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(Second Part)

Co-operation between European space research institutes

REPORT

submitted on behalf of the Technological and Aerospace Committee
by Mr. Galley, Rapporteur

ASSEMBLY OF WESTERN EUROPEAN UNION
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1. Adopted unanimously by the committee.

2. *Members of the committee:* Mr. *Lopez Henares* (Chairman); MM. Lenzer, *Borderas* (Alternate for Mr. Palacios) (Vice-Chairmen); MM. Arata, *Atkinson*, Biefnot, Blaauw, Mrs. Blunck, MM. Böhm, Coviello, *Curto*, Mrs. Gelderblom-Lankhout, Mrs. *Guirado*, MM. Jeambrun, Le Grand, Litherland (Alternate: *Alexander*), Lorenzi, *Marshall*, Poças Santos, Pozzo, Roger (Alternate: *Galley*), Sarens, *Theis*, Sir Donald Thompson, MM. *Valleix*, Wolfgramm.

N.B. *The names of those taking part in the vote are printed in italics.*

Draft Resolution

on co-operation between European space research institutes

The Assembly,

(i) Considering that space research is essential for meeting the challenges of guaranteeing the scientific standing, economic competitiveness and political autonomy of Europe;

(ii) Reaffirming that only an integrated Europe will be able to take up the challenge of space;

(iii) Considering that European co-operation in certain sectors of space is an example of the achievements to which our countries can aspire by uniting their efforts;

(iv) Noting with satisfaction that space research has enabled our continent to attain a high level of technology and goals which were almost inconceivable quite recently;

(v) Believing that this considerable progress is largely due to the existence and the rôle of the European Space Agency;

(vi) Welcoming likewise the remarkable work done by the national space research institutes;

(vii) Noting the present need for ever more investment, which is increasingly difficult for states to meet in isolation, is encountering ever tighter budgets;

(viii) Noting furthermore that the absence of an overall strategy on a European scale is leading to the duplication of efforts by the various countries;

(ix) Considering that this dispersion is leading to competition, excess capacity and overlapping programmes and infrastructures;

(x) Believing that WEU member states must co-ordinate their research policies if they wish to use available funds more efficiently, thus avoiding their dispersal and contributing to the creation of new synergies;

(xi) Considering that Europe is lagging behind to some extent in the military uses of space as compared with the United States;

(xii) Taking account of the fact that there is insufficient co-operation at present in military space research and that such co-operation is essential for the security and political independence of Europe;

(xiii) Believing that it is essential to exploit existing synergies between the civil and military sectors of space in order to give impetus to the technological and industrial development of space applications;

(xiv) Welcoming moreover the major contribution of national space research institutes to following up and evaluating feasibility studies for the future European space-based observation system;

(xv) Warmly appreciative of the initiative of the various European space research institutes in moving towards a convergence of their work on aeronautics,

INVITES THE GOVERNMENTS OF MEMBER COUNTRIES

1. To create a study group composed of representatives of governments and national space research institutes with the following aims:

(a) lay the foundations for an overall European space strategy;

(b) promote a more rational use of available resources, be they economic, technological, human or infrastructure, in order to avoid as far as possible excess capacity, competition, and, in short, duplication of effort and expenditure;

(c) establish the bases for close co-operation between national space research institutes similar to that already existing between them in the aeronautics sector;

(d) foster greater harmonisation between the national space research institutes and ESA so as to achieve greater coherence in existing programmes and derive optimum advantage from closer co-operation between these institutes;

(e) give priority to the military space sector in order to develop European independence in space matters and also to take account of the fact that military applications of space in large measure coincide with civil applications;

(f) study the possibility and expediency of amending the ESA Convention so as to enable ESA also to devote its efforts to certain very specific areas of the military space sector;

(g) reflect on the need to establish a co-ordinated strategy for the national space research institutes, ESA, the European Union, WEU and other organisations concerned with space in order to achieve a more efficient use of available resources;

(h) take steps to ensure that the national space research institutes develop closer working relationships with establishments working in related or complementary branches and that they maintain the same type of relationship with industry in order to enable the results of their research to be transferred and applied;

(i) invite WEU associate member countries, associate partners and observers to participate in this study group.

Explanatory Memorandum

(submitted by Mr. Galley, Rapporteur)

I. Introduction

1. It is now recognised that space is a key factor of power in the modern world and must be regarded as a major platform for nations to demonstrate their scientific, technological and industrial capabilities. It is therefore extremely important in every respect for Europe to play an active rôle in space research.

2. The volume of European public expenditure on space has not to date equalled that of the United States. Europe has nevertheless developed very substantial expertise in many space sectors thanks to the successes of ESA (European Space Agency), the ambition of certain national space programmes and the very high level of expertise among the scientific community. Europe's achievements in space matters are therefore very positive and enable our continent to be ranked among the first on the world technological scene.

3. European co-operation in space matters is an example of the best our countries are able to do when they join forces. Indeed, ESA is a remarkable example of success in European integration and collaboration.

4. However, Europe cannot rest on its laurels. It must strengthen its cohesion and increase its efforts to meet, under optimum conditions, the challenges thrust upon it by a period in which achieving or maintaining a degree of competitiveness is the more difficult as growing numbers of large new countries are demonstrating their intention of gaining a leading position. This situation, together with budget constraints everywhere, calls for ever-increasing levels of investment which cannot readily be borne by each state in isolation. The space challenge can only therefore only be met effectively at the scale of Europe as a whole.

5. Various European countries have often large national programmes which are advancing in parallel with European co-operative programmes. There is a perceptible trend towards a proliferation of effort by each country in an attempt to carve out for itself the best or even the largest " slice " of a space Europe. This situation is indicative of the relative absence of an overall strategy in the area of space research.

6. For this reason, the Technological and Aerospace Committee has decided to devote a report to co-operation between European space research institutes.

II. What is at stake in space research?

7. Various reasons (national prestige, support for advanced science and technology, industrial and commercial factors, the decisive rôle of space technology in security and defence matters, etc.), may be at the root of involvement in numerous space programmes, but ultimately space research is essential above all, as has already been stressed, for meeting the scientific and technological challenges that will allow us to build our future and thus safeguard our scientific edge, our economic competitiveness and our political independence.

8. However, space must not be regarded as an area apart; many of the results of space research find application in industrial production and scientific and technological know-how. They thus contribute to maintaining industrial and technological centres in Europe.

9. Major challenges face our countries today and in the immediate future. Military space, an area in which our continent lags well behind the United States, must be considered as the main sector of our activity, not only in order to be able to develop our autonomy in defence matters, but also because military space applications, in large measure, overlap with civil applications. Europe must follow this course in order to allow the space industry to maintain a degree of competitiveness vis-à-vis the space industry of the United States.

10. Launch systems, for which space Europe has had outstanding industrial and commercial success, space-based communications, which have a very large growth potential and earth observation, the applications of which are very wide-ranging indeed, are so many areas in which it is essential for us to have expertise.

11. Scientific programmes, even if not directly linked at the outset to commercial markets, are the source of space equipment and applications and the laboratories for the space industry; this justifies a more ambitious approach commensurate with the excellence of the skills and knowledge available.

12. There are still further areas which may act as catalysts in the development of the European space industry and open up new prospects. Your Rapporteur is thinking in particular of research activities linked with a weightless environment, which seem interesting for high added value industrial applications; optical intersatellite links providing high information flow by low power

transmission; space-based radio communication; mini-satellites, space robotics, rendez-vous sensors, etc.

13. The whole range of space-based applications is therefore a source of major industrial and commercial opportunities, either existing or potential. It is imperative for Europe to provide backing for their development and testing, to enable our industry to compete on the market for the new products or services, some of which are mentioned in very futuristic studies but which evade us today.

III. National frameworks

(a) Germany

(i) DARA (Deutsche Agentur für Raumfahrangelegenheiten)

14. Germany founded the German Space Agency (DARA Deutsche Agentur für Raumfahrtangelegenheiten) as a central management organisation of German space matters in the summer of 1989; the federal government is the sole shareholder. As it has developed, DARA has been steadly invested with growing responsibilities: the Federal Ministry for Research and Technology (BMFT), for example, has delegated responsibility for managing its space programmes to DARA [1].

15. DARA's legal status as a company with limited liability (GmbH), guarantees the necessary flexibility and the desired proximity to industry. The Cabinet Committee on Space Activities [2] is responsible for advising the federal government on space policy decisions as well as fundamental strategic and planning aspects. Funds are made available to DARA from the budgets of the responsible ministries. The Cabinet Committee's work is prepared by a State Secretaries' Committee on Space chaired by the Secretary of State in the BMFT [3].

16. DARA's functions can be summarised as follows: to draw up plans for German space policy for approval by the federal government by planning German participation in international programmes and projects, planning national projects with due consideration for European, bilateral, and multilateral programmes, providing technological, economic, and financial recommendations, analyses, and project proposals; to implement German space programmes and to award contracts and grants to industry and to scientific and research bodies by advising the federal ministries and public institutions involved, promoting, directing and monotoring projects, evaluating their results, planning and coordinating operating facilities, providing initiatives to promote commercialisation, allocating funds from the space budget in accordance with its statutory authority and determining financial requirements; to represent German space interests in the international arena, particularly within the European Space Agency.

17. Germany participates in most areas of space activities. In manned space flight, attention in 1993 should focus on the MIR mission, a joint project of the former Soviet Union and Germany and the national D-2 Spacelab mission, with the participation of NASA, ESA, CNES and a consortium of Japanese firms. In space exploration, the German programme is concentrated on the provision of instruments and additional flight opportunities through participation in long-term multilateral and bilateral projects. In launch rockets, German programmes have always been concluded as a part of European co-operation in ESA. Germany is also very active in satellite communications, earth observation, space flight and space flight systems. It is possible for management of military space programmes to be assigned to DARA.

18. The 1994 programme budget is around DM 1.37 billion, 74% of which is allocated to ESA.

(ii) DLR (Deutsche Forschungsanstalt für Land-Und Raumfahrt e.V)

19. Today, the DLR [4] is the main scientific and technical research institute in Germany, with approximately 4 000 collaborators (1 170 in the space sector) and a budget of DM 700 million (some 340 million of which are devoted to space). It has research centres in Berlin-Adlershof, Braunschweig, Göttingen, Köln-Porz, Lampoldshausen, Oberpfaffenhofen and Stuttgart.

20. DLR is a multi-mission research organisation engaged in aeronautics (45% of total human resources), space (35%) and energy-related research (20%).

1. Today, DARA manages approximately 500 current projects and studies and awards contracts to around 130 institutes and firms (the close partner in this context is the DLR).

2. Under the chairmanship of the Federal Chancellor, the Cabinet Committee has the following members: the Head of Federal Chancellary, the Foreign Minister, the Ministers of Finance, Economy, Defence, Transport, Research and Technology and Posts and Telecommunications.

3. The Technical and Scientific Advisory Board is made up of representatives of the scientific community and industry. The specialist advice provided by the Board ensures that scientific and economic requirements are taken into account by DARA when drawing up and implementing space programmes.

4. The DLR (Deutsche Forschungsanstalt für Luft-Und Raumfahrt e.V) was created in 1969 from the merger of Aerodynamische Versuchsanstalt Göttingen e.V., Deutsche Versuchsanstalt für Luftfahrt and Deutsche Forschungsanstalt für Luftfahrt; until March 1989 it went by the name Deutsche Forschungs- und Versuchsanstalt für Luft- und Raumfahrt e.V. (DFVLR).

21. In essence, DLR's rôle is to bridge the gap between basic research in academia and technology development by industry, to operate large test facilities for the benefit of scientific and industrial users and to provide expertise for national authorities.

