multinational complications remain real. Similar problems arise with tendering for other international contracts, since the prolonged bidding procedures take place for a small number of expensive contracts in a context in which competition is politically constrained.

Public attitudes

Europe also suffers from persistent problems arising from differing perceptions and misunderstandings among ESA partners. For example, while some countries tend to criticize France for its overly 'nationalistic' approach to joint European programmes, the dominant perception in France is that many successful European space activities would not have been possible without the French contribution and drive.

More importantly, perhaps, the fragmentation of European space activities in a politically fragmented Europe is reflected in the absence of broad public support for a European presence in space. This sometimes shades into a wider public disenchantment with high-technology ventures, both military (SDI) and civilian (nuclear power). The result has been a vicious circle. On the one hand, neither the limited and fragmented national programmes nor the equally limited ESA projects have been able to generate on a European scale the kind of public support necessary to convince both tax payers and legislative authorities to increase their investment in space. And yet without the new resources required to produce a qualitative jump in European ambitions, the various programmes are likely to stagnate at their present levels, and thus fail to produce the kind of highly symbolic and ambitious project which could unite the Europeans in a common vision. There has after all been no European equivalent to the Apollo programme. This handicap is especially relevant at a moment when the Europeans face important decisions about two large new ventures: Hermes and the space station.

Consequently, where public support does exist, for example in France, it is still largely associated with mainly national activities and goals (including in the political-strategic area) rather than with 'Europe' as a whole. This further reinforces the fragmented character of the various national activities. Meanwhile, elsewhere in Europe, public opinion tends to view space as an esoteric field which should be left to the superpowers or in which, at best, Europe should simply follow in their shadow.

Civilian and security options

Political and industrial fragmentation has been most obvious in the use of space for defence and security. Here there has been, thus far, virtually no European cooperation, except partially through Nato. ESA has limited itself to the 'peaceful uses of space', an important touchstone for its neutral members, which do not belong to Nato. France does not currently belong to Nato's integrated military structure and therefore is not tied into the Nato system of communications satellites. Furthermore, bilateral collaboration may be a counter-attraction, as in the US-UK case, which removes what might otherwise be a powerful impetus for European collaboration.

Bilateral cooperation in Europe itself is not always easy. The failure of the proposal for a joint Franco-German surveillance satellite is a case in point. There were differences over the technologies to be chosen, over the distribution of costs and production shares, and over the operational nature of the satellite. The Germans had the impression that they were being asked to pay for a 'pre-cooked' French project. The French had the impression that they were dealing with German self-imposed (or US-imposed) political limitations. Although such disputes between France and Germany do not necessarily prejudice European cooperation as a whole, they certainly complicate it.

This fragmentation has major implications, not just for Europe's long-term security interests, but also for the overall technological strength and volume of European space efforts. For it should be kept in mind that in the US and the USSR, military applications have acted as a primary driving force for civilian space programmes. By contrast, Europe has not been able to generate the civilian benefits that often result from military R&D and production in terms of dedicated budgets, dual technologies in which the R&D costs can be spread, the volume of activity and some economies of scale. Only in France has the spin-off been significant. Yet this outcome is paradoxical in so far as many of the European space firms are also defence contractors, and would presumably welcome the opportunity to foster more dual use with military space requirements.

Strategic doctrines

For the superpowers, the essential importance of a space-based dimension to their respective force structures flows from their strategic nuclear confrontation and military capabilities on a global scale. In Europe only France and, to a lesser extent, the UK have significant military space programmes. But there is as yet no explicit strategic consensus upon which the common requirements and precise mission for an integrated military space component could be built. The military doctrines and strategic postures of the different European countries remain divergent, largely because of the wider geostrategic considerations inherent in the political-strategic order in Europe since World War II. This situation is unlikely to be radically modified overnight.

Significantly, although Europe's two nuclear powers – France and the UK – have each developed independent military programmes for space communications (the British Skynet and the French Syracuse), they have done so quite separately. In 1993 France will launch a military reconnaissance satellite, Helios, but again after failing to convince West Germany to join that venture. Although Italy and Spain recently decided to play a modest part in it, the project still falls short of being genuinely multilateral. The essentially national character of these military activities has aggravated the fragmentation of European space efforts, especially given the extremely high cost of military programmes. In the case of France, for instance, the rapidly developing military effort is expected to produce a driving impetus for space programmes as a whole, but it will necessarily put a strain on other commitments. By 1995 France's military space budget might exceed its annual contribution to ESA.

Pressures for change

Nevertheless, it is clear that in military space activities autonomy, however it is defined, is not an achievable goal for individual European countries, because the costs are prohibitive. For both financial and strategic reasons, European collaboration in military space activities could play an important role in strengthening Europe's global defence capability and in diminishing its dependence on the USA. Europe's existing space assets have the potential for security applications on a collective basis. There is already some dual use, in that some European civilian satellites have capacity reserved for military use. Technologies either achieved or under development provide Europeans with the means to operate a reconnaissance system for arms control and verification and crisis-monitoring, or to support collectively the deployment of military forces. The industrial infrastructure could fairly easily adapt. The political context is evolving fast and could well promote acceptance of shared European needs to be pursued through Europe's different institutional frameworks.

European strengths and weaknesses

If we take a closer look at what Europe has so far achieved in space, a mixed picture emerges, revealing different strengths and weaknesses from sector to sector. In space science and launchers, Europe's successes are remarkable, but the results are less satisfactory across the range of applications satellites and even worse in the ground segment.

Science

ESA's scientific programme has been one of the foundations of European cooperation in space. The development of scientific missions was the initial goal of ESA and was based on a wide consensus among the member states that has not so far been questioned. ESA's scientific budget, linked to GNP shares, has been very stable in comparison with both other European space programmes and the cognate investments of other space powers, notably the United States.

As a result, Europe has been able to achieve and maintain a real strength in science on a world scale, with an eminent scientific community and industrial capabilities for the development of highly sophisticated platforms and instruments. Between 1968 and 1986, 15 scientific spacecraft were launched, ranging from simple payloads for studies of the magnetosphere to ESA's X-ray observatory satellite, Exosat. The recent success of Giotto demonstrated that European space science now stands at the forefront of scientific research. Moreover, European involvement in projects such as the joint ESA/Nasa Spacelab and Hubble space telescope, and French collaboration with Soviet programmes, has enhanced European capabilities and expertise.

These achievements stem from Europe's success in allocating financial and human resources prudently, but also selectively, to key projects of considerable scientific yield, a potentially crucial point for the future of the European space programme as a whole. Clearly, however, the scientific challenge is by no means over. The very successes of the past have widened our research horizons. These now require a broader range of resources, including substantial new flight opportunities. The trend of space research is towards the use of large multi-purpose facilities that will be able to supply a permanent flow of scientific data. All this adds up to major new challenges over the next twenty years for European space cooperation, challenges as great, if not greater, than those made during the pioneering years after 1964.

Launchers

In the field of launchers, Europe's achievements are also quite remarkable in terms of both production and commercialization. A relative latecomer to the launcher market, Europe has succeeded, thanks to the development of the Ariane family of ELVs, in moving closer to the two major space powers. Since the 1973 decision to initiate the Ariane programme, Europe has had the means to launch its own satellites. Despite a series of technical mishaps and delays as well as a limited production capability, Ariane now represents about 45 per cent of the world market in conventional launchers, and its launch schedule is booked up for some time ahead. It should, however, be noted that Europe cannot yet launch on demand for unexpected and time-constrained needs. The success of Ariane is linked to two positive factors. First, the European launcher, with a geographically advantageous launch site, became operational in December 1979, when there was a growing demand for launches, particularly in GTO, and especially for telecommunications satellites. Second, the European partners were able to set up Arianespace, an organization that was well adapted to market conditions.

Success is linked to the very specific nature of the launchers: the high costs and crucial requirement for technological standardization make a collaborative venture absolutely vital. This is not the case for satellites: once a country has reached a certain level of technological and industrial development, the natural step is often to go for indigenous production.

However, the decision to concentrate all the efforts on ELVs left major gaps elsewhere. For manned space flight in particular, without a re-usable orbiter Europe was completely dependent on the US. Until the Challenger accident, the operation of Spacelab was possible only through cooperation with Nasa and the Shuttle. The programme has since then been brutally stopped. But it is not just a question of maintaining the current generation of launchers. Europeans have also prudently to look towards the next generation, which will be necessary early in the next century. In the medium term a small launcher could be useful, such as the Marianne proposal by Eurospace.

Commercial pressures

Results are less satisfactory when it comes to applications satellites. As regards their production and commercialization, Europe today faces two major problems. First, it has to preserve its own home market in the face of competition from other satellite producers (for the moment, essentially the major US firms such as Hughes, RCA or Ford Aerospace). In this context, the recent Luxembourg purchase of Astra and the decision of the new British Satellite Broadcasting Consortium to accept Hughes's tender, both US-made telecommunication satellites, are setbacks. Second, Western Europe's position in external markets is still very weak: Arabsat has been a rare example of European success in marketing space products on a worldwide scale. European firms may win part or all of a major contract outside Europe perhaps just once every eighteen months.

Europe's fragility in the face of growing international competition is even more evident in the ground segment, a market of possibly greater commercial importance which also happens to be far more open than that of operational space systems. The US and Japan account for some 80 per cent of the ground segment market. Since all producers have to respect strict technical standards set up by international space-user organizations, such as Inmarsat or Intelsat, competition in this field is essentially a matter of price, financial arrangements and delivery schedules – decidedly weak points in European performance. This has already become clear in the field of large telecommunication ground stations, in which Europe has to contend with the growing capability of Japan, the world's first producer of ground receiving stations and switching systems. One telling example is the sale in 1983 by Japan's Nippon Electric to the Arab League of a ground station for the Arabsat satellite, despite a tender from Aérospatiale, the satellite's prime contractor.

To make things worse, key elements of the ground station market are only just beginning to be developed in Europe, although the imminent stimulus provided by DBS to new markets for antennas is likely to result in increasing competition between European and non-European producers. Finally, as regards ground stations for receiving remote-sensing data, Europe again lags behind – in this case, Canada and Japan.

Industrial collaboration

These weaknesses in the satellite and ground sectors are linked to a series of structural problems that affect the European space industry, as well as to the specific character of the European market for space products. For a long time, the European industrial landscape in the field of space was dominated by three consortia – Cosmos, Mesh and Star. However, this initial structure has changed significantly. The scientific programmes in which the consortia still operate have decreased in number, and other ESA programmes – in both space transportation systems and applications satellites – have been supplied by differently composed industrial groupings.

In the 1970s new European groupings were formed notably to develop Spacelab and the Meteosat satellites. Another telling example was the group established to construct L-Sat/Olympus. This group came into existence as a response by British and Italian companies to the German and French decision to build TDF-1 and TV-Sat independently (Germany and France having judged ESA's telecommunication satellite programme, adopted in 1979, to be too slow-moving). New groupings are currently being formed to prepare the Columbus and Hermes programmes.

Europe's growing involvement in the field of operational systems resulted at the industrial level in increased competition among aerospace firms for the contracts awarded within ESA's optional programmes, and in the establishment of *ad hoc* groupings precisely to supply these new programmes. In tendering for international contracts, European firms have formed alliances with American companies: BAe and Thomson CF with Hughes, Aérospatiale and MBB with Ford, Matra with TRW. These alliances have contributed to a sharpened commercial edge to the European firms. In the meantime, national procurement has been substantially supplied by national contractors, sometimes, as in Italy, organized into a national consortium. Many of the major European companies are substantially publicly owned. Only in France has competition between two prime contractors been a regular feature.

Finally, the national mergers between firms belonging to different consortia have undermined the original framework of the European space industry. At the same time, the decrease in the number and change in character of programmes adopted by ESA, together with the increase in their technological complexity and overall costs, have contributed to the breaking up of the 'historical' consortia. This picture sharply contrasts with the US industry, where the consortia are occasional, project-related and based on commercial and technical criteria.

Today, Europe's industrial scene is characterized by a growing disparity between European aerospace firms: the most competitive among them (Aérospatiale and Matra in France, MBB-Erno and Dornier in West Germany, British Aerospace and Marconi in the United Kingdom, Aeritalia and Selenia-Spazio in Italy) tend to dominate the market and become obvious 'prime contractors'. More and more frequently, these companies form joint ventures, such as Eurosatellite or Satcom International, generally with the aim of exploiting together a commercial market, and in recognition of the importance of entrenching habits of collaboration.

Obstacles to rationalization

One result of this pattern is that the division of tasks and responsibilities among European industrial firms has proved rather rigid. Space platforms are developed by companies belonging to the aeronautics sector (such as Aérospatiale, MBB and BAe), and their payloads are generally produced by firms in the telecommunications and electronics sectors (such as Alcatel-Thomson-Espace, AEG, ANT and Marconi). In the United States, the same firm is responsible for the whole product. Consequently in Europe the prime contractor usually manufactures only 30 per cent of the product value, whereas in the US the share is in the region of 80 per cent. It is, however, often the case that the US supplier subcontracts, but on a commercial basis and not by international negotiation as in Europe. Thus in America a highly concentrated national industry benefits from a large, open national market, whereas in Europe there are too many overlaps between too many national competitive units; insufficient industrial linkages take place across national borders; and the national markets are smaller and still fragmented. As a result, European firms find it more and more difficult to maintain a sufficient 'critical mass' (in terms of financial capacity, employment and R&D), in comparison with an increasingly concentrated US aerospace industry. However, the state of the US industry is changing: the combination of delays in launch opportunities and a saturation of the satellite market has produced overcapacity. US firms are consequently chasing international contracts even harder and sometimes with terms which European firms cannot reasonably match.

These problems are aggravated by a business planning cycle which is vulnerable to significant fluctuations that are linked to long lead-times and poor correlation between political decisions and industrial capacities. For example, since the costs of satellite systems have increased more rapidly than space budgets, the number of programmes has declined and the industrial firms have had to contend with an unhealthy succession of fat and lean years. Thus, today's apparent overcapacity in the European space industry might actually be a problem of underbudgeting: the big programmes decided by ESA in the mid-1970s are reaching completion, and governments have not agreed new programmes over the past few years that reach the level of industrial capacity. This situation may, however, improve in the future as the new round of programmes (Columbus, Hermes, Ariane 5) is adopted at ESA's ministerial conference scheduled for late 1987. Even so, however important these programmes may be, they account for perhaps only a quarter of the combined effort of European firms.

Market conditions

On the purchasing side, the structure of national monopolies still largely dominates the organization of European markets for satellites (especially in telecommunications). The PTTs are the key players in the relevant procurement and operating organizations, both international and European – Intelsat, Inmarsat and Eutelsat. In West Germany, for example, resistance to the loosening of the Bundespost's monopoly runs deep, although it is recognized that new services will have to be provided at internationally competitive rates. A recent comparison, published in the report of a governmentappointed commission, showed that tariffs for a few services may be as much as 15 times as expensive as their equivalents in Britain or the US. That this is so even in a relatively liberal country demonstrates the scale of the European problem.

