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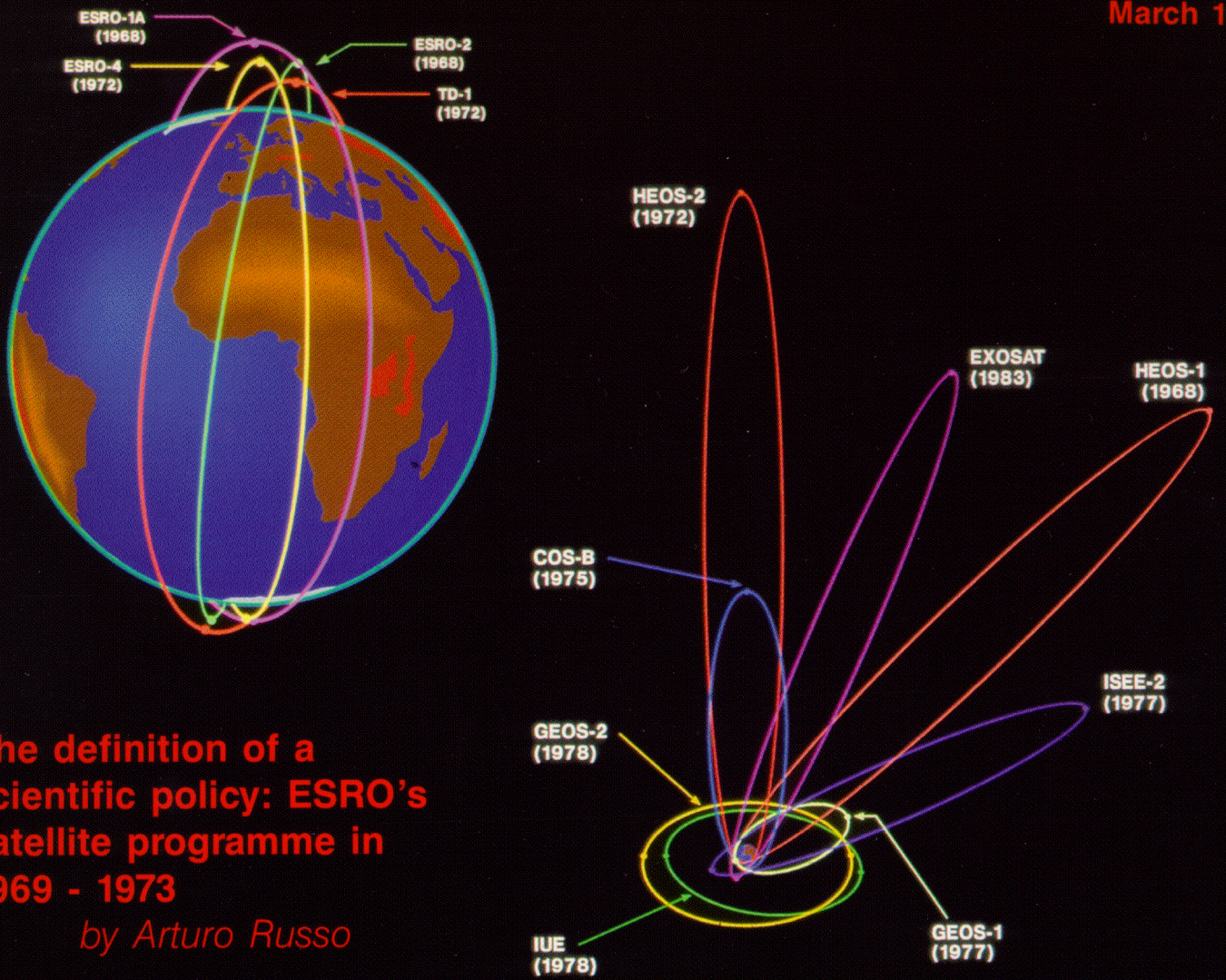
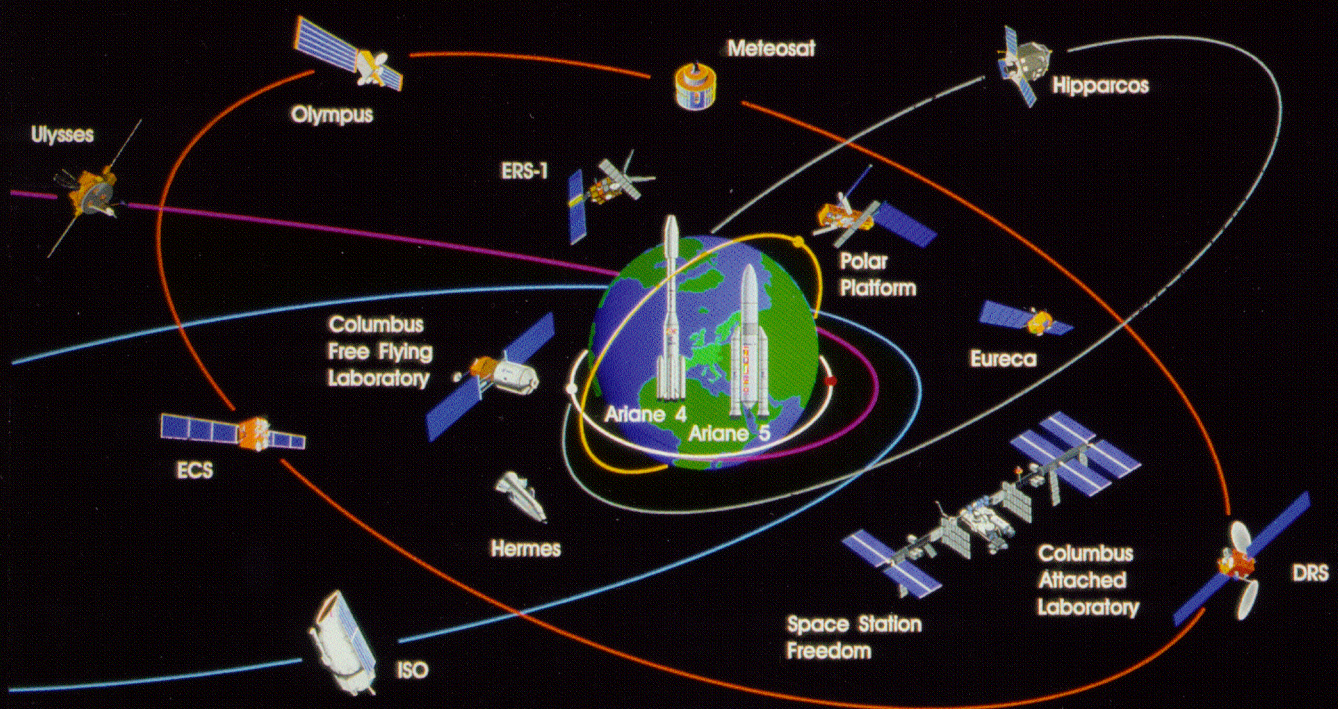