22. DLR's technical expertise lies with the institutes of its five scientific research departments: Flight Mechanics/Guidance and control (Institute of Flight Mechanics, Institute for Flight Guidance, Institute for Flight Systems Dynamics and Robotics, Institute for Aerospace Medicine, Aerospace Psychology Section, Transport Research Division); Fluid Mechanics (Institute for Theoretical Fluid Mechanics, Institute for Experimental Fluid Mechanics, Institute for Propulsion Technology, Institute for Design Aerodynamics); Materials and Structures (Institute for Structural Mechanics, Institute for Aeroelasticity, Institute for Materials Research,; Institute for Space Simulation, Institute for Structures and Design); Telecommunications Technology and Remote Sensing (Institute for Telecommunications, Institute for Radio Frequency Technology, Institute for Optoelectronics, Institute for Atmospheric Physics, Institute for Planetary Research, Institute for Space Sensors) and Energetics (Institute for Technical Physics, Institute for Technical Thermodynamics, Institute for Physical Chemistry of Combustion, Institute for Chemical Propulsion and Chemical Engineering).

23. The scientific-technical facilities include the German Space Operations Centre (GSOC) in the research centre at Oberpfaffenhofen and the division crew operations and astronauts office, central data processing, flight operations and wind tunnels, applied data technology, and the German remote sensing data centre (DFD).

24. DRL's involvement in space research and development is closely co-ordinated with the German space effort. Under national space policy, co-operative European and bilateral programmes are the preferred modes of operation. Less than one third of Germany's space budget is reserved for purely national activities. The domestic space programme currently does not foresee the creation of national space orbital infrastructure or space transportation assets. Unlike CNES, therefore, DLR is not engaged in technology work for fully-fledged space systems, but concentrates on specific areas of strength.

25. DLR's space competence relates mainly to:

- space vehicle and experiment operation: the German Space Operations Centre (GSOC) of the DLR is responsible for preparing and staging manned and ummanned space projects with the tasks of communication with space missiles via ground station and data-relay satellites; measuring orbits, predicting place and speed, as well as planning out-orbital corrections; determining and controlling the orientation of satellites and probes in space. Because of DLR's unique experience with manned Spacelab flights, the BMFT made an offer to ESA in 1987 that gives GSOC the responsibility for all manned space laboratory flight operations within the Columbus programme; substantial national advance funding was made during the period 1987-92 with the installation of the Manned Space Laboratories Control Centre (MSCC) consisting of a control centre building equipped with a basic flight operations infrastructure, as well as a high-bay area to house operations mission sequence simulators (OMSS) for the attached laboratory and the free flyer. EPOS (European proximity operations simulator) test facility for rendez-vous and docking of spacecraft will be developed jointly by the DLR and ESA which is affiliated to the MSCC.

  The GSOC operates mobile rocket launches for carrying out Germany's high-altitude research rocket programme and, in addition to space missions, the GSOC also conducts research and development work to support these programmes in the field of future technologies (particularly dynamics and control of space-travel structures).

- Space propulsion systems testing: there are 5 test facilities at DLR's test site at the Institute for Chemical Propulsion and Engineering in Lampoldshausen. The Institute's main objectives are the provision and operation of test facilities for space propulsion systems and research and development in energetics and propulsion technology. A major objective of the Institute is the design and contract test facilities for space propulsion systems which are operated on behalf of European space agencies (ESA, CNES) and in co-operation with the European space industry. Test facilities are provided for the development and qualification of liquid propellant rocket engines and complete stages of rocket launchers, including propulsion systems for satellites and interplanetary space problems. Work focuses on development and qualification of the 900 KN Vulcain hydrogen/oxygen engine designed to power the main stage of Ariane 5. An important activity of the Institute, partly in co-operation with the CNES, is research and development in energetics and propulsion technology.

- Remote sensing[5] : DLR has developed a variety of optical and microwave sensors which were successfully flown and operated on various shuttle missions. DLR has established a national remote sensing data centre to serve users nationally and worldwide. In addition, a processing and archiving facility (PAF) has been set up under ESA contract as part of the European Earthnet infrastructure. Concerning data interpretation, DLR is one of Europe's leading authorities in remotely sensed data product generation and it has special expertise in Algorithms for radar image interpretation. DLR remote sensing efforts are currently organised in two institutes (one for optical and one for microwave remote sensing) and in the German remote sensing data centre (DFD) in Oberpfafenhofen[6].
- Microgravity: Germany's scientific competence in microgravitational research is internationally recognised[7]. The payload for the D-2 April 1993 mission included facilities to be used by the astronauts, and instruments operated automatically. One might recall the semiconductor experiments, in which two different heating facilities were used within the Medea payload (material sciences experiment double-rack for experiment modules and apparatus); Anthorack, a special medical research facility developed by ESA (for this laboratory Germany provided some important experiments), the robotic technology experiment (Rotex), and the newly-developed photographic system MOMS-02 (modular optical multispectral scanner)[8]. For supporting the spacelab payload elements Anthorack, and Medea on D-2, DLR developed a ground support programme equipment (GSPE) to acquire, process and store realtime measurement data. DLR is the host of ESA's European Astronaut Centre (EAC).

26. To conclude we have to remember that DARA and DLR advise national defence and intelligence authorities on the use and potential of space-based observation means. Moreover, DLR is involved, on behalf of the German Government, in WEU's satellite observation study and data interpretation.

(b) Spain

27. Spain does not have a specific national space plan. Activities related to space are spread among several organisations (ministries, public research centres, universities etc.); there is no centralised government body in charge of a national policy on space matters. The CDTI (Centro para el Desarrollo Técnico y Industrial) represents Spain in ESA; the CICYT (Spanish Commission for Science and Technology) is an interministerial agency for co-ordinating and funding research and development projects within the research and development national plan. This national plan gives institutional support for scientific, technical and industrial initiatives in various disciplines, among them space activities.

(i) INTA

28. INTA (National Institute for Aerospace Technology) is an independent organisation with a legal personality and its own assets which falls within the area of responsibility of the Secretary of State for Defence. Since its foundation in 1942, it has become the true Spanish centre for the development of aeronautics technology to which space technology has been added.

29. Under the Science Act of 1986, the Institute acquired the status of public research body specialising in research and development in aerospace technology and was given specific functions allowing it to administer and implement national and sectoral programmes assigned to it by the CICYT (Spanish Commission for Science and Technology), the Ministry of Defence or other relevant government departments.

30. INTA's mission is to raise technological standards in the Spanish aerospace industry in its specialised fields through its own research and technology development programmes or programmes undertaken in collaboration with industry and other centres of research and development, with emphasis on areas of interest; INTA must also have the necessary means at its disposal to manage aeronautical and space programmes of national interest at the request of government and particularly of the Ministry of Defence; it must provide quality services through various establishments for experimental testing and through specialisation; lastly, it should encourage advanced technology transfer, while providing efficient backing to industry and government and in particular the Ministry of Defence.

5. DLR's remote sensing activities are not solely of a civilian nature; radar-related work is being co-funded by the Ministry of Defence.

6. The DFD has so far been involved in balloon launches in the South of France and Sweden and, as a part of the national Atmos programme, a stabilisation system for the Mipas (Michelson interferometer passive atmospheric sounder) balloon was developed and represents a new generation measuring equipment in environmental research. Mipas was selected by ESA as a sensor for the polar platform.

7. The German Government took the initiative which led to the development of the space laboratory spacelab under the supervision of ESA in 1983. The first flight was on board the NASA space shuttle. The first German Spacelab mission, D-1, followed in 1985 and D-2 in April 1993.

8. A variant of MOMS will be flown on the European polar platform.

31. At 31st December 1993, INTA employed 1 364 staff; its investments stood at 12 billion 569 million pesetas (666 million in 1989). Increases in investment over the last five years demonstrate the effort made to equip the Institute with facilities adapted to the rôle it was soon to play in the development of Spain's aeronautical and space industries and of its armed forces.

32. The principal research and development activities of the INTA laboratories are centred around four major technology programmes: Minisat, Capricornio, SIVA and SAR. A large number of research activities have been undertaken in parallel with these major programmes.

33. The aim of INTA's mini-satellite programme (Minisat) is to provide the Spanish aerospace sector with the means of designing, manufacturing, testing and operating a full space-based system and its associated ground sector so as to enable space-based devices of 100-200 kg weight to be placed in orbit. In 1993, technical research began on the TTC (tracking, telemetry and command) antenna to be installed on Minisat and providing ground control of the platform and on board instruments; the development of instruments to be carried on board the satellite has also begun.

34. Three scientific experiments will be conducted from the first Minisat (launch scheduled for 1995): EURD (an instrument for studying diffuse radiation from outer space in the far ultraviolet band); CPLM for studying the physical deformation of a liquid bridge subject to different acceleration conditions within a weightless field, and LEGRI (a technological demonstration device designed to test the feasibility of constructing a new generation of telescopes).

35. The aim of the Capricornio programme is to provide INTA and the Spanish aerospace industry with the technology necessary to develop a microsatellite launcher for exclusively civil applications. In view of the increasingly marked tendency towards ever smaller and cheaper satellites, INTA has selected a microsatellite launcher capable of launching a payload of 50 kg to an altitude of 600 km in polar orbit. The development phase as such will boost work on propellants in Spain; the establishments of the Institute working in this area have received additional support to this end.

36. The present programme envisages the development of a wholly national two-stage solid propellant demonstration vehicle. Thanks to this vehicle, it will be possible to conduct in-flight testing of all Capricornio's basic technologies. A study has begun of a launch site on the Canary Islands.

37. SIVA (integrated aerial surveillance system) will supplement military satellite observation capabilities.

38. The synthetic aperture radar (SAR) programme begun by INTA in January 1993 aims to develop technology for producing high-quality SAR images; initially this technology will allow a prototype system to be designed, manufactured and tested on board an aircraft with a view to obtaining certification of this technology. It is proposed, in a second phase, to design and produce a system for use in space that could be installed on a small-size platform of the Minisat type.

39. INTA is establishing a vast programme of research in advanced materials. In collaboration with the DLR, it has launched a programme for reciprocal certification of materials, procedures and measurement techniques used by the two institutes for composite materials. The aim of the programme is to arrive at a joint method for certifying materials used in space which might benefit ESA in its work.

40. At ESA's request, studies have begun for developing a rendez-vous mechanism and a Ku band antenna for communications from the polar platform. In the framework of the Eureca programme and in co-operation with other European centres, a start has been made on the I-Ares project (an experimental model for a planetary vehicle for exploring Mars). Furthermore, a programme for building a space manipulation arm is underway, again managed by INTA in collaboration with other European research centres. This arm will be used for maintenance and repair of satellites in orbit. INTA, together with DLR, has also embarked on a programme for developing intelligent composite material structures.

41. In space technology, the Institute has completed the connecting cabling, manufacture and certification testing of energy sources for the Golf and Virgo instrumentation of ESA's Soho scientific satellite.

42. In the course of 1993, INTA has continued its technical and scientific participation in developing the X-Spectrum (Russian astronomic observatory). It has carried out the environmental testing of the mirrors of the telescope used for the Sodart experiment (detection of X-ray astrophysical sources) and has also collaborated with the Danish Space Research Institute in continuing to develop a mass memory unit for this experiment.

43. As to the Integral satellite, besides participating in the scientific side, INTA is responsible for the design and manufacture of the real time image processing system of the optical chamber.

44. In the field of space antennae, the Institute has been involved particularly in the design and manufacture of the TTC S band antennae of the Italsat satellite and the Eureca platform. It hopes to acquire technological means for designing TTC antennae for Ku band communication satellites. These technologies are being obtained in the fra-

mework of ESA's advanced systems and technologies programme (ASTP).

45. The Institute has generated its own research in astrophysics and the atmosphere. In terms of energy use in space, it has become the official certification body for the solar batteries used in ESA space programmes.

46. It should also be noted that the Institute has provided substantial backing, both in terms of technology and management, to the Spanish Hispasat satellite communication system[9] (INTA is a 15% shareholder in Hispasat SA). Technical supervision of the Helios programme has been assigned to INTA by the Spanish Ministry of Defence as has management of the CICSAT (initial capacity of satellite communications) programme which is to start using the full potential of the Hispasat system for the communications infrastructure of the armed forces.