European industries have not yet benefited from the deregulation process that took place in the United States in the early 1980s, although the UK is now beginning to follow suit. But firms are still dependent upon public purchasing by the various national agencies as the driving force for the development of space products and services in Europe. In short, what Europe lacks above all is the momentum of a truly open market: the weakness of private-sector demand and the persistence of national monopolies contribute to the continuing fragmentation of the European space industry.

Deregulation is of crucial importance. The early American decision to opt for an 'open skies' policy dramatically reinforced the buoyancy and sharp competition which have characterized the American market and given US firms such an edge internationally. The Americans are now taking this a stage further by possibly allowing private business networks to compete with Intelsat. Hence deregulation also carries risks for Europe. Open tendering means contracts go to the company or consortium which can offer the most attractive terms.

As the use of space technology spreads from the more esoteric to the more routine applications, more of the purchasers will be operating agencies or companies for which space *per se* will be irrelevant but the commercial product and its apparent profitability will be vital. Space technologies have to compete with alternative technologies. In the telecommunications sector the evolution of fibre optics has fundamentally changed the questions and the relative costings for the purchaser. Moreover, traffic by cable is much more amenable to national control than traffic by satellite, even though satellite links offer immense advantages for communications to remote areas, over great distances and to mobile ground stations. The various issues at stake also raise difficult choices about the respective character of satellites and ground stations: for instance, is it better to opt for more complex satellites and simpler ground systems or vice versa; and should one go for niche markets or for higher volume and more diverse markets? The sophistication of engineering and the tight specifications needed for ground stations that serve scientific satellites may be too complex and too costly for routine telecommunications.

The opening up of the European space market, a necessary condition for future competitiveness, is by no means an easy task. ESA's contribution in this area is minimal, since it is fundamentally a product-development and R&D organization with little competence in the operation of space systems and their commercial uses. It has no regulatory teeth or enforcement capabilities.

Meanwhile, the impact of the European Community on the space sector has so far remained very limited. Its rules on opening up public procurement have been slow to bite in the telecommunications sector. The various satellite consortia have done some of the standard-setting, but more remains to be done. The EC has now begun to move in the field of direct broadcasting, but only just.

The interconnections between adjacent technologies have hardly been addressed on a concerted European basis. There is no collective stimulus to users and potential users of some space technologies. Remote sensing is a good case in point: large mass markets remain a very distant prospect, but specialized trans-European markets might be viable, especially perhaps for those applications which are relevant to European public policies. Crop-forecasting is an obvious example.

The dynamics of adjustment

But the situation is rapidly evolving. The drive within the EC to create a single internal market by 1992 is serious and has now been reinforced by the Single European Act, which is relevant not just to the EC but to its other European associates, which include the other ESA members. The EC is involved in many relevant areas of technology, as its burgeoning R&D programmes make clear, and may well serve as a vehicle for enmeshing space technologies in a wider process of technological modernization, a dimension which goes beyond the functionally specific remit of ESA. The EC has user needs of its own and to an extent can promote them in its developing country associates. And the EC has the European Parliament, which can be a vehicle for promoting a wider political awareness of the relevance of space, as its recent debates on the 1987 Toksvig report illustrate. The important question which follows is how far ESA and the EC will succeed in establishing complementary and mutually supportive roles.

It is clear that overall Europe's industrial infrastructure and performance in the space segment could be improved, and indeed must be improved if Europe is to sustain a larger space programme and withstand international competition. Firms, governments and institutions have a common interest in this, though inherited patterns and divergences of interest will remain limitations. Some are more interested in the less exotic and potentially more profitable areas, while others see their best returns from large projects with a long life-cycle. In neither field do the conditions in Europe currently exist for effective competition. In the contemporary climate it will be difficult to persuade politicians and public opinion across Europe to support larger public investment in space, unless the economic and technological returns are demonstrably positive.

It would be unrealistic to expect a wholesale restructuring and rationalization of the European space industry. But there is a visible and increasing willingness on the part of the firms to improve the industrial infrastructure on a sustained and trans-European basis. The most likely prospect is a continuation of the regrouping of alliances among European firms in response to contract opportunities, an adjustment process which could result in a smaller number of larger firms with a network of smaller companies clustered around them. But this will not happen unless both governments and the various European organizations help to nudge that process along. And a balance remains to be struck between the development of large public programmes and the opening up of markets for products and services derived from space technologies.

Larger programmes and big projects also demand a different management style from that appropriate to the majority of ESA programmes so far, with the key exception of Ariane. Managerial difficulties within Nasa provide a salutary warning. More than one management model is possible, from the hegemonic to the collective. Hegemonic methods, however valuable, are probably not appropriate within Europe. Some lessons can be drawn from other areas of technology, both civilian and military, especially in the aviation sector. Collective management can be made to work, but it requires more than loosely-knit consortia.

As for the link with adjacent technologies, many European collaborative initiatives are now under way through Eureka, the EC's R&D programmes (notably, for space purposes, Esprit, Race, Brite and Star) and the IEPG. The optimization of resources and technology transfers within Europe are unlikely to be achieved unless bridges are built to produce effective cross-disciplinary technologies and greater competitiveness.

US-European relations

Lastly, Europe's relationship with the US raises difficult policy issues across the range of space applications. Many ESA missions have depended on Shuttle launches, with the current result that the science programme, for instance, is now way behind schedule. Europe remains dependent upon the United States in certain important technologies: above all, its dependence in the field of electronic components for space systems is becoming alarming, as a recent IEPG report argued in the context of European defence industries in general. Overall, about 10 per cent of components used are US-sourced and not currently capable of European substitution – for example, high-quality magnetic tape recorders. But on some projects the imbalance is disturbing: ERS-1 is 60 per cent sourced from Europe, 30 per cent from the US, and 10 per cent from Japan; and on Rosat, more than 50 per cent of the inputs are from the US. No doubt the relevant technologies could be produced indigenously, but not necessarily at competitive prices.

The development of the US military space effort has had positive effects on the technological level of the US civilian programmes, whereas in Europe there are still practically no such spin-offs to the civilian space sector, and the European electronics industry anyway has many other problems. So far, however, Europe has not been technologically dependent upon Japan on a major scale, even though there is growing European-Japanese competition in an increasing number of space-oriented activities.

On the other hand, the European space industry has had access to important international markets through consortia with US firms. To take one example, British Aerospace does more business with Hughes than it does for ESA, a commercial response to the level and character of demand in the market-place.

This is not to say that the European space industry's experience of collaboration with the US has always been happy. Several European firms have found the conditions attached to collaboration onerous. US federal regulations impede the access of European firms to the US market. And not far down the road lie important issues about technology transfer which will arise the moment the first decision is made, if it is, to accept a Soviet (or even Chinese) launch of a European or part-European satellite. The attractive terms being offered for Proton may prove irresistible. The foreign policy dimension is of crucial importance.

But the most sensitive issues in US-European civilian space relations arise from the big projects in which Europeans have joined, or contemplated joining, Nasa. ESA took part in Spacelab with a degree of real enthusiasm. It provided a welcome opportunity to take part in a manned programme with important scientific opportunities. ESA could perhaps have negotiated more advantageous terms, but it could not overcome dependence on American decision-making over which Spacelab missions flew and when. This negative experience has bred intense European caution over the international space station. The Americans see the station as an extension of their national territority and thus governed by their own laws. For example, they consider that all inventions aboard the space station will be American. Similarly, they have proposed a rather unequal sharing of the workload: experiments on material in microgravity will be conducted in American modules; the European laboratory is to deal more with life sciences, which are far less attractive commercially. A request by the DoD that the space station be utilized mainly for military programmes and functions is also posing a grave political problem for ESA, which is limited by its charter to activities of a 'peaceful nature'. Even so, it may be a valuable means for Europe to develop an indigenous space station at a later date. Everything hangs on whether terms can be negotiated which will permit European interests to be adequately safeguarded.

Conclusion

Since European space activities remain characterized by the coexistence of national and collaborative programmes, Western Europe's space policy reflects a complex game of competition and cooperation among member states. For reasons of national pride and economic interest (space programmes help maintain a country's industrial capacities and are expected to have a positive impact on employment), European governments are reluctant to move squarely towards a fully integrated space policy, even though the size of investments and of the programmes ahead require such a qualitative jump to be made urgently. In the meantime, national agencies (for example, in the case of PTT administrations) still behave as competitors, and the virtual absence of transnational actors favours the persistence of individual interests. In the field of defence and security Europe still lacks the political cohesion and the common definition of requirements needed to promote a collective view of where space technologies can enhance security goals.

All in all, despite remarkable achievements over recent decades, Europe is still far from having a true *policy* of its own in space. Persistent protectionist tendencies, a fragmented industrial base, differing security perspectives and the lack of wide popular support constitute major obstacles to the much-needed unification of European space efforts in both the civilian and the military sectors. Yet recognition of these constraints and weaknesses is beginning to be reflected in a debate which is both more realistic and more open. The key question is whether this can produce the redefinitions of policy goals and the capabilities necessary to guarantee an effective future in space for Europe.

8

PRIORITIES

There are no insurmountable obstacles to maintaining and improving Europe's performance in space. Nothing is needed that cannot be built upon existing assets. Some courage, coupled with a limited increase in space budgets and a greater awareness of common aims, should suffice. But the time for decision is now: international competition is growing, and the European space industries and scientists need time and money to set the necessary programmes in motion. Different perceptions and priorities, in the various European nations, are part of the problem. Should the required qualitative jump in space activities be made only by some European countries, leaving the others behind, the outcome would probably not improve Europe's international competitiveness. These differences should not, however, overshadow the importance and the degree of consensus already in place. The biggest threat to Europe's future role in space comes from its cumbersome and slow procedures for decision-making and from the delays in coordinating and integrating the various European activities.

The limitations

The importance of the national and European programmes described earlier in this report cannot be denied. However, they will not easily guarantee Europe's autonomy in space, the sustained competitiveness of its space industries or its position as the 'third' space power.

External constraints

Some uncertainties derive from the past experience of cooperation between ESA and Nasa. Many European programmes have been based on cooperation with the United States. Should this cooperation become more difficult, a complete re-examination of the European programmes would be unavoidable. The lessons from the past give ground for future concern. The negative experience of Spacelab is a case in point and may have held Europeans back from exploiting the potential of applied science in space.

In general, the major space projects have been decided by the major space powers, the USA prominent among them. The US-European experience has been one in which the Europeans have only been able to reject or accept participation in US-defined and US-led projects, and never the other way round. Even good European ideas have sometimes had to be implemented as American-led projects, with European involvement only later. France, to a lesser extent Britain, and now also ESA, are enlarging their options by cooperating with the USSR; Japan and China, too, are already attractive collaborators. But the USA is, and will remain, Europe's main partner for many years to come.

Internal constraints

Problems within Europe also have negative repercussions on European space policy as a whole. The level of funding, in particular, is crucial. ESA members have accepted a significant increase in the ESA budget, while at the same time expanding their national space budgets. But the new programmes, with their ambitious aims, require far larger funding. By mid-1987, calculations of the total cost of programmes such as the Ariane 5 launcher, the Columbus space station and the Hermes shuttle had grown from 7.2 to 11.3–12 billion EAU. The total cost of these big programmes was thus broadly comparable with the US share of the international space station's total cost, then estimated at about $12 billion.

Financial allocations in a time of heavily constrained budgets and lukewarm public support increase the temptation to identify 'national' ventures based on 'national' perceptions of what should be done. Differences between the various national space budgets in absolute terms, the fragmentation of those budgets between various ministries, the division between military and civilian expenditures, as well as the division between European and national allocations, have to be taken into account as added weaknesses. If any major European country were to drop back from its commitments to ESA, as has been contemplated in Britain, the new ESA package would be put in jeopardy. The other members would then have to face the choice between increasing their own financial contributions and scrapping or delaying parts of the programme.

Many of these problems could be avoided if there was a direct source of secure funding for the European space programme. For example, a levy based on national wealth, building on the existing arrangements for funding ESA's mandatory programmes, would enlarge the resource base available for optional programmes.

Pressures of time

The timing of the proposed European programmes is crucial. It is clear that some projects will not become fully operational until well into the 1990s, by which time other space powers will have significantly progressed in competitive areas, such as space transportation, electronic intelligence and telecommunications, ground stations and cheap expendable space launchers. Therefore Europe cannot risk major delays.

Industrial performance

A further constraint is Europe's limited industrial and technological capacity in some space activities. European dependence on certain American and Japanese technology is undeniable, as is the relative difference in scale between European and American space manpower.

In short, the biggest risk for Europe is that of remaining the junior partner of the two existing major space powers (and particularly the USA), while losing ground to Japan. The objective of European 'autonomy' identified by ESA would then become unachievable and Europe's competitiveness would decline.

The challenges

Two challenges are particularly relevant, and whether or not they are met depends on how far West European governments are prepared to go in taking effective independent action. Telecommunications and security are the two key fields in which Europe must develop independent capabilities if it is to achieve real autonomy in space. And so far Europe has not found a satisfactory way of dealing with them on a collective and multilateral basis.

Telecommunications
It is in the field of telecommunications that space has had its greatest economic success and has attracted the largest number of 'private' users. But Europe still lags behind the US and Japan, because a combination of industrial inefficiencies, national protectionism and the monopolistic structures of most PTTs continues to impede European effectiveness. American industry has thus been able to capture much of the world market, notwithstanding the existence of important European technological capabilities and significant ESA and national programmes. An energetic European policy must therefore include not just high-quality hardware and software, but a deregulation of all the PTTs and the elimination of protectionism in this field. This in turn should be part of the implementation of the Single European Act and the drive to complete the European internal market by 1992.

Security
The second challenge is security, for which there is no multilateral European space policy. European space requirements that are not dealt with nationally are generally handled through Nato or in direct cooperation with the USA. Even bilateral European projects in this field, so far generally inspired by France (which is outside Nato's military framework), have not been easily agreed.

There is, however, a growing awareness of the utility of space for security purposes. Although defence budgets, too, are heavily constrained and cannot easily be stretched to increase spending on space activities, there is an obvious advantage in planning, wherever possible, for the closer integration of military and civilian ventures. Already some of Europe's civilian satellites have a built-in capacity reserved for military use. The increasing 'need to know' and the necessity of having better, more secure C3I systems are recognized by European military establishments.

Satellite reconnaissance stands out as a crucial resource for the future international and diplomatic role of Europe: without satellites the Europeans will lack a very important element of independent appraisal of developments in many regional theatres, for example, Libya and Afghanistan. The resolution of images required for such a purpose is higher than the 10–20 metres offered by existing commercial optical satellites such as Landsat, though it does not need to be as sharply defined as the 1–2 metres used for specific, tactical military purposes. (See Table 8.)

Already Landsat and Spot images have been very useful for assessing such events as Chernobyl; the Iran-Iraq war; the purported construction of a SAM SA-5 Soviet site in Libya; the launch test of Soviet SLBMs beneath the ice of the Arctic Ocean near Wrangel Island; the purported construction of new Soviet air and naval bases in the Kola peninsula; the establishment of an alleged new Soviet base of mobile intermediate-range ballistic missiles (SS-20s) near Kirov; the Soviet space shuttle facilities at Tyuratam; and the secret Iraqi facility near Samarra, allegedly producing chemical weapons. In January 1986 it was also reported that Landsat imagery was being used to monitor Soviet military activities in the Far East.

Arms control may now stand a better chance than it has for some while, and as a result increased attention will be paid to the balance of conventional forces. The Atlantic Alliance will need enhanced capabilities for observation from space, both to verify arms control agreements and to ascertain whether the military situation is stable. The European members of Nato could contribute to an equitable sharing of burdens within the Alliance by creating an observation capability of their own. A West European system, adapted to the special circumstances of the European continent, would guarantee a desirable degree of redundancy within the Alliance and could also strengthen the strategic consensus between the United States and its European allies. Both domestic public opinion and other interested parties could be reassured that such a West European observation system would serve no other purpose than to ensure compliance with agreed understandings and to give support for world stability.

Although ESA cannot deal with military programmes, a case could be made for involving it in arms control programmmes of a clearly peaceful nature, and in other systems of communication and warning. More specific military programmes, directly related to battle management and crisis management, could be dealt with through other European institutions, such as WEU, or specific multilateral agreements. So, too, could systems for communications and electronic intelligence, though they also have a utility for arms control purposes.

Industrial competitiveness

No long-term solution to Europe's future in space can be found without a more competitive European space industry. National divisions (evident in the telecommunications field), the quicker pace of some competitors (such as Japan), the absence of a large military sector (in contrast to the American and Soviet cases) and the comparative economic advantage of less developed countries (such as China) represent tremendous challenges. Europe should first of all tackle its internal industrial problems.

Lack of standardization and economies of scale are problems for the entire European space industry, particularly in the critical field of space launchers. The whole of the Ariane programme has produced a very large number of single 'prototypes', without yet developing sufficient capacity to permit launches 'upon request'.

The economic and industrial importance of the 'ground segment' of space operations should not be underestimated. In commercial terms ground stations and infrastructure are crucial, and it is here that Japanese and American competition is toughest. More open public markets are needed, especially in the PTT field, as well as common European standards. In specific fields such as telecommunications, links should be encouraged with other European ventures in high technology.

It should be possible to develop cost-effective collaboration which would both stimulate competition and avoid wasteful duplication. But it would be wrong for Europe to rely on a single launcher system, a single engine construction site and a single launch site. European needs are not necessarily best served by monopolistic suppliers of space systems: some intra-European competition is desirable in each main area of application. Many national programmes were justified in the past by the absence of a European alternative. The problem now is to avoid the persistence of purely nationalistic approaches and protectionist measures, since these increase the user's costs and progressively push the European industry out of the market. Only if these conditions are fulfilled can there be an effective industrial base in Europe.

It is painfully clear, at this point, just how far Europe still is from a common and coherent space policy. What Europe needs is a common approach to the exploitation of space. The basic elements of that policy are set out below.

Autonomy: a new policy approach

European governments must accept the fact that Europe's future role and influence in world politics, in global markets and in the cultural life of the next century may largely depend on its capacity and willingness to explore and use space, to develop the necessary technology and to build up the required industrial infrastructure. At the same time governments and the public need to recognize space as an important instrument in achieving the political (including security), economic and cultural integration of Western Europe, as part of the process of developing a stronger European identity. These considerations all point to the overall political objective, already identified by the 1985 ESA ministerial meeting, of acquiring a European identity and autonomy in space. This autonomy, in the European context, can be defined as 'a capability to reach, to operate in and to return from space, and to do so, not on sufferance of friend or foe, but according to its own perception of what is to the common good'.

Autonomy thus connotes the ability to shape a future space programme independently of others. It presupposes that Europe should have space transportation and recovery systems for crews and materials; a space infrastructure consisting of scientific satellites and observatories, space-based remote-sensing systems and telecommunications networks, manned or man-tended space platforms, and a satellite-based capacity for the verification of arms control agreements and the observation of relevant military developments; and the necessary ground installations to establish, maintain and use these systems. Europe would also need to deploy both people and robotics in space in complementary roles.

There is, however, an important difference between autonomy and autarky. Europe is not, and cannot be, autarkic in space, whereas European autonomy, even if based on a large utilization of foreign components and technologies, is politically and technically compatible both with Europe's industrial capacities and with its relations with the USA and Japan (and with the USSR). Moreover, Europe has a vested interest in creating an open and interdependent space market in which national preferences are not allowed to dominate international cooperation, and from which protectionist barriers have been removed. Our objective is to build a competitive and autonomous Europe in space, not to help segment space within national boundaries. On the contrary, Europe should also work towards establishing an international space order.

Components of autonomy

The first and most evident priority lies in the field of *launch capabilities.* Important economic and industrial interests in this field should be encouraged. Europe must free itself from its current dependence on the USA for the costs, timetable and completion of important European space projects.

The development of new launchers with greater lift capability (Ariane 5), of partially recoverable systems (Hermes), and possibly of new, fully retrievable ones, should increase the competitiveness of European space transportation, especially if a greater degree of 'industrialization' in the production and operation of launchers is established. More satellites and more activity in space will require more, and more efficient, launchers: Ariane 5 and Hermes, based on mature, traditional transportation systems, are already in sight. Industrialized launchers, routinely produced and operated, should be developed from the Ariane family. Fully retrievable and reliable launchers are rather further off, but remain the best hope for cheaper and wider access to space.

The present scale of European space operations does not seem to require new launch sites immediately. The industrialization of traditional launchers could, however, require an additional European launching site in the not too distant future. Should a new generation of launchers be developed, the problem would probably be simplified, since these 'space planes' might use traditional air bases, with few modifications.

The choice of whether or not to send human crews into space has, at some point, to be openly confronted. Although no robot can substitute for the versatility of a human being, people cannot be regarded as expendable. The cost of making a system 'safe' for humans, as opposed to making it 'reliable', is huge. Europe should aim at complementarity between robots and humans, and avoid concentrating on humans for the sake of it or to create an image of prowess.

Another key priority for any European space policy will remain the construction and utilization of *various kinds of satellite.* In this sector European technology is often very competitive; a high degree of autonomy can be reached, and a greater European presence in some fields (such as telecommunications, Earth observation) would have the beneficial effect of increasing international competition. Developments in direct broadcasting and TV distribution satellites, the growth of new services in education and training, and the prospect of the deregulation of telecommunications all point to the need for a determined European effort. The fact that telecommunications in space have already reached a degree of self-financing is a positive element.

In the field of Earth observation, the dual use of satellites for military and civilian purposes (both long-term evaluation and management), the forecast growth of a private market for satellite images, and the value of remote sensing in such fields as meteorology and environmental protection, all serve to emphasize the increasing importance of space systems. Similar conclusions can be drawn from recent developments in the field of communications (for maritime, aeronautical and land-based mobile vehicles), search and rescue, and monitoring systems such as Elint.

A third priority for European space policy is the *space station*. In the short term the likelihood is that this will be achieved by collaboration rather than independently. Cooperation with the USA and Japan through the Columbus project of ESA opens up bright prospects. This should allow Europe to develop capabilities which will increase its autonomy and identity in space. A higher degree of European control over the costs and operation of the space station, and especially of the European platforms, is an absolute requirement for European participation in the overall project.

Finally, the importance of the *ground segment* of space operations must be reiterated as a precondition of achieving effectiveness on a European scale.

Security

Europe has no collective space capabilites for security purposes. It is clear from the points made earlier in this report that it is in the security field that the challenge to Europe is the greatest. Like it or not, the militarization of space is already well advanced, as the sections on the USA and USSR show. Space has become a major arena of security. Even if Europe had all the means at its disposal, it should not opt for a massive and aggressive military presence in space. On the contrary, it should do its utmost to support the ABM

Treaty and to uphold all the legal instruments available to prevent the further exploitation of space for military purposes.

However, this does not mean that Europe should remain idle in this area; it must look to its own long-term security and be able to influence the international space order. Europe should therefore equip itself with the following minimum requirements: (1) autonomous capabilities for observation, reconnaissance and verification of arms control agreements, based on optical and radar satellite systems; (2) closer intra-European military communications systems, building on what is already available; (3) shared intelligence-gathering, to give European nations a capability for early warning and crisis management; (4) the means to protect European assets in space; and (5) studies of the option to deter attacks on European assets.

Obviously, to carry out such a programme would require an appropriate balance between the Nato framework and the existing programmes being pursued in Europe. It would, however, be a mistake to wait for a joint European military and defence authority to be created. Pragmatic bilateral or trilateral channels, as well as such institutions as the Eurogroup, the IEPG, WEU and EPC, have roles to play in developing a collective approach. The development of systems capable of performing the relevant civilian and security-oriented operations should also be encouraged within the ESA framework, where the existing technical infrastructure could be legitimately drawn on for peaceful security purposes. Reconnaissance satellites are a prime example of where ESA could make a contribution. An evolution of this kind would allow individual European nations to make differentiated use of the various systems available.

The legal order

One key feature of Europe's autonomy and identity in space will be its ability to develop a credible and influential role in worldwide space cooperation, both in specific space projects and through its capacity to envisage a new space order.

The problem of establishing a new space law, and new legal instruments (besides those already in force), capable of dealing with the many security and economic problems related to the human presence in, and utilization of, space, is becoming urgent. The interests of both producers and users must be taken into account, as must the legitimate concerns of the international community as a whole. Indeed, a greater awareness of the international interests of all mankind might help to defuse Soviet and American inclinations to engage in superpower confrontation in space. The establishment of a new space regime should be made a priority subject of EPC, so that Europe can become a major actor in this arena.

Institutional requirements
The future of Europe in space has to be built on the existing reality. European space activities are generally carried out by the various national agencies or ministries, since it is they that take the relevant budgetary decisions past institutional and political obstacles, lobby for greater space budgets, gather public support and identify economic interests and technical capabilites.

One necessary step forward, therefore, is a more strategic coordination of space activities and policy at the national level, to overcome at least some of the problems deriving from intra-governmental conflicts. One means to this end is the use of national space agencies, which may tend to promote particular national interests, but have the advantage of providing a single and coherent interlocutor.

Other institutions, such as the EC and WEU, have existing and potential competences related to space policy. ESA has a wider European membership than the EC or WEU, or even Nato. No real conflict need develop among these organizations. On the contrary, at least as far as the EC and WEU are concerned, there is a strong case for putting their political weight behind the general thrust of ESA's programme. The European Parliament, for example, has endorsed the necessity of increasing ESA's budget, as a way of helping Europe towards the goal of autonomy.

But there is a need for democratic scrutiny and control over the substantial expenditures needed for space, and for public debate on the strategic and security dimensions. Hence we welcome the general thrust of the debates in the European Parliament on this subject. But we deplore the Parliament's very limited impact on the actual decisions taken. Currently European space policy decisions are shaped by the demands, interests and the almost exclusive expertise of the specialized space policy community (the manufacturers, the military, the bureaucrats and the scientists, at both national and European levels). Space is more important than those interests.

The general goal of a strong autonomous European presence and identity in space will not be attained without greater public support.

Furthermore, a greater degree of democratic control and public awareness of the choices involved in European space policy is not merely desirable; it will become a necessity as that policy reaches a higher degree of importance and maturity.

9

RECOMMENDATIONS: TOWARDS EUROPEAN AUTONOMY

The analysis of Europe's needs and achievements in space clearly shows that a significant increase in European activities in this field is an urgent priority. The indispensable basis for European action consists of implementing ESA's Programme of Action. All governments and political forces in the participating countries should give full support to the ESA programme as the precondition for achieving Europe's stated goal of autonomy in space.

I Space transportation systems

1 European autonomy in space can be achieved only if Europe has the capability to place objects in space and to launch and recover manned spacecraft. The present policy of developing Ariane 5 should therefore be continued. The goal should be to turn Ariane 4 and Ariane 5 into cost-effective launchers for Europe that will allow routine production, and so be competitive in the market. This is all the more pressing now that Soviet and Chinese launches are being offered at attractively low prices. The present policy of developing Hermes should also be continued.

2 The next generation of fully retrievable space transportation systems, required early in the next century, should be embarked on within ESA, in order to give Europe a wider option for operational access to space. New and re-usable hypersonic systems which have air-breathing as well as traditional rocket propulsion systems, and which can start and land horizontally on conventional airfields (like the Hotol and Sänger projects), should

be pursued in the study phase today as competitive programmes, with the aim of then selecting one project for joint European development in the future.

3 Europe must ensure that it preserves the present launch site at Kourou. An expanded programme may require additional launch facilities.

II Satellites

1 Europe needs to have its own eyes and ears in space. It must make wider use of space-based systems for telecommunications, observation, navigation and meteorology, and in doing so strengthen Europe's technological base and its competitiveness in the world market.

2 Europe should develop and operate a joint reconnaissance satellite system in low earth orbit for safeguarding Europe's political and diplomatic interests, as well as for arms control verification, the monitoring of military movements and crisis control. This system should be based on existing remote-sensing techniques (optical and microwave) and could be complemented by a jointly operated electronic intelligence-gathering package.

3 Europe should lose no time in developing a data relay satellite (DRS) system for multiple purposes, and examine whether an international DRS system between Europe, the US and Japan would meet European needs.

4 European cooperation in using communications satellites for security purposes should be strengthened. Collective planning of the architecture of national systems, both civil and military, and of their management would be a valuable step towards achieving interoperability and operational flexibility.

5 In order to protect European satellites against potential Asat threats, Europe should actively prepare for and participate in negotiations on a code of conduct for the peaceful uses of space, based on a regime of confidence-building measures and rules for space use. At the same time, Europe should study means of protection for its satellites in the context of the right of self-defence.

III Space platforms and stations

1 Europe's long-term goal should be to establish a space station of its own to provide a central element of its space activities and a highly visible symbol of Europe's capabilities and common will.