47. The El Arenosillo experimental centre, the southern and westermost launch site in Europe, has taken part in many scientific and technological campaigns for studying the structure and composition of the atmosphere. For the last 17 years, this activity has been supplemented by the joint organisation with the ASI and the CNES of annual campaigns using large stratospheric research balloons launched from Sicily which drift over the western Mediterranean towards the Iberian peninsula.

48. Under international agreements, INTA owns or is responsible for three space stations: the Canaries space station, one of the most important installations of which is the Maspalomas station integrated into the ESOC network and ESA's Earthnet network, the Robledo space station which belongs to the network for monitoring NASA space vehicles and, lastly, the Villafranca station, which depends on the ESOC network and is managed by INTA.

(c) France

49. The French space programme is currently the most wide-ranging in Europe. France makes the largest national contribution to ESA and has the most important civil space programme as a nation and in terms of bilateral co-operation. Moreover, France has the most ambitious military space programme in Europe.

(i) CNES (Centre National d'Etudes Spatiales)

50. Created under a law dated 19th December 1961 as a scientific and technical establishment of an industrial and commercial nature, the CNES has led France's space programme since 1st March 1962.

51. The essential tasks of the CNES are, on the one hand, to analyse the long-term challenges and trends in space activities in order to submit proposals for action and means of implementation to the French Government and, on the other hand, in application of government decisions on space policy, to conduct major development programmes both at national level and in the framework of ESA.

52. In the pursuit of its tasks, the CNES has many and diverse rôles. In association with the scientific community, it implements a programme of basic research in space matters based on the laboratories of the Centre National de la Recherche Scientifique (CNRS) and the universities; it develops partnerships with French space users (the national headquarters staffs of the armed forces, France Telecom, Meteo France, etc.); it seeks to develop expertise and innovative capacity in industries by awarding them prime contractorship and implementation of programmes whenever possible and starting research and technology programmes through them. The CNES also has an important rôle in operational use and evaluation of technical assets, as it encourages the formation of companies for marketing the space-based applications which may be either public limited companies in which the CNES is a shareholder (such as Arianespace, Spot Image, Novespace, etc.), or economic interest groupings of which it is a member (Satel Conseil, Prospace, etc.). Lastly, and in conjunction with the Ministry for Foreign Affairs, it represents France in ESA.

53. In 1994, the CNES employed 2 446 staff across its various establishments in Paris, Evry, the Toulouse space centre (preparation and development of programmes, use of operational systems, heavy equipment) and the CSG (Guyana Space Centre).

54. The budget for 1994 stands at a little over F 11 000 million (+1% as compared with 1993), more than F 9 200 million is met through state subsidies, and the remainder from its own resources. This global budget is shared between participation in ESA programmes (47.95%, + 1.15%), bilateral co-operation (5.65%, + 0.13%), the national programme (19.44%, – 1.3%), functional technical programme support (15.06%, + 0.12%) and general operating costs (11.90%, – 0.10%).

55. The activities of the CNES are divided into three main areas: space transport, applications programmes and scientific programmes.

56. In space transport, the CNES is prime contractor for the Ariane family of launchers developed in the framework of ESA, which has given Europe a high-performance means of trans-

9. Made up of two geostationary satellites, the first launched in September 1992 and the second in July 1993, and linked to a ground sector.

port. The CNES, with the CSG, also provides Europe with one of the best situated and most modern space bases in the world – the Kourou base, located in Guyana.

57. For applications programmes, mention should be made of the Spot earth observation satellites in which Belgium and Sweden also participate; Spot 1, 2 and 3 are in orbit (the latter operational since November 1993) and Spot 4 is in the process of development with an anticipated launch date during the last quarter of 1997 and from mid-1995 if necessary. The Spot 5 programme is in preparation with the aim of providing a continuous service after Spot 4.

58. The CNES, in co-operation with the European Commission, Belgium, Italy and Sweden, is developing the on board " Vegetation " instrumentation for Spot 4 which is of great interest for monitoring natural ecosystems and agricultural systems.

59. Mention should also be made of the Telecom 2 communications satellite family (A was launched on 16th December 1991, B on 15th April 1992 and C is to be launched in 1995, followed by D with a scheduled launch date of 1996).

60. With regard to military space, the CNES is participating in the studies of the future military communications system by satellite, Syracuse 3, and in the military observation satellites Helios 1 and 2 (which will share the platform and the integration and test equipment of Spot 4 with the participation of Italy and Spain). Spain has just withdrawn from the Helios 2 programme for budgetary reasons.

61. To conclude with applications programmes, the CNES is also involved in monitoring a definition of new generation platforms for the geostationary Spacebus 3000 satellites; in conjunction with ESA, it is developing the test programme for Silex (interorbital optical links) on board the Artemis satellite; it is in charge of the Argos space sector (data localisation and gathering system) of which third generation instruments are being developed which will be installed on the American NOAA advanced Tiros N satellite platforms and last but not least it is one of the founders and suppliers of the space sector of the Cospas-Sarsat programme, in which there is wide international co-operation.

62. The CNES's scientific programmes are, for the most part, carried out in a framework of multilateral co-operation in ESA or bilaterally with the United States, Russia and other countries such as Italy or Japan. The national programme specifically covers the " balloon " programmes, space geodesy, weightless flight and ground activities in support of space-based programmes. In order to participate in such missions, the CNES requires the back-up of the CNRS laboratories, universities or other bodies.

63. In astronomy, solar physics and planetary exploration, the CNES participates in the Ulysses (ESA), Iso (ESA), Soho (ESA), Cluster (ESA), Cassini and Huygens (ESA-NASA), Magellan (Venus study/NASA), Galileo (Jupiter study/NASA) missions and in the Russian Mars 94-96 programme (exploration of Mars). Furthermore, the CNES participates, by providing the image compression system, in the Clementine (DoD/NASA) mission which will make a cartographic study of the moon and the asteroid Geographos; it is also involved in the first flight of the Pronaos submillimetric telescope (for studying cosmic rays and areas of star formation) and provides the on board Sygma telescope for the Russian Granat satellite. French participation in the XMM (ESA) programme is based on a major development contribution to the Epic camera.

64. In terms of programmes for studying our own planet, its climate and more generally its environment, the CNES pursues a policy of balance and complementarity between its contribution to the ESA's ERS and Envisat 1 programmes and bilateral co-operation. It is conducting, jointly with NASA, the Topex-Poseidon oceanographic mission (whose performance is now proving to be twice as good as anticipated); in co-operation with Russia it has developed the Scarab instrument for measuring the earth's radiation, launched on 25th January 1994 on board the Russian Meteor 3 number 7 satellite and also to be carried on Envisat 1. It should also be noted that the Polder instrumentation (imaging radiometer polarimeter) will be installed in 1996 aboard NASDA's Adeos satellite (first co-operation with Japan) and that the IASI infrared atmospheric probe [10] (studied in co-operation with the ASI) will form part of the nucleus of the payload of the Métop satellites of the future European low orbit meteorological network. The CNES is also beginning a study of the stratosphere using the French-Canadian Wind ii instrument.

65. In addition to all of the above, the Stella laser reflector satellite (Spot 3), the Doris positioning system (Spot 2, and 4 are also to be used with the European Envisat-1 mission) and participation in the Danish Oersted study mission of the earth's magnetic field, for which the CNES is developing a scalar magnetometer, are contributing to the progress of research into the core of the earth.

66. As to microweight, CNES teams are currently involved in research programmes and are participating in the main missions listed below, which are either being implemented or scheduled for the coming years: Antares (July-August 1992) and Altaïr (July 1993) on the MIR space station

10. By providing temperature and humidity profiles and profiles of certain minor constituents, this will meet both the requirements of the world climatic research programme and the need for operational digital prediction of the weather.

(manned fllights, physiological, biological and materials testing) and the Cassiopée flight (scheduled for 1996); IML 1/International Microgravity Laboratory 1 (manned flight, physical and life sciences, January 1992) and Microgravity Laboratory 2 on Spacelab which, in the framework of co-operation between the CNES and NASA, will carry the Ramses electrophoresis instrumentation in the development of which the CNES has been associated with a consortium of French, Spanish and Belgian industries brought together in the Eureca Space Bio Separation project; Mephisto (October 1992 and March 1994) on a USMP platform of the American space shuttle; Eureca-1 (August 1992) on a platform launched and recovered by the Bion 10 shuttle (December 1992-January 1993); Gezon (April 1994) and the Ibis biology laboratory (October 1994) on Russian recoverable capsules.

67. Lastly, the national programme has two major focuses: the network of Spot satellites and the system for exploiting them and the research and technology programme. Action in the framework of the research and technology programme undertaken in 1994 will contribute to achieving three major objectives: *(i)* improving competitiveness in radiocommunications, maintaining the technological edge in earth observation and developing advanced instrumentation; *(ii)* continuing the effort already undertaken in the priority areas of new uses of the orbital infrastructure; *(iii)* developing basic and prospective research techniques linked to future launch equipment (propulsion etc.). Such action is accompanied by studies providing a permanent research basis which helps to maintain the technical and technological base necessary for all space-based activities.

68. The national programme also includes an important component of scientific research thanks to the balloon programme (in particular in the framework of the campaigns and research programmes backed by the European Union) and national support actions for space-based transport programmes (Ariane, MSTP).

(ii) ONERA (Office National d'Etudes et de Recherches Aérospatiales)

69. ONERA is a scientific and technical public body of a commercial and industrial type under the supervision of the Ministry of Defence and financially independent.

70. ONERA's task is to develop and guide research in aerospace matters; to plan, design and implement the necessary means for carrying out its own research and testing for manufacturers; to ensure dissemination of the results and encourage their use by the aerospace industry; to facilitate the application of these results outside the aerospace area whenever possible and to assist with training policies.

71. Apart from its basic (24% of its activity) and applied (55%) tasks, ONERA plays an important rôle between science research bodies and industry; its position, in short, is that of scientific and technical expert to official departments.

72. ONERA's activity extends to a number of areas, the main ones being aircraft (31% of its activity), space (16.8%) and military systems (15%). Other activities cover turbomachinery, helicopters and tactical and strategic missiles.

73. 1993 funding stood at F 207 million provided in large measure from grants from the French Ministry of Defence (68.4%) and the regions (2.8%), the remainder being obtained from contracts and through self-financing.

74. At 1st January 1994, ONERA employed 2 320 staff at its Châtillon, Chalais-Meudon, Palaiseau, Fauga-Mauzac and Modane-Avrieux centres, the Toulouse Centre for Study and Research, the Lille Fluids and Mechanics Institute and the ONERA-Ecole de l'Air research laboratory.

75. With regard to space, one can mention the testing of cryogenic propellants (Mascotte assembly), the ASSM (aerodynamics of segmented solid motors) programme and the TOP (thrust oscillations programme) which give rise to theoretical research and testing by CNES. The Prepha programme (research and technology programme for advanced hypersonic propulsion) for space launchers and hypersonic vehicles in the next century studies the possibility of super-ramjet propulsion; there has been aerodynamic testing of space shuttles.

76. ONERA is also involved in satellite programmes and projects: the transportable test bench using the synthetic aperture radar technique has been delivered to the CELAR to complete the Siros simulator and thus aid the definition of requirements for future military satellites.

77. The Ramses (multi-spectral airborne radar for signature research) station has been improved and has been involved in several inflight testing campaigns; progress has been made in discretion radar; lastly, a study of a system which might be a European one for monitoring space-based activity from the ground has been completed: this led to the launch of a new operation which aims to develop over three years a specific experimental space watch radar. In parallel, studies on an optical system capable of indentifying objects in space, have been carried out.

78. ONERA constantly uses and improves upon a range of aerospace test facilities at world level with their associated instrumentations. In particular, a bank of research and industrial wind tunnels covers all of France's requirements and meets the needs of major foreign manufacturers.

Discussions have begun with agreed European organisations with a view to greater co-operation in the area of heavy equipment. ONERA is a 31% shareholder in the ETW (European trans-sonic wind tunnel), sited in Cologne.

79. In 1993, its international volume of business accounted for approximately 10% of ONERA's total budget; in space matters, it co-operated with European bodies while funding of its own research was met either by a French state body or by a European agency (ESA, WEU).

80. Its most important activities are still bilateral exchanges in Europe and co-operation actions are sometimes long term but more often short term, since they tend to be terminated when funding dries up and states' annual budgets can often be unpredictable.

81. In this context, the main partner country is Germany and the DLR co-operates in some 40 areas with ONERA; among those worthy of mention are the studies on unmanned operations and flexible structures in an ESA framework, the parallel theoretical research in the framework of the MSTP programme and analysis of materials. Bilateral co-operation with the United Kingdom has mainly taken place with the DRA (Defence Research Agency) in the framework of the AFDRG (Anglo-French Defence Research Group). Co-operation with other Western European countries is on a modest scale.

82. ONERA has particular areas of responsibility in instrumentation used for scientific purposes. The research is funded by the CNES or ESA but ONERA makes a contribution to it from its own resources. Examples of this are the grating spectrometer (an instrument for measuring components present in small quantities in the atmosphere) which was aboard the American shuttle (Atlas project) and will also be used on board MIR; this instrument has been developed in close co-operation with the IASB (the Belgian Institute for Space Aeronomy).

83. As to third countries, ONERA has links with Australia, Canada, the People's Republic of China, Israel, Japan, Russia and the United States.

(d) Italy

(i) L'ASI (Agenzia Spaziale Italiana)

84. In just a few years, Italy has evolved into one of Europe's key space powers with the third largest contribution to ESA and has invested in ambitious national projects. With a large budget deficit, Italy has recently been forced to rein in its spending on space, but has still managed to pour huge sums into important programmes.

85. In May 1988, the Italian Parliament established the Italian Space Agency, ASI (Agenzia Spaziale Italiana) with the legal status of a public corporation. Its activities are conducted under the supervision of the Ministry for the Co-ordination of Scientific and Technological Research.

86. The agency has the responsibility of promoting, co-ordinating and managing national programmes and bilateral and multilateral co-operation programmes, promoting and supporting Italian scientific and industrial participation in ESA programmes in harmonisation with national programmes.

87. A national space plan (Piano Spaziale Nazionale) was established to promote, support and control a co-ordinated programme for the scientific, technological and commercial applications of space activities as well as to promote new technological capabilities in the Italian Aerospace Industries [11]. The PSN is defined by ASI for a five-year term, with annual up-dating, for the approval of the Ministry of University and Research and final approval of CIPE (Interministerial Committee for Economic Planning).

88. Through the eighties, the Italian civil space budget rose significantly and reached almost $500 million in 1993, shared between ESA and national activities.

89. Major national programmes have been developed in many fields such as telecommunications with the Italsat programme which is a domestic preoperational communication satellite, with a highly-sophisticated communications payload, working at 20/30 GHz.

90. For space infrastructure, the Tethered satellite (TSS) [12] has been created. This is a co-operative programme with NASA [13] for a reusable multi-disciplinary facility to conduct space experiments in earth orbit. The first Italian astronaut, Franco Malerba, flew as payload specialist with the first TSS mission.

91. In space geodesy, a geodesic satellite was developed to improve the performance of the system for measuring movement of the earth's surface in co-operation with NASA. Lageos II [14]

11. A minimum of 15% of the annual plan budget is earmarked for scientific research activities.

12. TSS-1 is a spherical satellite, with two fixed booms; the Tethered system consists of two elements, the " deployer " (TSS-D) that permits the tether to be deployed and retrieved, and the satellite (TSS-S), the two elements being interconnected by a 20 km thin conducting tether.

13. NASA was given responsibility for the development of the cable deployment and retrieval mechanism, for engineering activities at system level and for the integration of the scientific experiments located on the shuttle. For its part, ASI took responsibility for the development of the satellite system and of the core equipment and the integration of the scientific experiments carried on board the shuttle.

14. The Lageos II spacecraft is composed of two separate elements, i.e. the satellite and its propulsion stage LAS (Lageos Apogee Stage).

(laser geodynamics satellite). Lageos is designed to provide a reference point for laser ranging experiments that will monitor the motion to the earth's crust, measure and understand the wobble in the earth's axis of rotation, collect information on the size and shape of the earth and determine more accurately the length of the day.

92. For space science, Sax, an X-ray astronomy satellite, was set up in co-operation with NIVR (Netherlands) to perform spectroscopic, spectral and time variability studies of celestial X-ray sources in the energy band from 0.1 to 200 Kev.

93. The Iris (Italian research interim stage), a solid-fuelled perigee stage, within the framework of space transportation, is an upper stage used in conjunction with NASA's space shuttle. Iris is capable of boosting a 1000 kg payload into high orbit (5 900 km) starting from the space shuttle's nominal parking orbit of 296 km; the system contains two modules, the Iris spinning stage (ISS) and the airborne support equipment (ASE).

94. For remote sensing, X-SAR was created to elaborate a co-operative programme with DARA and NASA to develop an x-band synthetic aperture radar to be flown on board the shuttle with the spaceborne imaging radar-C (SIR-C) as part of the space radar laboratory (SRL) for multispectral radar observation.

95. There is a ground infrastructure, which is the I-PAF, a multimission facility, located at ASI/CGS Matera, for archiving, processing and distributing remote sensing data.

96. There are other important activities under development and realisation, such as microgravity – Carina – a re-entry capsule for microgravity experiments; telecommunications with Italsat 2; for earth observation the IASI has been created and this is a co-operative programme with CNES for the development of a sounder for meteorology and atmosphere chemistry; for robotics the Spider (space inspection device for extra vehicular repairs); for space infrastructure, logistic modules have been created for the space station, in co-operation with NASA and the last one is a scientific programme, Cassini/Huygens which is an interplanetary mission to Saturn and Titan.

97. Italy, with roughly an 18% contribution to ESA's total budget, is the third member country after France and Germany. It participates in many ESA programmes, the most important of which are the following: for telecommunications, the Artemis/DRS programme, and EMS programme (mobile communications payload to be flown on Italsat F2); for earth observation, the ERS 1/ERS 2, Envisat 1, Metop 1, polar platform and meteosat second generation programmes; in-orbit infrastructure, the Columbus attached laboratory programme; for space transportation, Ariane 5 and MSTP programmes and finally for the scientific programme there is a significant Italian scientific and industrial involvement in the horizon 2000 programmes, and in particular in Soho, Cluster, ISO, XMM.

98. Italy is equipped with operational facilities such as the Centro di Geodesia Spaziale " Giuseppe Colombo " in Matera for space geodesy, remote sensing and robotics. In Trapani-Milo (Sicily), ASI has developed a modern stratospheric balloons launch in a favourable geographic position which guarantees long duration flights on the Mediterranean sea from Sicily to the western Spanish coast; besides the Odissea programme, co-operation between ASI, CNES and INTA for trans-Mediterranean flights during summer months and a collaboration memorandum with NASA, many technological and scientific activities have been planned.

(ii) CIRA (Centro Italiano di Ricerche Aerospaziali)

99. CIRA was established on 9th July 1984 by the Campania region and the main Italian aerospace industries with the aim of developing scientific and technological research and testing in the aerospace sector in order to implement the PRORA (national aerospace research programme).

100. CIRA's tasks are twofold, consisting in:

- acting as a catalyst for national aerospace research and technology by providing the industry with research and development support, encouraging the development of applied research and technology acquisition, providing public authorities with assistance in approval and control and developing basic research;
- international relations, acting as a point of reference for other research centres.

101. In January 1994, CIRA employed 149 staff[15].

102. Many research activities are being developed at CIRA in several scientific areas such as aerothermodynamics, sub-transonic aerodynamics, flight mechanics and control, propulsion, vibration and acoustics, crash analysis, high-temperature resistant materials and structures and aerospace technologies.

103. Activities in fluid dynamics began in early 1987 when the Italian Ministry for Research and Technology appointed CIRA as co-ordinator of the Italian contribution to the Hermes fluid dynamics research and development programme of ESA. The renewed interest in hypersonics and the involvement of CIRA in the Scirocco plasma

15. Staff numbers are expected to rise to 500 over the next five years.

wind tunnel project brought about the formation of a hypersonics section; activities are presently grouped around three main areas:

- manned atmospheric re-entry; CIRA is active in the European Hermes re-entry shuttle (currently included among the MSTP) particularly in experimental research;
- supersonic civil transport;
- the winged launcher.

104. CIRA is also involved in other lesser research activities on specific problems, among them the study of irreversible thermodynamics with special emphasis on the impact of real gas effects, and numerical investigation of fundamental problems (under ASI-contract).

105. In flight mechanics and control, the activities of the relevant departments have mainly been focused on stability analysis and automatic control of vehicles and dynamic system modelling and analysis, in relation both to aeronautics and space. At the request of ASI, CIRA participated in a joint research programme to study the feasibility of a flight control system for microgravity experiments. In space matters, research is centred around two main themes: guidance and control problems for reusable re-entry modules (problems dealt with include aeroassisted orbit transfers and re-entry phase of these modules) and orbital altitude control of spacecraft with manœuvrable flexible structures (particular attention has been paid to the modelling phase of these mixed structures).

106. As to CIRA's operating capabilities, the CIRA PWT (plasma wind tunnel) is one of the largest and most advanced facilities in the world for manned vehicle trajectory studies and is a development facility for materials and structures for all possible configurations of space transport systems. Ths facility is, moreover, a research and development tool applicable to supersonic propulsion systems development and obrothermodynamic research studies. The project is co-funded by ESA and the Italian Ministry for Scientific and Technological Research. The facility will be operational by mid-1997.

107. The CIRA myogenic propulsion plant (CRYP) facility is a test bench for development and approvals testing of CRYP propulsion systems. The facility has been designed with reference to approvals specifications for the IOX turbopump in Ariane 5's Vulcain MK11 engine. The CRYP test facility will be available from July 1997.

(e) The Netherlands

108. In the Netherlands, various organisations, industries and scientific institutes are active in space research and the development of space systems.

(i) NIVR (Nederlands Instituut vor Vliegtuigontwikkeling en Ruimtevaart / Netherlands agency for aerospace programmes)

109. Founded in 1946 by the Netherlands Government, the NIVR is a semi-governmental, non-profit-making agency with the general aim of promoting industrial aerospace activities in the Netherlands.

110. This general aim is translated into the following tasks for NIVR: to advise the Netherlands Government on all policy aspects of aerospace industrial activities; to initiate and monitor aerospace development programmes carried out by the Dutch aircraft and space industry funded by NIVR and using financial resources provided by the government; to initiate, monitor and fund aerospace research and technology programmes carried out by the National Aerospace Laboratory (NLR) and other research institutes as well as by Dutch industry; to represent the Netherlands Government in international projects in which the Dutch aircraft and space industry participate and for which NIRV provides the financial resources; to act as the Netherlands' national space agency, participate in the national space consultations process and provide delegates and/or advisors for the Netherlands delegation to the ESA Council, boards and committees.

111. NIVR thus acts as a managment agency for government-sponsored aerospace research and development. The agency itself does not execute research and development activities, but monitors the definition and execution of research and development activities conducted by the Netherlands industry and laboratories, both in national projects and in international collaborative projects. As the Netherlands national space agency, NIVR has many contacts with sister organisations and especially with NASA, the CNES, DARA, ASI and others.

112. Responsibility for the general policy of NIVR is shared by government (Ministries for Economic Affairs, Transport and Public Works, Defence, Finance, Foreign Affairs and Education and Science), industry and the scientific community all of which are represented on the NIVR Board.