2 Europe's immediate and medium-term goal should be to participate through the Columbus programme in the development and operation of the space station proposed by the US and augmented by a man-tended free-flying module. This should be done as a step towards establishing an autonomous European space station at a later stage. However, that participation should be contingent on European conditions for using Columbus being met: namely, genuine partnership in the management, utilization and financing of the station. If the negotiations fail to create the preconditions for such a partnership, Europe should build, launch and operate a space station of its own.
3 Europe should continue to develop partially or fully automated space platforms for scientific and industrial purposes.

IV Ground infrastructure

1 The ground segment for the operation and use of space systems must be planned and built as an integral part of Europe's space activities.
2 Nationally operated ground facilities should be incorporated more closely in a European system. To this end, European countries should agree on common technical standards for the ground segment. The export of ground stations should be strengthened through the production of standardized and low-cost systems.

V Industrial effectiveness

1 Governments and the European organizations should set the framework for achieving the competitive and sophisticated industrial infrastructure that is required to underpin a more vigorous European space policy in both civilian and security uses of space.
2 It is vital to ensure that collaborative programmes are developed with a steady rhythm, to provide steady business expansion and to raise the level of skilled employment.
3 Greater economic efficiency should be sought by urgent efforts to improve the competitiveness of the space sector and to liberalize markets. Europe must deregulate, unify its internal market, europeanize public procurement, consolidate viable transnational consortia of space companies, supply a larger share of the home

market for the ground segment, and improve its capacity to bid successfully for international contracts in both the space and ground segments. The implementation of the Single European Act is an essential precondition.

4 Further efforts are needed to promote technological innovation across the sectors relevant to both the production and the application of space technologies. This should be accompanied by measures to stimulate user demand on a European basis.

VI Space science and research

Europe should maintain a strong scientific programme, in order to improve its position in the exploration of the universe and in the widening of our horizons. European scientists should take a broader share of space science activities than in the past and be encouraged to give greater emphasis to the application of science to practical use. The ESA programme 'Horizon 2000' points in the right direction and deserves full support by the governments.

VII Institutional framework

1 ESA should be supported and strengthened as the centre of European space policy. Its successful mixture of mandatory and à la carte programmes and its focus on peaceful purposes should be maintained. Over time it should consolidate its role as the central policy-making body for Europe in the civilian field and represent Western Europe vis-à-vis the rest of the world.

2 Europe should continue to develop and operate jointly European applications satellites through specialized European organizations such as Eutelsat and Eumetsat.

3 The European Community should play a greater role in setting common norms and standards for the European market and in helping to develop relevant technologies.

4 The development of European security collaboration in space should proceed in spite of the current institutional inadequacies. But it will eventually require an appropriate institutional framework, building on the existing potential of WEU, EPC, IEPG and the Eurogroup. A strengthened WEU, for example, could become

the European institutional framework for reconnaissance satellite systems and eventually electronic intelligence satellite systems.

VIII And beyond ...
An effort should be made within ESA to study European space policy up to the middle of the next century. The study should in particular cover the possibility of using a European space station for the exploration of, and the establishment of bases on, the Moon and planets of the solar system, either in a European context or in cooperation with non-European countries.

To achieve autonomy, a substantial increase in funding has to be decided on and a fairer distribution of the costs among our countries has to be accepted. Even though it is notoriously difficult in this field to pin down exact and reliable figures, it should be realized that the implementation of the recommendations outlined above would require approximately the doubling, in volume terms, of the current level of annual European expenditure up to the year 2000. This would provide the resources for our recommended ESA plan and a new European security programme, as well as enabling national expenditure to continue. This figure of on average about 4.5 billion EAU per year over 13 years, while considerable in absolute terms, would represent only about one-fifth of current US spending. A reasonably modest price to pay for European autonomy in space.

TABLES AND FIGURES

Table 1 European members of relevant international organizations

	ESA	Eutel-sat	Eumet-sat	EC	WEU	Nato (Pol.)	Nato (Mil.)	Intel-sat	Inmar-sat
Austria	×	×	×	–	–	–	–	×	–
Belgium	×	×	×	×	×	×	×	×	×
Cyprus	–	×	–	–	–	–	–	×	–
Denmark	×	×	×	×	–	×	×	×	×
Finland	–	×	×	–	–	–	–	×	×
France	×	×	×	×	×	×	×	×	×
W. Germany	×	×	×	×	×	×	×	×	×
Greece	–	×	×	×	–	×	–	×	×
Iceland	–	×	–	–	–	–	–	×	–
Ireland	×	×	×	×	–	–	–	×	–
Italy	×	×	×	×	×	×	×	×	×
Liechtenstein	–	×	–	–	–	–	–	×	–
Luxembourg	–	×	–	×	×	×	×	×	–
Malta	–	×	–	–	–	–	–	–	–
Monaco	–	×	–	–	–	–	–	×	–
Netherlands	×	×	×	×	×	×	×	×	×
Norway	×	×	×	–	–	×	×	×	×
Portugal	–	×	×	×	–	×	×	×	×
San Marino	–	×	–	–	–	–	–	–	–
Spain	×	×	×	×	–	×	–	×	×
Sweden	×	×	×	–	–	–	–	×	×
Switzerland	×	×	×	–	–	–	–	×	–
Turkey	–	×	×	–	–	×	×	×	–
UK	×	×	×	×	×	×	×	×	×
Vatican City	–	×	–	–	–	–	–	×	–
Yugoslavia	–	×	–	–	–	–	–	×	–

Table 2 European collaborative programmes for satellites and vehicles (a broad selection)

Name	Date	Function	Sponsors
Heos 1	1968	Scientific/magnetic fields	ESRO/ESA
Heos A2	1972	Scientific probe	ESRO/ESA
TD-1A	1972	Scientific/radiation	ESRO/ESA
ESRO-4	1972	Scientific/particles	ESRO/ESA
Symphonie A/B	1974-5	Experimental Comsats	Franco-German with Belgium
Cos B	1975	Scientific/cosmic rays	ESRO/ESA
ISEE	1977	Earth-sun probe	Nasa/ESA cooperative
Meteosat 1/2	1977	Weather satellites	ESA/Eumetsat
IUE	1978	Ultra-violet	Nasa/ESA/UK
Geos 2	1978	Scientific geomagnetic	ESA mandatory
OTS-2	1978	Pre-operational Comsat	ESA
Marots	1978	Maritime communications	ESA
Marecs A/B2	1981–4	Maritime communications	ESA, lease to Inmarsat
Spacelab	1983	Manned scientific module	ESA/Nasa using Shuttle
ECS-1-5	1983–5	Comsats	ESA, lease to Eutelsat
Giotto	1985	Halley's Comet intercept	ESA mandatory
Exosat	1986	X-ray observation	ESA mandatory
Meteosat PL	1987	Weather satellite	Eumetsat
TDF-1/TV-Sat 1/2	1987–9	TV satellites	Franco-German
Inmarsat 2	1988	Maritime communications	Inmarsat, procured in Europe
Olympus (L-Sat)	1988	TV satellite	ESA
Hipparcos	1988	Scientific/astronomical	ESA mandatory
TDF-2	1988–9	DBS	Franco-German
Meteosat 3	1988-90	Weather satellite	ESA/Eutelsat
Eureca	1988–9	Retrievable carrier	ESA
ERS-1	1989	Ocean sensing	ESA
Ulysses	1989	Scientific/astronomical	ESA mandatory
Iso	1992	Scientific/astronomical	ESA mandatory
Columbus	late 1990s	Space station module	ESA
Hermes	late 1990s	Manned spaceplane	CNES/ESA study

Table 3 European national satellites

Country/Name	Date	Function/remarks
France		
Asterix	1965	First French satellite
Diapason	1966	Scientific
FR-1	1966	Scientific
Diadème 1	1967	Scientific
Diadème 2	1967	Scientific
Wika/Mika	1970	Scientific (first foreign payload)
Peole	1970	Experimental Meteosat
Eole	1971	Experimental Meteosat
Tournesol 1	1971	Scientific
D-2A	1973	Scientific (launch failure)
Starelette	1975	Research vehicle
Castor/Pollux	1975	Twin scientific launch
Aura	1975	Scientific
Télécom	1985	Civil/military Comsat
Spot 1/2	1986–9	Remote sensing
W. Germany		
Azur	1969	Scientific
Dial	1970	Scientific
Avos 1	1972	Scientific
Avos 2	1974	Scientific
Helios 1	1974	Solar probe
Helios 2	1976	Solar probe
SPAS–01	1983	Shuttle payload
IPS	1985	Shuttle payload
Rosat	1987	X-ray telescope (launch deferred)
Italy		
San Marco 1	1964	Scientific
San Marco 2	1967	Scientific
San Marco 3	1971	Scientific
San Marco 4	1974	Scientific
Sirio	1977	Experimental Comsat

(*continued*)

Table 3 (*concluded*)

Country/Name	Date	Function/remarks
Netherlands		
ANS-1	1974	Scientific
Iras	1983	Scientific (with US and UK)
Spain		
Intasat 1	1974	Experimental
Sweden		
Viking	1985	Experimental
Tele-X	1987	DBS, launch pending (based on TDF)
UK		
Ariel 1	1962	Scientific
Ariel 2	1964	Scientific
Ariel 3	1967	Scientific (first *all*-British satellite)
Ariel 4	1971	Scientific
Ariel 5	1974	Scientific
Ariel 6	1979	Scientific
X-4 (Miranda)	1974	Experimental
UoSat 1	1981	Experimental (ham radio)
UoSat 2	1984	Experimental (ham radio)
UKS	1984	Scientific
Skynet 1	1969	Military Comsat
Skynet 1B	1970	Military Comsat (failed in orbit)
Skynet 2A	1974	Military Comsat (launch failure)
Skynet 2B	1974	Military Comsat
Skynet 4	1987	Military Comsat (launch pending)

Table 4 Profile of expenditure for ESA programmes 1987–2000 (in millions of EAU at 1986 value)

Programmes	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	Total
General budget	124.7	120.0	126.0	138.1	148.0	161.0	167.0	170.0	170.0	170.0	170.0	170.0	170.0	170.0	2174.8
Associated to general budget	66.1	55.0	52.6	57.7	62.9	67.1	67.1	68.1	68.4	69.7	70.8	71.8	72.9	74.0	924.2
Science	170.3	176.8	185.3	196.7	206.4	216.7	227.9	232.0	232.0	232.0	232.0	232.0	232.0	232.0	3004.1
Other technology programmes	6.7	4.4	12.8	21.0	23.9	27.3	30.3	32.4	32.4	32.4	32.4	32.4	32.4	32.4	353.2
Earth observation	174.1	197.9	228.3	224.2	234.9	239.7	237.2	236.9	230.7	252.3	255.9	251.4	261.1	267.4	3292.0
Microgravity	13.0	46.9	78.1	110.0	110.0	110.0	110.0	120.0	130.0	142.0	142.0	142.0	142.0	142.0	1538.0
Telecommunications	289.6	248.5	215.5	192.6	228.7	244.1	235.7	267.8	293.0	319.0	339.0	275.7	222.9	247.9	3620.0
Space station and platform	195.3	228.1	312.5	363.4	469.0	478.0	513.0	525.0	555.0	600.0	678.0	681.0	890.0	877.0	7365.3
Space transportation systems	446.4	516.4	669.6	833.0	867.0	980.0	1074.0	1010.0	952.0	810.0	707.0	772.0	599.0	575.0	10811.4
Grand total	1486.2	1594.0	1880.7	2136.7	2350.8	2523.9	2662.2	2662.2	2663.5	2627.4	2627.1	2628.3	2622.3	2617.7	33083.0

Source: European Space Agency, 1987.

Table 5 ESA: industrial returns, from 1 January 1972 to 31 December 1984 (in thousands of EAU).

Country	Unweighted amount[a]	Weighted amount[b]	Ideal amount[c]	Surplus/ deficit[d]	Return coefficient
Austria	14866	11597	12481	– 884	0.93
Belgium	174609	163451	175390	– 11939	0.93
Denmark	76696	62237	60551	+ 1786	1.03
France	1665255	1384526	1353034	+ 31492	1.02
W. Germany	1204736	1118191	1085754	+ 32437	1.03
Ireland	4772	3933	2716	+ 1217	1.45
Italy	532404	497197	519210	– 22013	0.96
Netherlands	201864	142776	145633	– 2857	0.98
Norway	7130	7053	7741	– 688	0.91
Spain	120608	101257	120572	– 19315	0.84
Sweden	92219	82672	89215	– 6543	0.93
Switzerland	87123	78684	84303	– 5619	0.93
UK	658996	592787	574134	+ 18653	1.03
Canada[e]	55435	55435	61712	– 6277	0.90
Total	4896713	4301896			

Source: European Space Agency, ESA/IPC (85)4, 15 January 1985.
[a] I.e., actual amount spent.
[b] Amount after correction, to take account of distortions.
[c] ESA's notional calculation of what ought to be the case.
[d] Difference between weighted amount and ideal amount.
[e] Associate member.

Table 6 Launchers: a historical survey by area

Area/name	Date	Performance	Remarks
Europe			
Europa	1962–71		ELDO experiment, failed
Black Arrow	1969–71		UK, discontinued
Diamant	1970–3	0.23 tonnes LEO	France, pioneering venture
Ariane 1	1979–86	1.7 tonnes GTO 0.95 tonnes GEO	ESA series
Ariane 2	1984	2–2.5 tonnes GTO	
Ariane 3	1984	2.5 tonnes GTO	
Ariane 4	1986	1.9–4.2 tonnes GTO	6 versions
Ariane 5		15 tonnes LEO 8 tonnes GTO	Preparatory study
USA			
Atlas family	1958–87	3.8–5.9 tonnes LEO 1.2–2.2 tonnes GEO	Includes Agena and Centaur
Delta	1960–87	1.8 tonnes LEO 1.25 tonnes GEO	Future use under review
Saturn family	1963–75		Heaviest US launcher, discontinued at end of Apollo/Spacelab missions
Saturn 5		152 tonnes LEO 53 tonnes lunar mission	
STS (Shuttle)	1981–	29.4 tonnes LEO 14.5 tonnes polar orbit 1.99 tonnes GEO	Launches halted in 1986 by Challenger accident
Thor	1959–76	0.43 tonnes LEO	10 in store, ex-IRBM*
Titan	1959–	15.87 tonnes LEO 3.1 tonnes planetary missions	Main military ELV
USSR			
A1/A2	1959–60	5–7.5 tonnes LEO	B1 and C1 used for less heavy LEO missions
D (Proton)	1967–	20+ tonnes LEO 2.5 tonnes GEO	
F1/F2	1970s	4–5.5 tonnes	
Energiya	1987	100–250 tonnes LEO	Under test

(*continued*)

Table 6 (*concluded*)

Area/name	Date	Performance	Remarks
Japan			
M Series	1970	0.7 tonnes LEO	
N Series	1978	0.35 tonnes GEO	
H Series	1986	0.55–2 tonnes GEO	
China			
CZ-1	1970–1	0.3 tonnes LEO	Long March One
FB-1	1975–83	1.2 tonnes LEO	
CZ-2/3	1984–	1.4–2.2 tonnes LEO 1.3 tonnes GTO	Long March Two
India			
SLV-3	1980	0.05 tonnes LEO	
ASLV	1985–	0.15 tonnes LEO	Under development
PSLV	Early 1990s	1 tonne polar orbit	Under development

* Intermediate-Range Ballistic Missile.