113. Since the development of successful aerospace programmes is impossible without advanced research, NIVR also sponsors a programme of aerospace research, mainly carried out at the NLR. This programme provides for continuous research in the various fields of aerodynamics, structures, materials, flight mechanics and space sciences.

Space Programmes

114. This NIVR policy is implemented by executing national satellite programmes and by participating in ESA programmes. So far, two national satellites have been launched: the astronomical

Netherlands satellite (ANS) in co-operation with NASA, launched in 1974 and the infrared astronomical satellite (IRAS) in co-operation with NASA and the British Science Research Council, in January 1983.

115. The success of ANS and IRAS has greatly contributed to the Netherlands' knowledge and reputation in space research, space technology and industrial space activities. Following these space projects, it was decided to take a modest participation in the Italian X-ray satellite Sax to which Dutch scientists and companies contribute the wide field cameras and the attitude control system. NIVR is responsible for programme management of the Dutch share and co-operates with SRON (Space Research Organisation Netherlands) and the Italian Space Agency (ASI).

116. The major part of the Netherlands' space activities is in the framework of participation in ESA programmes.

117. Part of the Dutch contribution to the ESA earth observation programme is to supply (in co-operation with DARA) the Sciamachy instrument for the Envisat-1 satellite. Development of this instrument will be the most important national space project of the mid-nineties.

118. To stimulate national technological developments, NIVR is conducting a multi-year NIVR space technology programme (NRT). Partly financed by the NRT programme, studies and pre-developments are carried out by industry and research organisations.

119. NIVR also monitors the space activities sponsored by the Netherlands Defence Department. In this connection a NIVR senior project officer is a member of the WEU study management team which supervises industrial study/ development efforts to define a European earth observation satellite system for crisis-management and treaty verification.

120. Funding for space programmes in the Netherlands is provided by various government departments. The Netherlands space budget for 1994 (240 million Dutch guilders) is made up as follows: contibution to ESA and Eumetsat: 193 million; NIVR technology programme: 13 million; SRON space research: 20 million; participation in SAX and Sciamachy: 14 million.

(ii) SRON (Space Research Organisation Netherlands / Stichting Ruimteonderzoek Nederland)

121. SRON has a total staff of approximately 150 with 90% of its budget funded by the Netherlands Organisation for Scientific Research (NWO) and 10% commissioned research.

122. SRON is a foundation within the framework of the NWO. It is responsible for the space research programme which is carried out by the three laboratories for space research, located in Utrecht, Leiden, and Groningen (collectively referred to as the National Space Research Institute). Activities comprise the design, development and manufacture of space instruments and data-processing and interpretation – the latter in close co-operation with university groups.

123. Additionally, SRON co-ordinates all space research activities on a national level, advises the Dutch Government in all matters concerning space research and, as the Netherlands Space Research Agency, endorses co-operation in international scientific programmes.

124. SRON's laboratories are mainly engaged in X-ray and gamma-ray astronomy. At present, this includes inter alia the following projects: the development of wide field X-ray cameras (two WFCs are being developed for the Italian X-ray satellite SAX, to be launched in 1994); the development of an infrared short-wavelength spectrometer for the ESA ISO (infrared space observatory) satellite; development of a low-energy transmission grating for cosmic X-ray spectroscopy with the NASA satellite AXAF (advanced X-ray astrophysics facility); the development of a reflecting grating spectrometer for the ESA " X-ray multi-mirror " cornerstone (XMM) mission; analysis of data obtained from Comptel (Comptom telescope, launched April 1991), one of the four instruments in the NASA gamma-ray observatory, Exosat (European X-ray observatory satellite, 1983-1986), IRAS (infrared astronomical satellite, 1993) and Comis.

125. Through its present involvement in the development of infrastructures like GOME (for ERS-2, to be launched in 1994), Scimachy and MIPAS (for Poem) SRON prepares itself for a future rôle in earth observation programmes.

126. SRON co-ordinates and stimulates other space research activities in the Netherlands, such as microgravity research, and earth oriented space research (solid earth physics, oceanography, atmospheric physics). Presently, SRON is funding some 17 experiments in the field of life sciences and materials sciences.

(iii) NLR (Nationaal Lucht- en Ruimtevaartlaboratorium / National Aerospace Laboratory)

127. The National Aerospace Laboratory (NLR) is the central institute in the Netherlands for aerospace research. It provides scientific support and technical assistance to aerospace industries and organisations, civil and military aircraft operators, and government agencies concerned with aviation and space flight. In space flight, NRL takes part in ESA programmes. NLR co-operates closely with Fokker in various space-related projects supported by the Netherlands Agency for Aerospace Programmes (NIVR).

128. The annual turnover of NLR is around 141 million guilders. About 70% of turnover stems from research under contract to industries and institutes and 30% stems from a government subsidy for NLR's basic research programme. NLR employs a staff of about 900, of which two-thirds are graduates from universities or advanced technical colleges.

129. The laboratory operates a series of large wind tunnels, including the transonic HST and supersonic SST that are used extensively in test programmes for the development of Ariane launchers and the former ESA programme Hermes.

130. NLR operates facilities for research in structures and materials used in space projects. Expertise in load and use monitoring is combined with structural response analysis and materials characterisation to perform damage tolerance assessments. Advanced dynamic and non-linear analysis and test systems are applied to solving problems associated with design and verification of spacecraft structures.

131. Materials science and engineering projects include evaluation of properties of metallic, composite and hybrid materials, also at elevated temperatures.

132. For the development and application of space technology, NLR uses special facilities for testing and simulating satellite units and subsystems. Test and simulation systems are developed for attitude and orbit control systems. In the area of thermal control, research takes place on two-phase flow and heat transport systems in a low-gravity environment. Several studies are performed on instrumentation of fluid physics experiments in microgravity.

133. NLR acts as national point of contract for the dissemination of remote sensing data to Dutch users. Optical and microwave remote sensing systems are developed and are operated from NLR's Metro II and Queen Air 80 laboratory aircraft.

134. Recent work in space technology includes: development of test and simulation assemblies for the attitude control systems of ISO and SAX; development of on-board attitude control software for SAX; studies on the modelling of dynamics simulation; development of a two-phase quality sensor, support of industry to produce heat transport components for in-orbit demonstration; development of telescience equipment including teleoperated optical diagnostics instrumentation; data acquisition and control equipment for microgravity experiments in Maser flights; development of an ejectable fluid physics experiment in a Maser flight; research in space automation and robotics; participation in definition studies for the Columbus user support organisation; development of a satellite ground station (Artemis) for monoriting vegetation and rainfall in Africa, operated by the United Nations Food and Agriculture Organisation.

135. NLR's extensive computer network featuring a supercomputer is used for theoretical research, especially in computational fluid dynamics and structural design of aircraft and spacecraft. The network is also used for processing data from wind tunnel tests and flight tests. Standardised connections to national and international networks are available.

(f) The United Kingdom

(i) British National Space Centre (BNSC)

136. The British National Space Centre (BNSC) was established as a result of an administrative decision by the British Government in 1985. It acts as a focus for the civil space interests of the Department of Trade and Industry, the Cabinet Office, the Department of the Environment, the Ministry of Defence, the Foreign and Commonwealth Office, the Department of Education and Science, the Meteorological Office, the Science and Engineering Research Council and the Natural Environment Research Council.

137. The Secretary of State for Trade and Industry has overall governmental responsibility for United Kingdom civil space policy, but other departmental ministers are involved in major policy decisions where they have funding responsibilities.

138. Most BNSC activities are carried out with ESA (60% of the annual budget of £160 million; the United Kingdom is the fourth contributor). The Centre has some 230 staff at its London headquarters and technical centres. The Rutherford Appleton Laboratory co-operates with research establishments, companies and universities in the study of astronomy, solar/terrestrial physics, earth observation and advanced space communications systems. It also co-operates with universities in the design, development and building of space instruments. The Space Department of the Royal Aerospace Establishment, RAE (part of the Defence Research Agency, DRA) is active in research and development on spacecraft and remote sensing, mission analysis, orbital dynamics and ground facilities. BNSC's national programme of research and development in satellite telecommunications is managed by DRA's Satellite Communications Division at Defford.

139. Among the main areas of space activities of interest to Britain are earth observation, satellite communications, space science and space transportation. Earth observation, with 50% of United Kingdom space expenditure, is the centre-piece of British space policy.

140. ERS-1 carries two instruments developed

in Britain: AMI, the active microwave instrument is an integrated radar system that operates both as a SAR and as a scatterometer and enables ERS-1 to see through clouds as well as in darkness and ATSR (along track scanning radiometer), an advanced four-channel infrared imaging radiometer.

141. ERS-2 will include a replica of the ATSR with additional land channels (ATSR-2). There are plans for BNSC partner SERC (Science and Engineering Research Council) to fly instruments like HIRDLS (high resolution dynamics limb sounder), SAFIRE (spectroscopy of the atmosphere using far infrared emission) and EMLS (enhanced microwave limb sounder), on NASA's EOS (earth observation system) series of satellites.

142. Britain contributed two complementary atmospheric analysis instruments for UARS (NASA's upper atmosphere research satellite), the improved stratospheric and mesosphereic sounder (ISAMS) and the microwave limb sounder (MLS).

143. Britain's Meteorological Office (BMO), partners in BNSC, will fly AMSU-B instrument (advanced microwave sounding unit), a five-channel microwave radiometer, for the next generation of NOAA satellites. Measurements of water vapour from Envisat-1 will be given greater accuracy by MHS (microwave humidity sounder) being developed by BNSC partners in the Meteorological Office. Also for the future, Britain is defining and studying designs for a new instrument, OMI (the high resolution optical mapping instrument), as candidate for a bilateral mission with France.

144. The Earth Observation Data Centre (EODC) at Farnborough is the national centre for acquiring, processing, storing and disseminating remotely sensed data; EODC was developed for the BNSC and it incorporates an important international space facility, one of the four ESA PAFs (processing and archiving facilities)[16].

145. Space science represents 26% of the United Kingdom's space expenditure. BNSC funding through SERC (Science and Engineering Research Council) supports the universities and RAL (Rutherford Appleton Laboratory) in developing and producing instruments for science missions and interpreting their data.

146. International collaboration is an essential element in the United Kingdom's space science programme and is undertaken primarily through ESA. However, in some bilateral programmes with, for example, Germany, Japan, Russia and the United States, current and projected space science programmes are:

- X-ray astronomy, the current programme includes analysis of data from past missions and exploitation of their Germany-United Kingdom-United States ROSAT mission (X-ray satellite) for which Britain provided the wide field camera. Britain is also leading a European consortium to build an X-ray telescope (Jet-X) for the planned Russian Spectrum-X mission, and has provided the X-ray instruments for Japan's Yohkoh mission, which is studying high-energy aspects of solar flares. RAL and universities have a major involvement in all three instruments (camera, spectrometer and optical monitor) selected by ESA for its XMM mission. In the field of optical astronomy and astrometry, the Hubble space telescope (ESA-NASA) carries a United Kingdom designed faint object camera and the United Kingdom is involved in the processing of data from the Hiparcos mission.
- In infrared astronomy, current activities are devoted to the development of instruments for ISO (infrared space observatory) with a United Kingdom contribution to all four instruments; United Kingdom participation in the ESA First mission is also planned.

147. In solar-terrestrial physics, the United Kingdom is involved in ESA's missions Ulysses, Soho (with the coronal discharge spectrometer) and Cluster (with the fluxgate magnetometer, plasma analyser and digital wave processing package).

148. The United Kingdom has a major involvement in the NASA/ESA major planetary Cassini-Huygens mission; the University of Kent has the leading rôle in the ESA surface science package for the Huygens Titan probe and Imperial College, London, for the dual technique magnetometer on the NASA Cassini orbiter, together with other contributions which reflect the range of British expertise in the planetary and solar-terrestrial field.