Table 7 Unmanned US missions: approximate numbers launched by December 1986

Military		Civilian	
Photo-reconnaissance	255	Communications	62
Electronic surveillance	99	Astrophysics	76
Nuclear explosion detection	22	Land remote sensing	5
Early warning	51	Ocean remote sensing	1
Geodesy	19	Environmental and meteorological	65
Meteorology	80	Geodesy	10
Communications	138	Planetary	27
Navigation	39		
Ocean reconnaissance	31		
Total	734	Total	246
	Combined total	980	

Table 8 Image resolution for Earth observation (in metres)

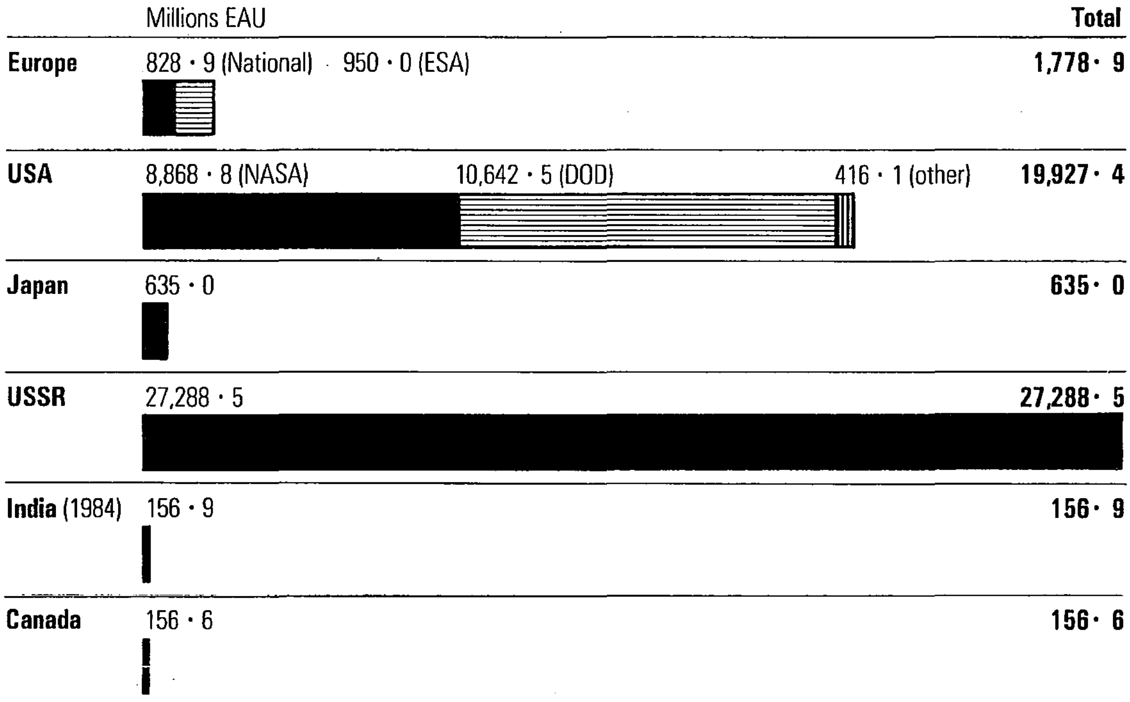
Objects	Detection	Identification	Precise identification	Description
Bridges	6	5	2	1
Radars	3	1	0.3	0.15
Telecommunication relay	3	1	0.3	0.15
Troops	20	2	1	0.3
Airfields	6	5	2	0.3
Artillery battery	1.5	0.5	0.3	0.2
Airplane	5	1.5	1	0.2
Control centre	3	1.5	1	0.2
Tactical missile sites	3	1.5	0.5	0.3
Ships	8	5	0.6	0.3
Vehicles	1.5	0.6	0.3	0.1
Fields	10	6	1	0.1
Ports	30	15	6	3
Railroad system	30	15	6	1.5
Urban zone	50	30	3	3
Submarine on surface	30	6	1.5	1

Note: the smaller the figure, the better the quality of the picture.

Table 9 People and robotics: operational modes and task allocation

Operation mode and basis	EVA-IVA	Teleoperation/ telepresence	Teleoperated hybrid system	Autonomous system
Task	People	Manipulator	Manipulator/ robotics	Robotics
Task and situation analysis and reasoning	People	People	People/robotics	Robotics
Strategy and path planning	People	People	People/robotics	Robotics
Procedure control	People	People	People/robotics	Robotics
Monitoring and control of robotics system	N/A	People	People/robotics	Robotics
Object handling	People	Robotics	Robotics	Robotics
Supervision of operational sequence	N/A	People	People	People/robotics
Contingency support	People	People	People	People/robotics

Figure 1 **Expenditure on space** International comparisons 1985



NB Figures for China not available
European figures do not include military expenditure
No account is taken of commercial expenditure

Figure 2 **European expenditure on space in 1985**

Millions EAU	National programme	ESA contributions	**Total**
Austria	0 · 3	2 · 5	**2 · 8**
Belgium	4 · 4	37 · 0	**41 · 4**
Denmark	2 · 5	13 · 0	**15 · 5**
France	437 · 5	255 · 2	**692 · 7**
Federal Republic of Germany	186 · 3	175 · 0	**361 · 3**
Ireland	0 · 0	1 · 5	**1 · 5**
Italy	81 · 7	105 · 0	**186 · 7**
Netherlands	9 · 5	32 · 0	**41 · 5**
Norway	3 · 1	3 · 0	**6 · 1**
Spain	2 · 5	21 · 0	**23 · 5**
Sweden	64 · 0	19 · 0	**83 · 0**
Switzerland	1 · 3	17 · 0	**18 · 3**
United Kingdom	36 · 0	129 · 3	**165 · 3**

NB These figures cover civil expenditure direct by governments and exclude both explicit defence and commercial expenditures.

Figure 3 **Member States' contributions to ESA programmes 1986**

Shown in Million Accounting Units and as percentage shares

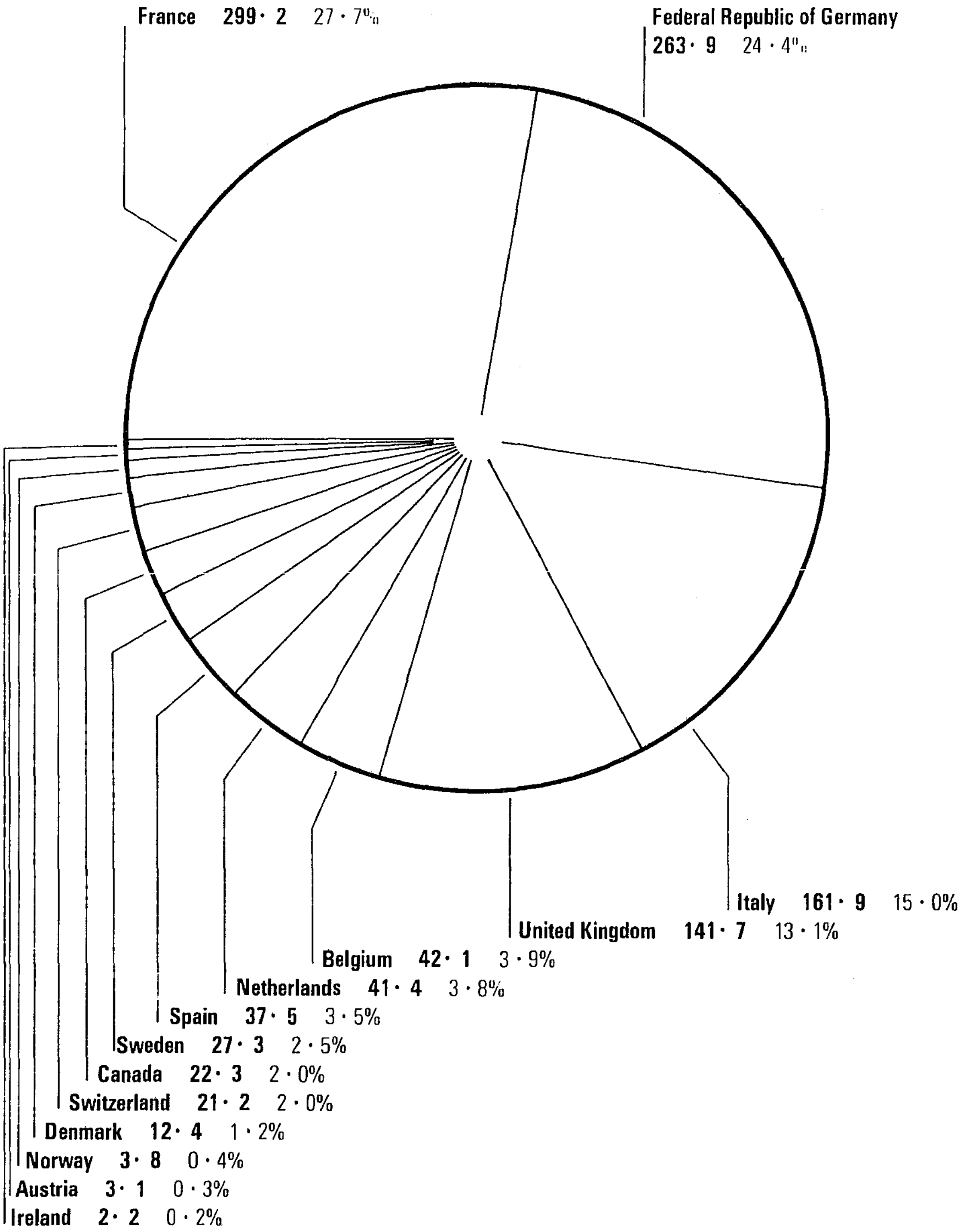
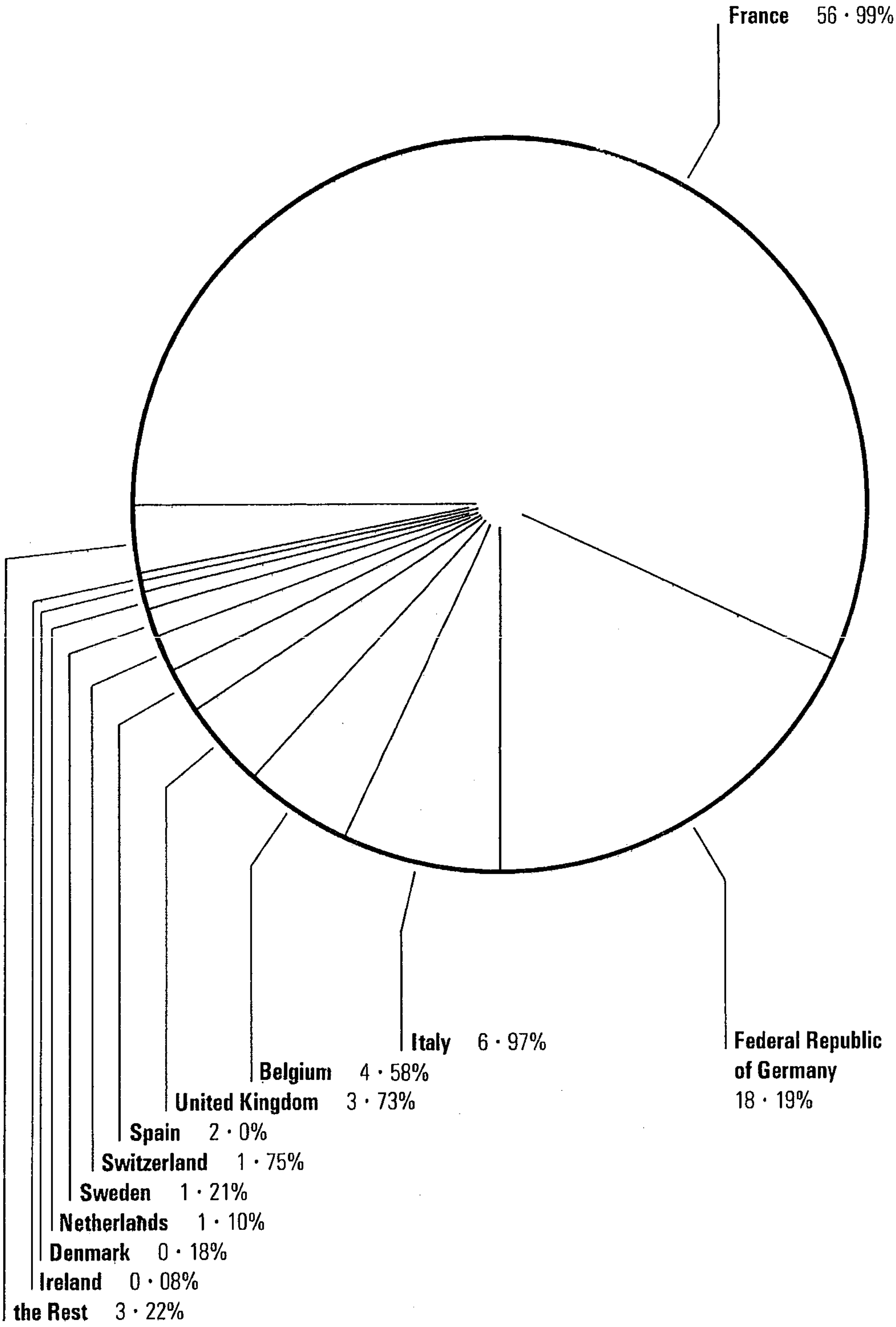