149. Satellite communications represent 12% of United Kingdom space expenditure. Through BNSC, the United Kingdom takes part in a number of ESA satellite communications programmes, like the DRTM (data relay and technology mission), in the two elements Artemis will provide a pre-operational data relay capability and demonstrate links with land mobile terminals, optical intersatellite data linking and electric propulsion) and DRS; the ASTP-4 (advanced sys-

16. A private sector company, NRSC Ltd. (National Remote Sensing Centre) will operate EODC on a progressively more commercial basis, initially with financial support from BNSC.

tems technology programme) and ARTES (advanced research in telecom system) PSDE.

150. BNSC, at the national level, has encouraged and supported a number of innovatory applications via ESA's large experimental Olympus satellite, has sponsored feasibility studies of aeronautical and integrated cellular/land mobile communications via satellite.

151. The Ministry of Defence, a BNSC partner, sponsors a comprehensive military satellite communications programme. Three Skynet-4 satellites currently serve the needs of the United Kingdom's armed services and there is a widespread ground segment. Feasibility studies for Phase 2 of Skynet-4 are under way and the Ministry of Defence's communications research and development programme is co-ordinated with BNSC's national programme; both are executed through the Defence Research Agency (DRA). DRA operates as a corporate organisation, supplying on a commercial basis to the Ministry of Defence and a range of other customers an expert, comprehensive, scientific, and technical service. It has a headquarters at Pyestock, and its four main operating divisions are Portsdown, Fort Halstead, Malvern, and the Royal Aerospace Establishment at Farnborough, as well as the Royal Signals and Radar Establishment (RSRE) at Defford.

152. Technology and transportation programmes account for 3% of United Kingdom space expenditure. BNSC supported research to help develop the performance, life and reliability of spacecraft (particularly in earth observation), and to support and encourage the United Kingdom space sector.

153. The United Kingdom is a minor player in ESA's launcher programmes, involved only in the Ariane-4 research and technology accompaniment programme.

154. Your Rapporteur regrets that he cannot include any information about space research establishments in Belgium and Portugal, as no reply has as yet been received from these establishments.

IV. The European Space Agency (ESA)

155. European co-operation in space matters dates back to the early 1960s. In 1962, six European countries (Belgium, France, Germany, Italy, the Netherlands and the United Kingdom, in association with Australia) came together in ELDO (European Launcher Development Organisation) and, in the same year, the same six countries, together with Denmark, Spain, Sweden and Switzerland, formed ESRO (European Space Research Organisation). Some ten years later, in Brussels, in July 1973, the European Space Conference in which the ministers of these ten countries participated, agreed in principle to create ESA (European Space Agency) [17] replacing ELDO and ESRO.

156. The member states assigned ESA the task of providing for and promoting collaboration among European states in space research and technology, exclusively for peaceful purposes (Article 2 of the convention).

157. ESA is developing a European space programme with the aim of bringing it to a successful conclusion. Its expertise covers the areas of science, earth observation, communications, space sector technologies including orbiting space stations and platforms and earth-based infrastructure, space transportation systems and microgravity research. Its rôle is also to co-ordinate the agency's own actions and the national programmes of its members so as to integrate them progressively into the European programmes. Finally, ESA also has an industrial rôle in developing and implementing a policy appropriate to its programmes while ensuring that each member receives a fair financial return on its investments and an equitable share of technological spin-offs.

158. ESA's activities fall into two categories: compulsory and optional programmes. Compulsory programmes are concerned with studies for future projects, technological research, joint technical investments, information systems, training programmes and the development and use of scientific satellites. All member states contribute to these on the basis of national income. Programmes described as optional are of interest only to some of the member states who decide freely on the extent of their participation in them. Optional programmes include earth observation, communications, space transportation, space stations, platform projects and microgravity research.

159. In the pursuit of its programmes, ESA devotes the main part of its budget to contracts with industrial firms in the member countries. Its policy ensures that each member receives a fair financial return on its investments and an equitable share of technological spin-offs. Thus each unit of account from a member state contributed to the agency's budget should, strictly speaking, come back to that country in the form of an industrial contract.

160. The headquarters of ESA is in Paris, where its general directorate is based. However, the organisation has several other establishments (ESTEC, ESOC, ESRIN, EAC) and a launch base at Kourou (in French Guyana).

17. Ireland joined the organisation and the founder members were joined on 1st January 1987 by Austria and Norway. Finland will become the fourteenth member state on 1st January 1995 and co-operatation contracts have been concluded with Canada.

161. Situated at Noordwijk, in the Netherlands, the European Space Research and Technology Centre (ESTEC) is ESA's largest establishment. Scientific, communications, earth observation, microgravity research projects and projects for manned orbital infrastructure and unmanned platforms for which responsibility has been given to European industry are managed from ESTEC, the true nerve centre of ESA. ESTEC also has responsibility for defining future scientific satellite or applications programmes and programmes for the development of the new technologies necessary to achieve them.

162. The European Space Operations Centre (ESOC) in Darmstadt (Germany) is responsible for monitoring that orbital space vehicles are working properly.

163. Despite its name, the European Space Research Institute (ESRIN) is primarily ESA's data management centre for information from remote sensing satellites. Situated in Italy, at Frascati, not far from Rome, ESRIN is responsible for processing, archiving and distributing data obtained from a large number of ground-based stations throughout the world. Moreover it is responsible for several services such as European Space Information Service (ESIS) or the Information Retrieval Service (IRS)

164. As the most recent of ESA's establishments, the European Astronauts' Centre (EAC) in Cologne (Germany) is responsible for recruiting and training men and women who will participate in a few years time in flight missions on the Columbus Laboratory linked to the international station " Freedom ".

165. Scientific programmes are as follows: of the ten satellites and scientific probes launched by ESA between 1975 and 1990, five are at present operational or in orbit. These are the international ultraviolet explorer (IUE) which, launched in 1978 in the framework of a NASA, ESA and United Kingdom joint programme, is still continuing in 1994 to supply data to a scientific programme despite some minor deterioration due to its obsolescence; the Giotto probe (launched in 1985); the high precision parallax collecting satellite (Hipparcos) [18], an astronomy satellite for determining with greater precision the positions and parallax of more than 1 000 stars in our galaxy; the Ulysses probe (launched in October 1990 in the framework of a joint ESA/NASA mission) which is to take measurements above the poles of the sun; the Hubble space telescope (outcome of a joint ESA/NASA project launched in 1990) which is one of the most ambitious astronomy projects ever conceived and which, despite a defect in its mirror, corrected in spectacular fashion at the end of 1993, has obtained far better results than those of ground-based observatories.

166. ESA foresees the following programmes for the future: the infrared space observatory (ISO) programme, (launch scheduled for September 1995) with a low-temperature cooled telescope equipped with four scientific instruments. The unit will take pictures and carry out photometric, spectroscopic and polarimetric observation. The Horizon 2000 programmes whose four " cornerstones " missions, namely the solar terrestrial science programme (STSP), the X-ray multi-mirror mission (XMM, to be launched in June 1999) and the First (far infrared and submillimetric space telescope) missions devoted to submillimetric wavelength astronomy and Rosetta (envisaged as a collaborative project between ESA and NASA with an anticipated launch date in 2003, the aim of which is to bring back to earth samples taken from the head of a comet) are the basic elements of ESA's scientific programme. STSP brings together two missions, Soho (the solar and heliospheric observatory with an anticipated launch date in July 1995) which will carry out research on the internal structure and dynamics of the sun and Cluster (scheduled launch date in December 1995) which includes four satellites with a payload of ten instruments, whose aim is a three-dimensional study of turbulence and small-scale structures of the plasma surrounding the earth.

167. Lastly, mention should be made of the Cassini/Huygens planetary exploration mission of Saturn and Titan (undertaken jointly by ESA and NASA) which will include a NASA probe orbiting round Saturn, linked to ESA's Huygens probe which will be released into Titan's atmosphere [19] and Integral (international gamma ray laboratory) a gamma-ray astronomy mission based on the service module common to XMM [20].

168. For observation of the earth, ESA relies on the following programmes:

- Meteosat [21], Europe's first geostationary meteorogical satellites, equipped with an imaging radiometer allowing pictures to be taken in the visible and infrared spectrum and in the water vapour wavelength designed basically to take pictures of the

18. Communication with the satellite was terminated on 15th August 1993 at the end of a remarkable mission lasting over three years.

19. The particular interest in Titan derives from the fact that its atmosphere has properties closer to that of the earth than any other body in the solar system.

20. This project will be conducted jointly with Russia and NASA. The Russians are to provide the launcher (Proton) free of charge in exchange for observing time. NASA is to take part in the development of the payload (spectrometer) and might contribute one or two ground stations in addition to the ESA stations.

21. Ownership of Meteosat satellites was transferred to the European organisation Eumetsat from the time of its formation in 1987. ESA continues to be responsible for their exploitation and technical management.

earth, broadcast meteorological data and collect environmental data recorded by unmanned stations on the ground; Meteosat 6 was launched on 20th November 1993.

- ERS-1 (European remote sensing): a European radar satellite placed in polar orbit by Ariane in July 1991. Since then, thanks to its main instrumentation, a synthetic aperture radar (AMI) (active microwave instrument), a wind scatterometer, a radar altimeter (RA) and a radiometer and sounder (ATSR-M) (along-track scanning radiometer and microwave sounder), ERS-1 carries out detailed observation of the structure of the earth's surface. Production of the second flight model, ERS-2[22] has continued with a launch date in prospect at the end of 1994.
- Envisat and Metop: these are two series of missions in polar orbit developed by ESA: a first and initially experimental series of environmental study platforms (Envisat) and a meteorogical series (Metop), oriented rather towards operational observation. Envisat, one of the most wide-ranging and ambitious satellites ever produced by ESA (with a payload three times greater than those of the ERS satellites) has a projected launch date of 1998. The first meteorogical mission will not, however, be launched until the year 2000, following a joint ESA/Eumetsat programme.
- The Meteosat second generation (MSG) programme is being conducted in close co-operation with Eumetsat and the first satellite launch is envisaged for the year 2000.

169. In communications, ESA has been present since 1979 in the geostationary arc through experimental orbital test satellites (OTS), then preoperational European communications satellites (ECS) constituting the first generation of European telecommunications satellites developed by ESA[23]. In addition to the ECS, there are the Marecs (Maritime ECS) satellites designed by ESA to provide communications capabilities with moving vehicles and in particular with ships at sea and leased to Inmarsat (international maritime satellite organisation) for the period of their use. Lastly, the Olympus satellite (launched in July 1989 by Ariane rocket with a payload consisting of four different missions: direct satellite broadcasting, Ku band communications, Ka-20/30 GHz band commuications and a beacon for propagation studies) was withdrawn from service in August 1994 following a failure.

170. ESA's principal objective in proposing a programme of data-relay satellites, essential for maintaining continuous and immediate contact between ground control teams and European orbital infrastructures, is to ensure Europe's total independence in data transmission from orbiting satellites or platforms to ground stations in Europe.

171. In this area, the Artemis (advanced relay technology mission) satellite should be launched at the end of 1996 with an optical laser beam communications payload on board, along with satellites in low earth orbit[24], a demonstration communications payload for the mobile service for land vehicles and a data-relay payload for preparing the operational data-relay system (DRS). ESA foresees placing up to two geostationary data-relay satellites in orbit (the first in 1999); these will contribute to optimising the future European orbital infrastructure and will be compatible with other similar networks (the American TDRS and the Japanese DTRS) in the framework of international co-operation.

172. Finally, in order to ensure that Europe has the necessary means of maintaining its capabilities and commercial competitiveness in the sector of communications by satellite, ESA has proposed the Artes (advanced research in telecommunications systems) programme[25].