Figure 4 **Ariane 4** National workshares



source **Flight International** 4 May 1985

Figure 5 **Orbit positions**

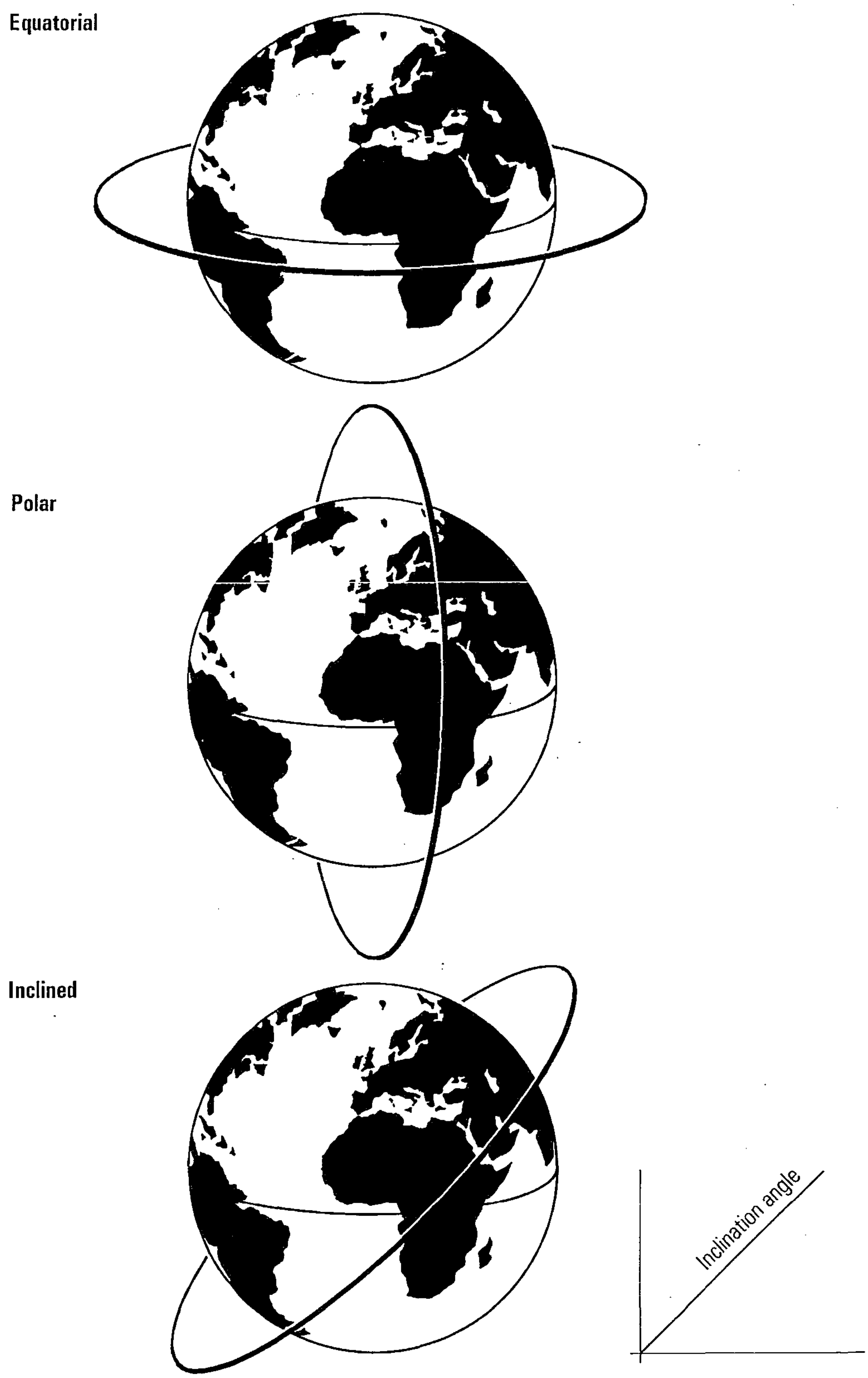


Figure 6 **Major orbital types**

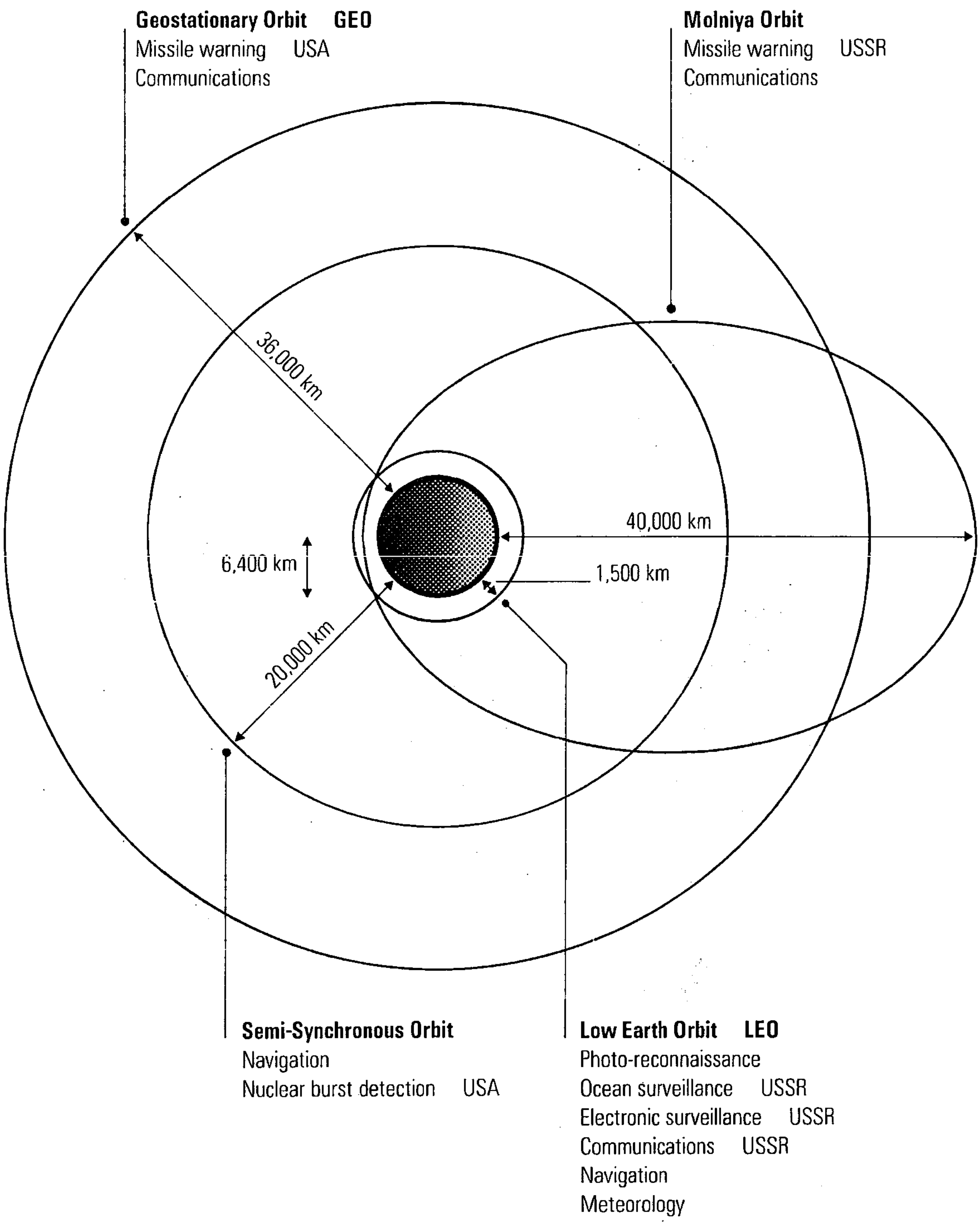
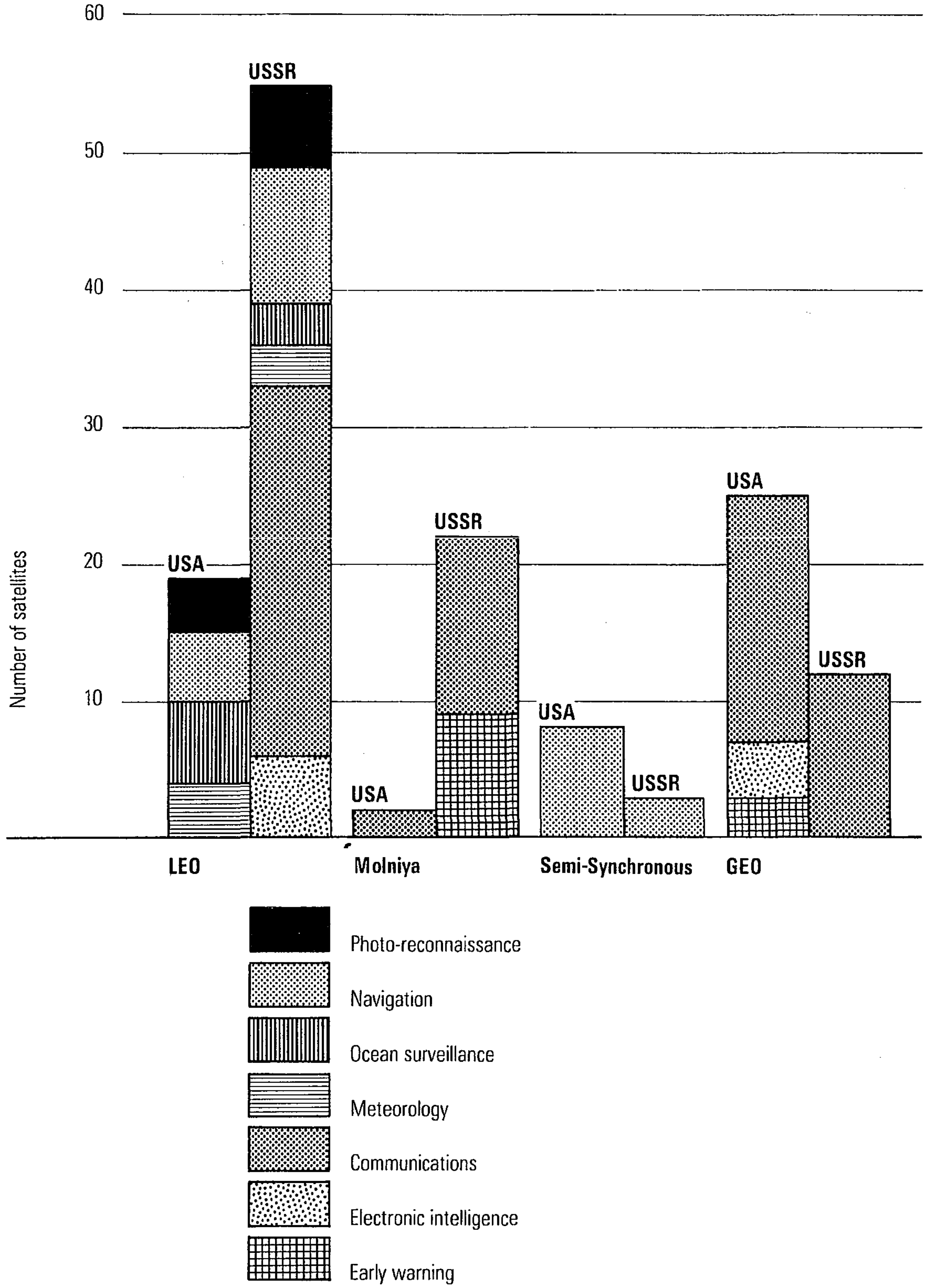
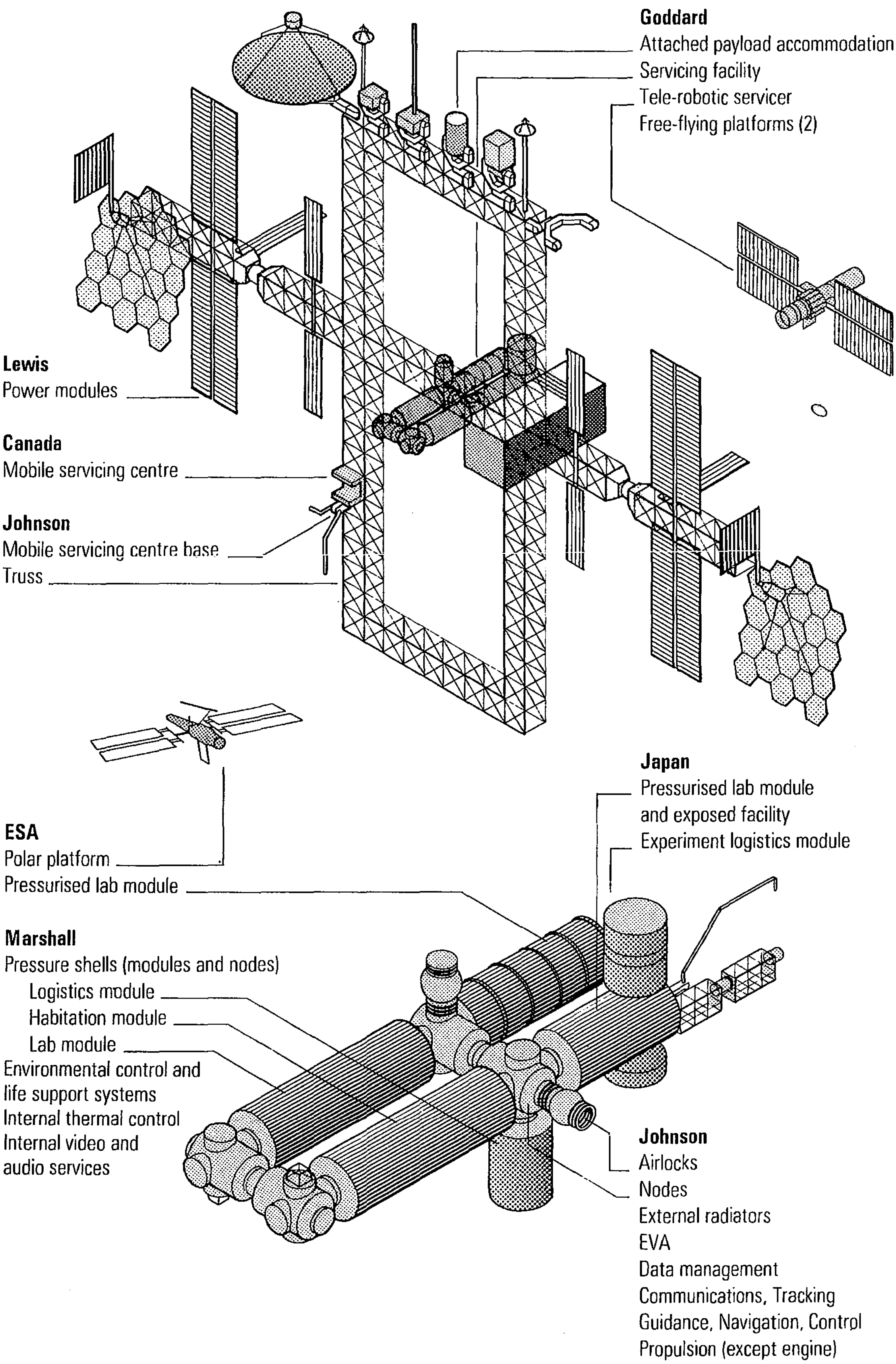


Figure 7 **Typical distribution of military satellites**
deployed by the USA and the USSR at any given time



source **Scientific American** June 1984

Figure 8 **International space station**



ANNEX: ORBIT TYPES

Orbital motion is independent of spacecraft size and weight, so all satellites travel around a given orbit in exactly the same way regardless of their nature. Orbits are either circles or ellipses. Circular orbits are described in terms of their altitude above the earth; elliptical orbits in terms of the altitude of their highest point (apogee) and lowest point (perigee). The lowest possible orbit – a circular orbit just above the atmosphere at an altitude of 200 km or so – has the shortest possible period, about 90 minutes. Satellites in high-altitude orbits have most of a hemisphere in view at any one time; satellites in low-altitude orbits have only a small patch of the Earth's surface visible to them.

Orbits are termed 'equatorial', 'polar', or 'inclined', depending on the orientation (inclination angle) of the orbital plane with respect to the plane of the Earth's Equator (Figure 6). As the satellite moves through its orbit, the Earth turns below it. The satellite's ground track, tracing the point on the Earth's surface directly below the satellite, is the composite of these two independent motions. The highest latitude surveyed by the satellite is equal to the chosen inclination angle. If the inclination angle is small, only a small band above and below the Equator can be surveyed. Only polar orbits overfly the Earth's entire surface.

If we assume a 90-minute orbit, the satellite makes 16 revolutions in a day, while the Earth turns just once beneath it. The ground track therefore crosses the Equator on 16 descending passes and 16 ascending passes, retracing itself every day. Since the period is exactly 90 minutes (i.e., 24 hours is an integer number of the period), the satellite retraces the same ground track every day, getting the same view. Changing the period to slightly more or slightly less than 90 minutes – by allowing the uneven shape of the Earth and other factors to cause natural precession –

would cause the entire ground track pattern to shift slightly sideways every day rather than reproduce itself exactly. The shifting pattern would pass over the entire Earth between 60° North and 60° South, allowing this whole region to be surveyed in detail.

As a consequence, if 24 hours is an integer number of orbital periods, two opportunities will exist every day to overfly a given location on the Earth, but a large portion of the Earth will never be overflown. Such an orbit is called harmonic. If 24 hours is not an integer number of orbital periods, it will be possible to scan the entire Earth over several days, but a given location will be overflown only every few weeks. Thus, harmonic orbits are best suited to monitor closely a crisis, or a sensitive area, whereas non-harmonic orbits are best suited to strategic surveillance.

Just five orbits contain all satellites (four of them are illustrated in Figure 7).

Low earth orbit (*LEO*) is the term applied to the region below an altitude of about 5,000 km. Orbits there have periods ranging from 90 minutes to a few hours. LEO is used for Earth observation.

Geostationary orbit (*GEO*) is circular orbit with an altitude of 35,700 km (6 Earth radii), and has a period of 24 hours. A satellite in eastward equatorial orbit at this altitude therefore remains over the same point on the Equator as both it and the Earth go around. The satellite has line-of-sight contact with more than 80 per cent of the hemisphere beneath it. To all observers who can see the satellite, it remains in the same position in the sky at all times. Several satellites spaced evenly around the Equator give coverage of the whole world except the polar regions. Most US, and an increasing number of Soviet, communications satellites are in geostationary orbit.

Satellite orbits may be sun-synchronous at different altitudes. Inclined to the Equator, they always follow the sun and thus the light, a feature which considerably simplifies satellite design.

Molniya orbits partially achieve the useful property of GEO and are named after the family of Soviet communications satellites that makes use of them. The orbit is highly elliptical – 40,000 km apogee and 500 km perigee – and has a 12-hour period. Because a satellite in Molniya orbit travels very slowly near its apogee and very rapidly at perigee, it spends more than 11 or even 12 hours on one side of the Earth. The orbit is inclined, so the satellite dwells high over the northern hemisphere, a convenient position for communications with the USSR. The particular inclination angle of 63° is chosen because at this angle the orbit is stable and does not drift under the influence of the Earth's equatorial bulge.

Semi-synchronous orbit is a circular orbit at an altitude of 20,000 km, and has a 12-hour period. This general altitude band is referred to as semi-synchronous orbit, although it is sometimes defined as ranging all the way from LEO to GEO.

Super-synchronous orbit. Orbits between GEO and the Moon are thinly populated today, but offer vast reaches for stationing future military satellites. The US deployed a constellation of nuclear burst detection satellites in 11-day orbits half-way to the Moon in the 1960s.

(NB. *Geostationary transfer orbit* is a temporary, highly elliptical orbit that satellites are put into before, for example, being placed more permanently in GEO or being despatched on interplanetary travel.)

GLOSSARY

ABM: Anti-Ballistic Missile.
AGV: Avion à Grande Vitesse, a hypersonic aircraft under study in France.
AI: Artificial Intelligence.
AM-136: Italian military telecommunications satellite programme.
ANS: Dutch astronomy satellite.
Anik: The Canadian network of communications satellites for domestic use.
Apollo: American lunar exploration programme, 1961–70.
Arabsat: Arab Satellite Communication Organization. Consists of 22 Arab PTTs and provides telecommunications and television services to the Middle East and North Africa from two satellites. The first was launched by Ariane in 1985.
Argos: French-US venture on platform location and data collection.
Ariane: ESA's launch programme, begun in 1973, and the first to be operated commercially. After development by ESA, manufacture and launch responsibility passed to Arianespace. Arianes 2 and 3 are improved versions of Ariane 1, and differ only in that Ariane 3 has two strap-on solid-rocket boosters. Ariane 4 is designed to carry heavier payloads. Ariane 5, at the design stage, will be able to carry even larger spacecraft, such as Hermes.
Arianespace: A commercial company formed to manufacture and launch Ariane. Its shareholders are 36 European aerospace and electronics firms, European banks and CNES. France is the major shareholder, with an approximately 60 per cent stake split between CNES and industry.
Ariel: Early British series of scientific satellites.

Asat: Anti-satellite system.
ASEAN: Association of South-East Asian Nations.
Asterix: First French satellite, launched 26 November 1965.
AT&T: American Telephone and Telegraph.
Atlas: Expendable launch vehicle developed for Nasa by General Dynamics from early US ICBM.
BAe: British Aerospace.
BNSC: British National Space Centre, established in 1985 to coordinate British space activities.
Brasilsat: Brazil's first communications satellites, for television, telephone, telex and data links.
Brite: Basic Research in Industrial Technologies for Europe (EC programme).
C3I: Command, Control, Communications and Intelligence.
CMEA: Council for Mutual Economic Assistance, also known as Comecon.
CNES: Centre National d'Etudes Spatiales, the French national space agency, founded in 1962.
CNR: National Research Centre (Italy).
Columbus: European programme to be operated as part of the international space station.
Comsat: a generic term for communications satellites, but also refers specifically to the Communications Satellite Corporation, established in 1962 by the Federal Communications Satellite Act to operate and supply satellite services commercially in the US. It is the US signatory to Intelsat. Its main satellites are in the Comstar series.
Copuos: Committee on the Peaceful Uses of Outer Space, established by the UN General Assembly initially as an *ad hoc* committee in 1958, following the launch of Sputnik; now a permanent committee with over 40 members, operating by consensus rules. Copuos has adopted four international agreements: the Treaty on the Use of Outer Space; the Agreement on the Rescue of Astronauts; the Convention on International Liability; and the Convention on Registration of Objects. A fifth agreement, on the Activities of States on the Moon, has not been ratified by all the members.
Cos B: ESA scientific satellite, 1975 (gamma-ray astronomy).
Cosmos: European industrial consortium of MBB, Marconi, Selenia and SNIAS.
Cospace: European industrial consortium to promote access for small firms to space contracts.
Cospar: (Soviet) Committee of Space Research.
Cospas/Sarsat: A search and rescue system using spacecraft, originally developed by the US, Canada and France (parties to Sarsat – Search and

Rescue Satellite-Aided Tracking) and the USSR (with the Cospas programme). The system became operational in July 1985.
CSG: Centre Spatial Guyanais, ESA launch site at Kourou in French Guiana.
DBS: Direct Broadcasting Satellite, capable of broadcasting TV and radio directly to ground-based stations.
Delta: Three-stage expendable launch vehicle developed for Nasa by McDonnell Douglas.
DFS/Kopernikus: Satellite developed for the German Federal Post Office by a consortium led by Siemens (including AEG, Standard Elektrik Lorenz and MBB).
DFVLR: Deutsche Forschungs-und Versuchsanstalt für Luft-und Raumfahrt, German Aerospace Research Establishment, founded in 1968.
Diamant A: Early French launcher.
DMSP: Defense Meteorological Support Program (US).
DoD: US Department of Defense.
DRS: Data Relay Satellite.
Dsat: Satellite defence system.
DSCS: Defense Satellite Communications System, the US DoD communications network of two spacecraft (often referred to as 'discus') at each of four geostationary locations.
Earlybird: US telecommunications satellite, launched in 1965, renamed Intelsat 1.
Earthnet: The European network for the acquisition, archiving and distribution of remote-sensing data, based at Esrin in Frascati. The network distributes information collected from the US Landsat. Dissemination services are handled nationally.
EAU: European Accounting Unit used by ESA and derived since 1979 from the ECU, the currency unit of the EC. Calculations of the rate are fixed for the current calendar year on the basis of the currency conversion rates for the previous year. Adjustments are then made retroactively to the contributions of member states to cover the difference between the fixed and the market rates. The EAU is close but not identical to the ECU in value.
EBU: European Broadcasting Union.
EC: European Community.
ECS: European Communications Satellites, developed for regional telecommunications within Europe under the direction of ESA and operated by Eutelsat. The first satellite was launched in 1983.
EIRP: Equivalent Isotropic Radiated Power.
ELDO: European Launcher Development Organization, created in 1962 with seven members to develop the European launcher.
ELGRA: European Low Gravity Research Association.

Elint: Electronic Intelligence, usually for military use.
ELV: Expendable Launch Vehicle, such as Ariane or Delta, which can be used once and then disintegrates on re-entry.
Energiya: New Soviet launcher.
EOSAT: American ocean surveillance satellite, based on Landsat.
EORSAT: Elint Ocean Reconnaissance Satellite.
EPC: European Political Cooperation.
ERS: ESA's Earth-Resources Satellite. ERS-1 is designed for ocean surveillance (wind and wave) as the forerunner for operational remote-sensing spacecraft in the next decade, using Synthetic Aperture Radar.
ESA: European Space Agency, formed in 1975 as the successor to ESRO and ELDO 'to provide for and promote, for exclusively peaceful purposes, cooperation between European states in space research and technology and their space applications'. Based in Paris, it has 13 member states, and Canada and Finland as associates.
Esdac: European Space Data Centre, based in West Germany.
ESOC: European Space Operations Centre, which runs ESA's satellite operations and the corresponding ground facilities and communications networks. Located in Darmstadt, West Germany, with a staff of over 200, its network includes a central control centre as well as telemetry, tracking and control facilities at various international ground stations, principally in Belgium, Spain, French Guiana, Australia and Gabon.
Esprit: European Strategic Programme for Research and Development in Information Technology (EC).
Esrin: European Space Research Institute, based in Frascati near Rome, created out of the never-completed Research Institute, operates ESA's Information Retrieval Service and the Earthnet distribution system for remote-sensing material.
ESRO : European Space Research Organization, set up to coordinate the scientific efforts of its members through shared satellites and ground facilities, and absorbed by ESA in 1975.
Estec: European Space Research and Technology Centre, based at Noordwijk, in the Netherlands.
ETS: Engineering Test Satellites, developed by Nasda. The first of the ETS series was launched in 1975 and the fifth, ETS-5, was launched in 1987.
Eumetsat: European Organization for the Exploitation of Meteorological Satellites, established in 1983 to coordinate and develop European interests in satellite systems for weather forecasting, in association with ESA and using Meteosats 1 and 2.
Eureca: European Retrievable Carrier, a re-usable payload carrier, designed by ESA to stay in orbit for up to six months. Eureca is part of

ESA's follow-on programme to Spacelab. The first flight, to include an inter-orbit communications package as a forerunner of a data relay system, was to have been launched by the Shuttle in 1987.
Eureka: European Research Coordinating Agency.
Europa: Unsuccessful ELDO programme for launchers.
Eurosatellite: Joint venture by AEG, Aérospatiale, Alcatel-Thomson, ETCA and MBB in the field of DBS.
Eurospace: Organization of European space companies, based in Paris.
Eurostar: Franco-British telecommunications platform, developed by Satcom International, a joint venture by British Aerospace and Matra.
Eutelsat: European Telecommunications Satellite Organization, based in Paris and with 26 members; the PTTs are designated by governments as signatories on an investment share basis. It provides telephone, telegram and telex communications throughout Europe, together with television and radio transmissions. It currently uses ECS leased from ESA and is procuring a second generation system.
EVA: Extravehicular Activities.
Exosat: European X-ray Observatory Satellite, launched in 1983 to examine the location, form and characteristics of X-ray stars as part of the ESA Space Science Programme. Results are received at the Villafranca Earth station in Spain.
Ferrets: Military intelligence satellites using electronics to pick up signals on radio and radar frequencies.
FGMDSS: Future Global Maritime Distress and Safety System, an automated communication system for deployment in 1991–7.
FOBS: Fractional Orbital Bombardment System.
FRG: Federal Republic of Germany.
GEO: Geostationary (or geosynchronous) Orbit (see Annex).
Geodesy: Study of Earth's gravity and magnetic field.
Geos: European scientific space probe.
Giotto: Named after the Italian Renaissance painter who included Halley's Comet in a fresco ('The Nativity'), this ESA spacecraft was launched in July 1985 by Ariane under the ESA Space Science Programme. It passed within 500 km of the nucleus of Halley's Comet in March 1986. The encounter lasted four hours, during which time Giotto took one picture every four seconds.
Glasnost: Soviet domestic mechanism equivalent to liberal democracy.
Glonass: Soviet navigation satellite system equivalent to Navstar.
GOES: Geostationary Orbit Operational Environment Satellite, a series of meteorological satellites operated by the NOAA in conjunction with its Tiros polar-orbiting spacecraft.
GPS: Global Positioning System.
GTO: Geostationary Transfer Orbit (see Annex).