173. Reference must be made in connection with manned space flight and microgravity of the first joint German/ESA/Spacelab mission in October 1985 carrying 75 microgravity and life sciences experiments; participation in Astro-1 missions (December 1990), SLS-1 (Spacelab space science, June 1991), IML-1 (January 1992), Atlas-1 (April 1992), the USLM-1 (United States microgravity laboratory) flight in June 1992, the joint mission with the Japan Spacelab-J in September 1992 and lastly the Spacelab D2 mission in April 1993. The European unmanned retrievable platform, Eureca (European retrievable carrier), an ideal laboratory for microgravity studies, was retrieved on 24th June 1993 by the Endeavour space shuttle after eleven months in low earth

22. ERS-2 should provide continuity of data transmitted by ERS-1 and also offer new possibilities for monitoring the ozone layer on a global scale.

23. The European space communications organisation, Eutelsat, is responsible for the exploitation of the ECS, renamed Eutelsat I after their entry into operational service.

24. Artemis's optical payload will communicate with an optical terminal on board Spot-4. Manufacture of this terminal led to Spot-4 being supplied with the first complete model, offering good optical, thermal and mechanical precision.

25. Activities within the Artes programme fall into the following categories: promotion of new improved services in communications by satellite; co-operation with users; improving industrial competitiveness and international co-operation.

orbit. In 1993 also, the European microgravity research programme, Emir-1, was adopted.

174. European participation in the large international space station " Freedom ", agreed by the Council of ESA meeting in the Hague in 1987, took the name Columbus programme. The attached laboratory programme had to be adapted to the constraints arising from the decisions taken at the Council meeting at ministerial level in Granada at the end of 1992 and the evolution of the international space station programme that took place in 1993. Two series of studies on possibilities for technical co-operation and future partnership between the ESA member states and Russia were carried out in the framework of the " future station Columbus " programme unit. The first of these series dealt with a limited range of contributions by ESA to the Russian MIR-2 space station, the second with possible wider co-operation after the year 2000 and the construction of MIR-2, in relation to major components of orbital infrastructure.

175. The Ariane programme (the first flight of which was on 24th December 1979) gave ESA its own reliable launcher, making it independent in terms of space transportation. The initial Ariane 1 gave way to the more powerful Ariane 2 and 3 from 1984 and these were withdrawn in turn with the arrival on the scene of Ariane 4 in 1988. The latter are available in six models, including a basic version and five other models equipped, depending on the satellite mass to be placed in orbit, with two or four high tech solid or liquid propelled booster engines. Ariane 5, with a radically different architecture, will be a new generation launcher, shorter and squatter, capable of giving rise to a new family of rockets adapted to the satellites of early next century. ESA has opted for a rocket in two stages: a lower stage, identical for all missions and an upper stage that can be adapted to the mission and the payload to be placed in orbit.

176. Given the evolution of projects for future space-based infrastructure, the concept of a winged re-entry vehicle which figured in the Hermes programme has been abandoned. The revised Hermes programme is now known as the manned space transportation programme (MSTP) and envisages further research and predevelopment work on which will be based the decisions to be taken as regards Europe's capability in equipment and cargo transportation and in carrying out repairs in orbit.

177. ESA is developing a range of co-operative relations in Europe and with the United States, Russia and Japan. In Europe, in accordance with the wish expressed at the Granada conference, complementarity with various international organisations (Eutelsat, Eumetsat) has been sought. Priority has been given to relations with the European Commission through strengthening regular contacts and improving consultation and co-ordination. Promising new areas for co-operation have been identified such as navigation, promoting remote sensing in developing countries and training.

178. ESA is, in short, at the root of a massive European effort in space matters to which, it should be stressed, the CNES has contributed in large part. There is possibly no other area as European as space technology. Last, but not least, ESA has no mandate to concern itself with the non-civilian use of space. In fact, whether or not its convention permits it to deal with this area is not a legal problem but basically a political one. Not all ESA member countries are interested in military space, but it is obvious that in maintaining a watertight partition between civil and military space (military space systems such as Helios or Eumilsatcom are developed outside ESA) does not encourage the most rational use of the available financial means and technological capabilities and often, moreover, stands in the way of synergies which would allow an integration of military and civilian objectives.

179. The problem is there and a solution must therefore be considered as soon as possible in order to derive the greatest possible benefit from our financial and technological capabilities.

V. The state of European co-operation

180. From this general overview, certain aspects can be discerned which are of interest to our national space research institutes.

181. It should be stressed at the outset that these institutes, intended as wholly national bodies, are intended first and foremost to be of service to national interests.

182. At European level, there is still a degree of divergence as regards the evolution of the space sector in individual countries and the political importance accorded to this sector, as revealed by major differences between space budgets and their allocation between ESA programmes and national programmes.

183. National space research institutes are often multidisciplinary and engaged in other fields of research such as, for example, aeronautics and energy. Their size, budgets, aims and the links they have with the military sector vary considerably.

184. A degree of overlap is evident in European space-based activities, both between various national programmes and between these and ESA programmes. There is a great deal of duplication in infrastructure, training and remote sensing and co-operation with third countries.

185. Your Rapporteur feels, however, that it is necessary to stress existing examples of co-operation and collaboration between national space research institutes outside ESA programmes. Among these, the programmes already considered in the descriptive account of the national space research institutes are worthy of note: Spot, Vegetation, Helios, Iasi, Sax, etc.

186. Moreover, in the framework of research and technology programme 9.1 of the Euclid programme, devoted to a feasibility study of optical and/or radar monitoring satellites, teams from state organisations with the task of identifying problems likely to prove sensitive in the future have been formed and trained. The following teams are contributing their particular expertise to this programme: ETCA and the University of Liège (Belgium), DLR (Germany), Alenia Spazio (Italy), NLR, TNO and Fokker (Netherlands), NDRE (Norway), INETI (Portugal), INTA (Spain) and ONERA (France). Each country participates equally and where there are no government establishments in the area concerned industries have been selected.

187. WEU is also involved in bringing the national space institutes closer together: WEU studies on satellite systems are monitored by the study management group in which engineers from the state bodies referred to above participate. Moreover, additional studies have been launched in order the better to identify needs; ONERA and DLR are working on synthetic aperture radar and INTA, NLR and ONERA on problems relating to optical payloads.

VI. The future of European space research (forms of research and interaction)

188. Your Rapporteur believes convergence between ESA and the national space research institutes is necessary in order to bring greater coherence to the programmes undertaken and maximise the advantages that might be obtained from wider co-operation between national space centres. Measures must be taken now to implement a co-ordinated strategy between the various national space research institutes, ESA, the European Union, WEU and other organisations such as Eumetsat, Eutelsat, etc.

189. Countries will have to abandon policies that seek to maintain their presence in the different sectors, an attitude which leads to resources being spread between numerous programmes instead of developing synergies. Individual countries must concentrate on doing what they know how to do best.

190. Co-ordination of the research policies of member states is essential if it is hoped to achieve more efficient use of funds allocated to research; such co-ordination could contribute to the emergence of new synergies and avoid fruitless dispersal of effort. When acting thus it is, however, necessary to ensure that a distinction is drawn between an unnecessary overlapping of effort and useful parallel research.

191. Since space technology now has a crucial rôle in defence and security matters (the C3I concept in space on a planetary scale) and given the high cost of military space programmes, increased European co-operation in military space matters is proving to be an essential condition for our security and political independence. Defence Europe must make a single and coherent collective response to the challenge of military space. To this end, co-ordination between the military and civil uses of space is essential for the technological and industrial development of space applications. The national space research institutes must be able to find a solution to this problem.

192. In the context of strengthening co-operative ties with countries embarking on space programmes and consequently potential partners or customers of Europe, joint rather than competitive action must be envisaged. It would also be desirable, starting from existing know-how in research and development of new space technologies, to encourage the creation at European level of new innovative commercial structures in conjunction with financial and industrial circles. The models adopted by the CNES in this area might be taken as an example.

193. Due to the complexity and variety of problems tackled, research activities cover disciplines and technologies extending beyond what might be strictly defined as the boundaries of space. Your Rapporteur considers it necessary for the national space research institutes to develop working ties with establishments covering related or complementary disciplines and to maintain very close ties with the industrial fabric in order to be able to apply and transfer the results of their research.

194. The national space research institutes must identify research sectors of mutual interest in order to define joint activities. Exchanges of scientific personnel and joint training can strengthen interaction.

195. All space agencies and research institutes are therefore encouraged to take these considerations into account and to envisage new forms of co-operation.

196. The aeronautics research institutes of seven European countries (France, Germany, Italy, Netherlands, Spain, Sweden and the United Kingdom) have taken the initiative of starting a process of convergence of their activities in aeronautics. Several of these institutes are also working in the space sector. The convergence of work in aero-

nautics is favourable to closer relations in space matters and could serve as an organisational model.

197. The Maastricht Treaty sets out the need for co-ordinating efforts in terms of technology policy and research.

198. For some time now, the Commission has made use of observation satellites, the information from which enables it to implement its various sectoral policies, in particular, agriculture, environment and development aid. Moreover, the Institute for Remote Sensing Applications provides scientific backing for such applications and directs high technology research on environmental change. The Commission also maintains close and regular co-operation with ESA and, additionally, participates as an observer in the Committee for Earth Observation by Satellite (CEOS). Moreover, in co-operation with ESA, it has started a new activity – the Centre for Earth Observation (CEO).

199. Lastly, the Commission should also encourage co-operation between the national space research institutes; such co-operation, as has already been noted, should if at all possible, avoid excess capacity and the major difficulties arising from abusive application of the principle of fair return and encourage a more integrated approach to space research.

VII. Conclusions

200. It is clear that space research has generally developed in relation to national interests and with the aim of achieving supremacy or at least of obtaining a certain political standing.

201. Moreover, the collapse of the Soviet Union, in large measure, brought an end to bipolarism and at the same time to the space race. Détente, too, has also opened up wider possibilities for international co-operation; to all the above must be added the arrival of new countries on the space scene and the emergence of new commercial opportunities.

202. In any event, space policy remains a matter for states and it does not seem likely that this situation will change very much in the immediate future; nor would it be realistic or desirable to seek to bring about such change.

203. In the framework of space policy, the defence sector is acquiring very specific importance as this sector is essential to national sovereignty. It retains considerable interest despite the generalised process of disarmament and the reduction of military budgets in most of our countries.

204. If this interest is sustained, it is mainly for two reasons: first, a consequence of disarmament is a new type of armed forces, technologically far more sophisticated and, second, verification of disarmament agreements calls for ever more complex means.

205. These two factors give space a leading rôle. On the one hand, it is an attested fact that the use of space for military ends is a source of high-technology generation for civil use, a situation which could, nevertheless, be reversed. On the other, from a political as well as from a purely economic point of view, there is a general consensus on the need for and expediency of international co-operation in space matters, mainly because of the considerable difficulty of meeting the major expenditure involved in space projects. However, other reasons also weigh in favour international co-operation; participation in industrial consortia and joint ventures; participation in international bodies and networks in order to expand markets; maintaining industrial positions; exchange of personnel, etc.

206. European co-operation in space matters has largely been conducted through programmes undertaken in the framework of the European Space Agency to which should be added other co-operative programmes between various European countries. In this connection, it should be recalled that the Maastricht Treaty highlighted the principle of subsidiarity which, when applied to the situation under consideration, might be summarised as follows: whenever a project might be carried out jointly, the country concerned should endeavour to propose this to its European allies with a view to partnership. If, however, a project derives solely from national concerns, the country concerned should implement it alone, leaving open the possibility, however, of subcontracting certain aspects of the project to its partners.

207. Moreover, your Rapporteur considers the agreement between six European research institutes on the possibility of closer co-operation in aeronautics as being of very great interest. The progress of this agreement should doubtless be followed most closely in the hope of drawing useful lessons for space research.

208. All the aims to which reference is made throughout this report should contribute to promoting the European space industry. Even if it may appear to be very difficult and quite illusory to standardise the political ambitions of each of the European countries in this sector, co-operation between space research institutes should be strengthened and areas of interdependence identified as soon as possible.

209. In order to enable the various countries to maintain their position and fulfil their ambitions without jeopardising existing investments and expertise already acquired, it is necessary to sustain and intensify efforts in space research as a

guarantee for the future. Indeed, space programmes themselves, their development and implementation depend in large measure on expertise that has been accumulated through research.