H-1 and H-2: Expendable launch vehicles being developed in Japan by Nasda, with the H-2 planned to place heavier satellites in orbit than the H-1.
Helios: Proposed French optical reconnaissance satellite system, expected to be operational in 1993.
Heos: European scientific satellite, to investigate interplanetary magnetic field.
Hermes: A mini-shuttle spaceplane proposed by France, to be launched by Ariane 5, designed to undertake manned operations in orbit for up to one month. The preliminary studies and contracts were approved by ESA in November 1986.
Hipparcos: An ESA space science craft, designed to measure the positions, parallaxes and motions of about 100,000 stars and due to be launched by Ariane in 1988.
HM-60: Large European cryogenic engine to be developed for Ariane 5.
Horizon 2000: Long-term European space science programme proposed by European scientists' panel in 1984. It envisages four 'cornerstone' elements: X-ray research, solar observation, plasma research and a cometary science project.
Hotol: Horizontal Take-Off and Landing Vehicle. Proposed British concept for a re-usable and man-rated spaceplane. It would make a novel combination of new air-breathing and conventional rocket technology in a single-stage vehicle.
HRV: High Resolution Visible.
Hubble Space Telescope : This will be the largest instrument ever orbited when it is launched by Nasa. It is to be maintained in orbit for 15 years, though instruments will be replaced. Among ESA's contributions are the Paint Object Camera and the solar arrays.
ICAO: International Civil Aeronautical Association.
ICBM: Inter-Continental Ballistic Missile.
Ice : International Cometary Explorer. Formerly the third International Sun-Earth Explorer, Nasa's ISEE-3 was redesignated Ice. It conducted the first close encounter with a comet in the autumn of 1985.
ICR: (Dutch) Interdepartmental Committee on Space Research and Technology.
IEPG: Independent European Programme Group, a European grouping for collective defence procurement.
IGBP: International Geosphere Biosphere Programme, an international study of global change.
IMO: International Maritime Organization.
Inmarsat: International Maritime Satellite Organization, based in London and operating since 1982; offers a system of satellites to provide telephone, telex, data and facsimile, distress and safety communications

services, for the shipping and offshore industries. It leases the Marecs A and B2 spacecraft from ESA, maritime communications subsystems from Intelsat, and three Marisat satellites from Comet. It is now procuring a second generation of spacecraft of its own. Inmarsat is financed by the designated signatories – the PTTs – of the 48 member countries, which include the USSR and other Eastern bloc countries, each with an investment share based on usage.

Insat: The Indian series of satellites, which combine telecommunications, direct broadcasting by satellite and weather-imaging in a single geostationary orbit craft. The operational network is for two satellites, which were built by Ford Aerospace. Insat 1A was abandoned five months after launch.

Intelsat: International Telecommunications Satellite Organization, based in Washington since 1965; owns and operates over two-thirds of the satellites used for international communications. With some 112 member countries, Intelsat operates as a financial cooperative, with investment shares linked to usage.

Intospace: European consortium led by MBB and Aeritalia to encourage private investment and commercial development in microgravity.

Intersputnik: CMEA/Soviet allied communications satellite system.

Iras: Infra-red Astronomical Satellite, Dutch-built for US-Dutch-UK research programme. Launched 1983.

Iris: Italian Research Interim Stage, a propulsion project for launchers.

IRS: Indian satellite for Earth observation.

ISAS: (Japanese) Institute for Space and Astronautical Sciences.

ISEE: International Sun-Earth Explorer.

ISMA: French-proposed international satellite monitoring agency.

Iso: Infra-red Space Observatory, an ESA space science project, intended to complement Nasa's space telescope, and to offer high sensitivity observing facilities for a large region of the electromagnetic spectrum. The satellite will be launched by Ariane in the late 1980s.

ISRO: Indian Space Research Organization.

Italsat: Italian telecommunications satellite, scheduled for launch in 1988.

ITU: International Telecommunications Union.

IUE: International Ultraviolet Explorer, a joint project between the SERC, ESA and Nasa, launched in 1978 to provide an observatory facility for ultraviolet spectrometry.

IVA: Intravehicular Activities.

Kopernikus: See under DFS/Kopernikus.

Kosmos: Soviet satellite series begun in 1962. Kosmos is a blanket term for Soviet military applications.

Landsat: The most important range of remote-sensing spacecraft so far, this American series flies in near-polar orbit at an altitude of about 900 km. The primary use of the five spacecraft is US crop forecasting and land surveying. A significant secondary purpose has been to provide data to numerous other countries, a number of which operate Landsat ground stations.

LDC: Less Developed Country.

LEO: Low Earth Orbit (see Annex).

Long March 2 and 3: Chinese ELVs.

LPI: Low Probability of Intercept.

L-Sat: Renamed Olympus.

LUA: Launch Under Attack.

Marecs: Maritime telecommunications satellites developed by ESA. Marecs A was launched in 1981 and Marecs B2 in 1984. These satellites are leased to Inmarsat.

Marisat: Maritime communications satellites developed for Comsat by Hughes.

Marots: ESA's Maritime Orbital Test Satellite.

Mesh: European industrial consortium of Aeritalia, British Aerospace, Erno, Matra and Saab.

Meteosat 1 and 2: Meteorological satellites developed by ESA and launched in 1977 and 1981. The Meteosat operational programme began in 1983.

Milstar: Military Strategic-Tactical and Relay.

Mir: Soviet space station.

Molniya: Elliptical orbit developed by USSR (see Annex).

MOU: Memorandum of Understanding.

MTFF: Man-Tended Free Flyer, proposed element of Columbus.

N-1 and 2: Expendable launch vehicles developed in Japan for Nasda by Mitsubishi Heavy Industries.

NACISA: Nato Command Informations System Agency, replacing NICSMA.

Nasa: National Aeronautics and Space Administration of the USA, founded in 1958.

Nasda: National Space Development Agency of Japan, founded in 1969.

Nato: North Atlantic Treaty Organization.

Nato III: The current generation of Nato communications satellites, which provide secure links within Europe and to the USA. The operational network comprises four satellites, one of which is a spare. The satellites are interoperable with the US DSCS series. Skynets built for Nato will provide the next series.

Navsat: Developed to provide precise positional updates to Polaris submarines. (Navsat is also the name of an ESA navigational satellite proposal under consideration.)

Navstar: A series of US DoD spacecraft using the Global Positioning System to provide continuous, worldwide and 3-D position, velocity and time checks. The full service is due to become available in 1989, when the planned constellation of 18 spacecraft is complete. The system will also accommodate an unlimited number of civilian users, who will receive slightly less accurate information.
NDS: Nuclear Detection System (US).
NICS: Nato Integrated Communications System.
NICSMA: Nato Integrated Communications Management Agency, now replaced by NACISA.
Nimbus: US remote-sensing system.
NIVR: Nederlands Instituut voor Vliegtuigontwikkeling en Ruimtevaart, Dutch Agency for Aerospace Programmes.
NOAA: National Oceanic and Atmospheric Administration (US).
NRL: National Aerospace Laboratories (Dutch).
NTM: National Technical Means (of verification of arms control agreements).
Olympus: Formerly L-Sat, this will be a new generation of large European communications satellites, developed by ESA. Olympus 1 will be a test satellite, combining DBS, business telecommunications and experimental communications payloads. One of the two DBS transponders on Olympus 1 will be available to the EBU for a three-year experimental period; the other DBS transponder will be used by the Italian broadcasting organization, RAI.
Orion: The first of six American communications companies to file applications with the Federal Communications Commission for the operation of private transatlantic telecommunications satellite systems in competition with Intelsat.
OTS: Orbital Test Satellite, developed by ESA for telecommunications experiments within Europe; launched in 1978.
Palapa B: The second generation of telecommunications spacecraft built for Indonesia. After the successful launch on the Shuttle of Palapa B1, the second craft was placed in the wrong orbit and was one of two satellites successfully rescued by the Shuttle in November 1984 at the instigation of the mainly London-based insurance underwriters. It is now up for resale.
Phobos: Soviet interplanetary space probe.
Progress: Soviet automatic cargo spacecraft.
Proton: Expendable Soviet launch vehicle.
PSN: National Space Plan (Italy).
PTT: Post, Telegraph and Telephone organization.
Race: Research and Development in Advanced Communications Technologies for Europe (EC programme).

Radarsat: A Canadian satellite which will fly in LEO to monitor Arctic ice conditions and Canadian renewable resources such as crops and forests. The first spacecraft was due to be launched in December 1990 on the Shuttle.
Rorsat: Radar-equipped ocean surveillance satellite.
Rosat: A German-sponsored scientitic satellite with some US and UK involvement. It was due to be launched on the Shuttle in 1987, and is intended to complete an all-sky survey of X-ray sources as well as a detailed observation of specific sources.
Sänger: Proposed German concept for a re-usable and man-rated space-plane, taking off and landing horizontally. One stage of it would use novel air-breathing technology, and the other (conventional) rocket propulsion.
Salyut: Soviet space station.
Samro: French Satellite Militaire de Reconnaissance Optique (now overtaken by Helios).
SAR: Synthetic Aperture Radar.
Sarsat: See Cospas-Sarsat.
Satcom: Term for military communications satellites.
Saturn: American heavy-lift launcher.
Sax: Italian scientific satellite.
Scout: US ELV used for small payloads.
SDI: Strategic Defense Initiative. US programme to explore a range of strategic missile defence technologies, many of which will depend upon deployment in space.
SEA: Single European Act.
Semyorka: Soviet launcher.
SERC: Science and Engineering Research Council (UK).
SES: Société Européenne des Satellites, DBS consortium.
SHF: Super-high Frequency.
Sicral: Italian military communications satellite system, to be used also by police and civil defence agencies, under AM-136 programme.
Sirio: Italian telecommunications satellite, launched 1977.
Skylab: US space laboratory, placed in orbit in the early 1970s and now disintegrated, originally the Apollo Applications Program.
Skynet: British military satellites for strategic and tactical communications between ships and both fixed and mobile land terminals. Skynet 4A was due to have been launched by the Shuttle in 1986. A further two spacecraft in the same series (Skynets 4B and 4C) are being built for launch by the end of 1988.
SLBM: Submarine-Launched Ballistic Missile.
SLV: Indian launcher.
SL-X-16: New Soviet launcher.

Soyuz: Series of manned Soviet space vehicles.
Spacelab: A re-usable and modular manned laboratory designed to fly in the cargo bay of the Shuttle, as ESA's contribution to Nasa's STS. By the terms of the agreement negotiated with Nasa by ESA, Spacelab became the property of Nasa after its first flight.
Space station: This will provide for a permanent, manned presence in space. Economic summit countries and ESA members were invited by President Reagan during his 1984 State of the Union address to make it an 'international' project. In January 1985 ESA agreed to take part in the initial design stage (Phase B) through the Columbus module, and associated free-flying, unmanned platform. Negotiations for intergovernmental agreements between America and participating countries began in September 1985. Both Canada and Japan are also taking part in Phase B studies.
SPAS: Shuttle Pallet Satellite, built in Germany.
Spot: Satellite pour l'Observation de la Terre, French-built for Earth observation. Spot 1 was launched in 1986 and three more are planned over 10 years.
Spot Image: The company, backed by the French government, with small contributions from Belgium and Sweden, which aims to make remote sensing from Spot a commercial enterprise.
SRON: Space Research Organization of the Netherlands (Stichting Ruimte Onderzoek Nederlands).
SSBN: Ballistic-missile-carrying nuclear submarine.
Star: European industrial consortium of British Aerospace, Dornier, SEP and Thomson.
STAR: Special Telecommunications Action for Regional Development (EC programme).
STS: Space Transportation System, better known as the Shuttle, is Nasa's largest programme since the Moon landings. It was conceived in 1972 as a replacement for all existing expendable civilian and military boosters. The first Shuttle flight, the orbiter Challenger, took place in April 1981. The loss of Challenger in January 1986 has grounded the Shuttle until at least mid-1988.
STW-2: Chinese telecommunications satellite.
Symphonie A and B: Early Franco-German communications satellites, launched in 1974 and 1975.
Syracuse: French military communications network, in operation since 1984.
TDF-1 and TDF-2: The French version of the Franco-German DBS craft, being built by Eurosatellite, a consortium of Aérospatiale, MBB, AEG Telefunken, Thomson, and ETCA of Belgium. TDF-1 was due to be launched on Ariane in 1986, and be operational from the start of 1987

with four channels. A second craft has been ordered to provide a fifth channel and a back-up service. A French commercial company, Télévision par Satellites, will lease the satellites from the French government.
Télécom 1: France's first domestic telecommunications satellites; the series provides business data and videoconferencing facilities in France, long-distance telecommunications to its overseas departments, and military communications.
Titan: Expendable launch vehicle developed for US Department of Defense by Martin Marietta.
Topex-Poseidon: French-US project on oceanographic satellites.
Transpace Carriers, Inc. (TCI): Started in 1982 by a group of Nasa technicians to exploit the US administration's decision to allow private companies to launch rockets, the organization secured the agreement of McDonnell Douglas to build the Delta rocket for it.
TSS: Tethered Satellite System, developed in Italy with US.
TV-Sat: Designed as the German equivalent to TDF-1, was due for launch in May 1986, but disagreements between the Federal and Land governments have delayed its development.
UHF: Ultra-high Frequency.
Ulysses: A joint ESA space science/Nasa project (formerly the International Solar Polar Mission) to investigate solar wind, the sun/wind interface, solar and galactic cosmic rays, cosmic dust and other phenomena. Ulysses was to have been launched by the Shuttle in 1986. After a 14-month journey it would be within Jupiter's gravitational field, and the entire mission would last five years.
Vega: Soviet interplanetary space probes.
VSAT: Very Small Aperture Terminal, a small antenna-sized satellite signal reception system.
WARC: World Administrative Radio Conference.
WEU: Western European Union.
WMO: World Meteorological Organization.
X-30: US National Aerospace Plane, a proposed hypersonic re-usable and single-stage vehicle, under study since 1986.
Zircon: Proposed British Elint satellite.

CHATHAM HOUSE SPECIAL PAPER

EUROPE'S FUTURE IN SPACE

Forschungsinstitut der Deutschen Gesellschaft für Auswärtige Politik (Bonn)
Institut Français des Relations Internationales (Paris)
Istituto Affari Internazionali (Rome)
Nederlands Instituut voor Internationale Betrekkingen 'Clingendael' (The Hague)
Royal Institute of International Affairs (London)

European space policy stands at the crossroads. The exploitation of space will play an increasingly important role in the economic and political future of Western Europe. Although Europeans together have a solid record of achievement in space, they have not yet developed the capabilities to match their potential. There is fierce competition with the US and Japan to provide the technologies. The US and the USSR are driving forward their military space programmes. This report argues the importance of establishing European autonomy in space and of ensuring that the Europeans have the means to safeguard their own security interests in space.

This English-language version is published by the Royal Institute of International Affairs. Dutch, French, German and Italian versions are being published simultaneously by the other institutes.

ROUTLEDGE & KEGAN PAUL

ISBN 0-7102-1444-8

9 780710 214447

Cover photograph:
Daily Telegraph Colour Library
Cover design: 20/20 Graphics

Price £9.95 net

ISSN 0143-5795