210. Such efforts also imply the need to maintain a strong basic research potential on a European scale (for example, in universities) essential for guaranteeing the credibility of the national institutes and European industry.

211. One of the major constraints weighing upon public support for space research is that of finance. It would therefore be extremely risky for expertise to be dispersed too widely when European resources are limited. The purpose of joint action should be to reduce excess capacity and to identify future needs.

212. Thus, the first consequence of financial restrictions should be rationalisation of the use of resources and concentration of effort.

213. Lastly, it should be suggested that in the future our committee might study the possibilities for co-operation between space research institutes in our own countries and in those of Central and Eastern Europe; the main objective of such co-operation would be to direct the work of these institutes into peaceful channels and to foster their integration and that of their scientists into the international community.

APPENDIX

Glossary

AFDRG – Anglo-French Defence Research Group
AMI – Active Microwave Instrument/Instrument actif hyperfréquences
AMSU – Advanced Microwave Sounding Unit/Sonde perfectionnée à hyperfréquences
ANS – Astronomical Netherlands Satellite/Satellite astronomique néerlandais
ANTHORACK – Medical research facility developped by ESA for D – 2 mission
ARGOS – Système de localisation et de collecte de données
ARTEMIS – Advanced Relay Technology Mission (ESA)
ARTES – Advanced Research in Telecommunication Systems/Recherche de Pointe sur les Systèmes de Télécommunications (ESA)
ASI – Agenzia Spaziale Italiana
ASSM – Aerodynamics of Segmented Solid Motors/Aérodynamique des propulseurs segmentés à combustible solide (ONERA)
ASTP – Advanced Systems Technology Programme/Programme de systèmes et de technologies de pointe
ATSR-M – Along-Track Scanning Radiometer & Microwave Sounder
AXAF – Advanced X-ray Astrophysics Facility (NASA)
BMFT – Federal Ministry for Research and Technology (Germany) Bundesministerium für Forschung und Technologie
BMO – British Meteorological Office
BNSC – British National Space Centre
CAPRICORNIO – Programme de lanceur de microsatellites espagnol
CARINA – Re-entry capsule for microgravity experiments (ASI)
CASSINI-HUYGENS – Mission ESA-NASA d'exploration planétaire de Saturne et de Titan
CDTI – Centro para el Desarrollo Técnico y Industrial/Centre pour le développement technique et industriel
CGS – Centro di Geodesia Spaziale (I)
CICSAT – Capacidad Inicial de las Comunicaciones por Satelites
CICYT - Comission espagnole chargée de la science et de la technologie
CIRA – Centro Italiano di Richerche Aerospaziali
CLUSTER – Satellites pour l'étude de la structure à petite échelle de la magnétosphère (ESA)
CNES – Centre national d'études spatiales
C.N.R.S – Centre national de la recherche scientifique (F)
COLUMBUS – Programme de l'ESA sur les vols habités
COMPTEL – Comptom Telescope
CRYP – Cryogenic Propulsion Plant Facility/Banc d'essai de propulsion cryogénique (CIRA)
CSG – Centre spatial guyanais
D-1/2 – German Spacelab missions
DARA – Deutsche Agentur für Raumfahrtangelegenheiten
DFD – German Remote Sensing Data Centre/Centre allemand des données de télédétection
DLR – Deutsche Forschungsanstalt für Luft- und Raumfahrt e.V.
DORIS – Système d'orbitographie fine et de localisation précise de balises (F)
DRA – Defence Research Agency (UK)
DRPP – Data Relay Preparatory Programme (ESA)
DRS – Data Relay Satellite/Satellite-relais géostationnaire
EAC – European Astronaut Centre/Centre des astronautes européens

ECS – European Communications Satellite (ESA)
ELDO – European Launcher Development Organisation
EMIR-1 – Programme européen de recherche en micropesanteur (ESA)
EODC – Earth Observation Data Centre
EOPP – Earth Observation Preparatory Programme
EOS – Earth Observation System/Système d'observation de la terre (NASA)
EPOS – European Proximity Operations Simulator/Simulateur européen d'opération de proximité (ESA – DLR)
ERS – Earth Remote Sensing Satellite
ESA – European Space Agency
ESIS – European Space Information Service (ESA)
ESOC – European Space Operations Centre/Centre européen d'opérations spatiales (ESA)
ESRIN – European Space Research Institute (ESA)
ESRO – European Space Research Organisation
ESTEC – European Space Research and Technology Centre/Centre européen de recherche et de technologie spatiales (ESA)
ETW – Soufflerie Transsonique Européenne/European Transsonic Wind Tunnel
EURD – Instrument pour l'étude du rayonnement diffus provenant de l'espace dans l'ultraviolet lointain
EURECA – European Retrievable Carrier (ESA)
EUTELSAT – Organisation européenne de télécommunications par satellite
FIRST – Far Infrared and Submillimetric Space Telescope
GALILEO – Mission d'étude de Jupiter/NASA
GEZON – Cristallogénèse sous champ magnétique (Russie)
GRANAT – Observatoire X/gamma (Russie)
GSOC – German Space Operations Centre/Centre allemand d'opérations spatiales
HELIOS – Satellites militaires d'observation de la terre
HIPPARCOS – High Precision Parallax Collecting Satellite
HIRDLS – High Resolution Limb Sounder/Sondeur du limbe dynamique à haute résolution
HISPASAT – Satellite militaire espagnol
HUBBLE – Télescope spatial (programme conjoint ESA-NASA)
IASB – Institut d'aéronomie spatiale de Belgique
IASI – Infrared Atmospheric Sounding Interferometer (ASI-CNES)
IML 1 et 2 – International Microgravity Laboratory
INMARSART – Organisation Internationale de Communications Maritimes par Satellites
INTA – Instituto Nacional de Técnica Aerospacial
INTEGRAL – International Gamma Ray Laboratory
I-PAF – Italian processing and archiving facility
IRAS – Infrared Astronomical Satellite (NL-UK-USA)/Satellite d'astronomie infrarouge (PB-RU-EU)
IRIS – Italian Research Interim Stage
IRS – Information Retrieval Service (ESA)
ISO – Infrared Space Observatory/Observatoire Spatial dans l'Infrarouge (ESA)
ITALSAT – Italian pre-operational communication satellite
IUE – International Ultraviolet Explorer (NASA-ESA-UK)
LAGEOS – Laser Geodynamics Satellite (ASI-NASA)
MAGELLAN – Mission d'étude de Vénus/NASA
MARECS – Maritime ECS (ESA)
MARS 94-96 – Etude de Mars (Russie/Coopération internationale)
MEDEA – Material sciences Experiment Double-rack for Experiment modules and Apparatus/Expérience DLR embarqué sur D-2

MEPHISTO – Etude de la solidification des alliages métalliques et des semi-conducteurs sur une plate-forme USMP de la navette spatiale américaine (F)

MSG – Météosat de seconde génération

METEOP – Satellite d'observation météorologique depuis l'orbite polaire

METEOSAT – Satellites météorologiques géostationnaires (ESA)

MHS – Microwave Humidity Sounder

MINISAT – Programme de minisatellites de l'INTA

MIPAS – Michelson Interferometer Passive Atmospheric Sounder/Sonde atmosphérique passive à interféromètre Michelson

MLS – Microwave Limb Sounder

MOMS – Modular Optical Multispectral Scanner (D-2)/Scanner multispectral à balayage optique modulaire

MSCC – Manned Space Laboratories Control Centre/Centre de contrôle des laboratoires spatiaux habités

MSTP – Manned Space Transport Programme (ESA)

NASA – National Aeronautics and Space Administration

NIVR – Nederlands Instituut voor Vliegtuigontwikkeling en Ruimtevaart/Netherlands agency for aerospace programmes

NLR – Nationaal Lucht- en Ruimtevaartlaboratorium/National Aerospace Laboratory

NOAA – Agence américaine pour l'étude des océans et de l'atmosphère/National Oceanic and Atmosphere Administration

NRSC Ltd – National Remote Sensing Centre (UK)

NWO – Netherlands Organisation for Scientific Research

ODISSEA – Co-operation programme between ASI, CNES and INTA for transmediterranean balloon flights

OERSTED – Mission danoise d'étude du champ magnétique de la terre

OLYMPUS – Satellite de télécommunications ESA

OMI – High Resolution Optical Mapping Instrument/Instrument de cartographie optique à haute résolution

ONERA – Office national d'études et de recherches aérospatiales

OTS – Orbital Test Satellite (ESA)

PAF – Processing and Archiving Facility/Etablissement de traitement des données et d'archivage

PNS – Piano Spaziale Nazionale (I)

POLDER – Radiomètre polarimètre imageur (F-J)

POP – Programme oscillations de poussée (ONERA)

PREPHA – Programme de recherche et technologie pour la propulsion hypersonique avancée (ONERA)

PRONAOS – Nacelle ballon d'astronomie submillimétrique (F)

PRORA – Programma Nazionale di Ricerche Aerospaziali (I)

PSDE – Payload Spacecraft Development on Experiments Programme

PWT – Plasma Wind Tunnel (CIRA)

RAE – Royal Aerospace Establishment (UK)

RAL – Rutherford Appleton Laboratory (UK)

RAMSES – Radar aéroporté multi-Spectral d'études de signatures (ONERA)

RKA – Russian Space Agency

ROSAT – X-ray Satellite (D – U.K – USA)

ROTEX – Robotic Technology Experiment (D-2)/Expérience de robotique

RSRE – Royal Signals and Radar Establishment (UK)

SAFIRE – Spectroscopy of the Atmosphere Using Far Infrared Emission/Spectroscopie de l'atmosphère utilisant l'émission dans l'infrarouge lointain

SAR - Synthetic Aperture Radar/Radar à synthèse d'ouverture

SAX – X-ray astronomy satellite (ASI-NIVR)

SCARAB – Radiomètres destinés à l'étude du bilan radiatif de la terre (France/Russie)

SCIAMACHY – Scanning Imaging Absorption Spectrometer for Atmospheric Cartography
SERC – Science and Engineering Research Council (UK)
SIGMA – Système d'imagerie gamma à masque aléatoire (France-Russie)
SILEX – Semi-conductor Interorbit Link Experiment (télécommunications)
SIR-C – Space-borne Imaging Radar-C/Radar d'imagerie en bande C
SIVA – Sistema Integrado de Vigilancia Aérea/Système intégré de surveillance aérienne
SOHO – Solar and Heliospheric Observatory/Observatoire du soleil et de l'héliosphère
SPACELAB – Space Laboratory
SPIDER – Space Inspection Device for Extra-vehicular Repairs/Système d'inspection spatiale pour les réparations extra-véhiculaires (ASI)
SPOT – Satellite pour observation de la terre (F-S-B)
SRL – Space Radar Laboratory/Laboratoire radar de l'espace
SRON Space Research Organisation Netherlands/Stichting Ruimteonderzoek Nederland
STELLA – Instrument pour la cartographie du champ de gravité dans les zones polaires (F)
STSP – Programme de physique des relations terre-soleil (ESA)
SYRACUSE – Système militaire de télécommunications par satellites (F)
TELECOM – Satellite de télécommunications français
TOPEX/POSEIDON – Satellite océanographique scientifique (USA)
TSS – Tethered Satellite System (ASI-NASA)
UARS – Upper Atmosphere Research Satellite/Satellite d'étude de la haute atmosphère (NASA)
ULYSSE – Mission polaire solaire internationale (ESA)
USLM-1 – US Microgravity Laboratory
VEGETATION - (Commission Européenne – F – B – I – S) Instrument pour le suivi des écosystèmes naturels et des systèmes agricoles
WINDII - Mesure des vents et de la température dans la haute atmosphère (Canada/F)
XMM – Mission miroirs multiples dans le rayonnement X
X-SAR – X-band Synthetic Aperture Radar (ASI-DARA-NASA)

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