The definition of a scientific policy: ESRO's satellite programme in 1969 - 1973

by Arturo Russo



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The ESA History Team comprises:

Prof. M. De Maria, Dipartimento di Fisica, Università di Roma 'La Sapienza', Piazzale Aldo Moro, I-00185 Rome, Italy.

Dr. J. Krige, Department of History and Civilization, European University Institute, Via dei Roccettini 9, I-50016 San Domenico di Fiesole, Italy.

Prof. A. Russo, Istituto di Fisica, Università di Palermo, Via Archirafi 36, I-90123 Palermo. Italy.

The project is based at the European University Institute, where the ESA archives are also housed. John Krige is the Project Leader.

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THE DEFINITION OF A SCIENTIFIC POLICY: ESRO'S SATELLITE PROGRAMME IN 1969–1973 [1]

Arturo Russo

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INTRODUCTION

The year 1968, the fifth of the official life of the European Space Research Organization (ESRO), was certainly very important: "The most momentous in the Organization's five years of existence", ESRO's *General Report* heralded, while the chairman of its Scientific and Technical Committee (STC) declared that 1968 was "ESRO's first glorious year [...] against the background of the growing pains of ESRO's formative years."[2] Three main reasons can be given for these optimistic claims. Firstly, ESRO could finally boast the succesful launchings of its first three satellites: ESRO II in May, renamed *Iris* after launch; ESRO I in October,

[1] This paper is based predominantly on the large collection of documents from ESA files deposited in the Historical Archives of the European Communities at the European University Institute, Florence. Unless otherwise specified, all the documents cited can be found there, arranged in a master set by their original reference code and date, and we need not refer to them by box number.

[2] ESRO, *General Report*, 1968, p. 7; P.A. Sheppard's "Foreword" to *ESRO/ELDO Bulletin*, Supplement, August 1969 (HEOS–1 Special), p. 4.

renamed *Aurorae*; HEOS-A in December, renamed HEOS-1. All were performing well and scientists were drawing good scientific results from their data. Secondly, ESRO's organizational structure had been significantly changed, following the recommendations of a group of experts chaired by J.H. Bannier, who had analysed in detail the Organization's structure, procedures and internal working methods. Finally, the third meeting of the European Space Conference, held in Bad Godesberg in November, put an end to a long institutional and financial crisis by drafting a tentative space policy for Europe which included ESRO's eventual involvement in application satellite projects. At the same conference, ESRO member states agreed to a level of resources for the scientific programme in the period 1969-1971 for the amount requested (860 MFF = 172 MAU) and authorised necessary commitments for individual projects that would extend beyond 1971, namely beyond the 8-year period covered by the original ESRO Convention.[3]

For the ESRO management this represented the way out a long period of uncertainty, and planning the future of the Organization became again "a rational and fruitful exercise." By the end of 1968, in fact, only one project had already been approved, namely the TD-1 satellite, scheduled for launch in 1972, and it appeared absolutely urgent to limit the large fluctuation in workload resulting from the protracted absence of decisions. The time was ripe for ESRO to choose new projects and to define more efficient long-term programming instruments: "Only with a real and challenging programme," they concluded, "can we keep and recruit staff of the necessary calibre and make proper use of our facilities."[4] And in fact several new projects were approved in 1969.

A first set of decisions was taken in March 1969, when the ESRO Council approved three small satellite projects: ESRO IB (*Boreas*), a follow-up of ESRO I carrying the same payload, eventually launched in October 1969; HEOS-A2 (HEOS-2), launched at the end of January 1972; and ESRO IV, the result of the TD-2 rescue operation, launched in November 1972. By these decisions, an acceptable continuity in the short term programme was achieved and the first phase of ESRO's satellite programme was concluded. Subsequently, by early July,

[3] MFF stands for Million French Francs and MAU stands for Million Accounting Units, ESRO's monetary unit defined on the basis of the set of member states' national currencies.

[4] ESRO/ST/302, 19/2/69, p. 1.

ESRO was able to bring to conclusion the long decision-making process to approve two satellite projects for the second phase. These were the COS-B satellite, to investigate celestial gamma rays, and the geostationary satellite GEOS for studies of the magnetosphere.[5]

In this paper we will analyse the development of ESRO's scientific satellite programme in the period 1969-1973, namely between this last decision and the choice of the next satellite projects: the ISEE-2 spacecraft in an ESRO/NASA three-satellite project devoted to magnetospheric and solar wind studies, and the X-ray astronomy observatory *Exosat*. These four years were the most important in the history of European cooperation in space. They marked the end of the illusion that ESRO's sister organization ELDO could ever build an all European heavy satellite launcher, and the transformation of ESRO itself from an organization solely devoted to scientific research to one mainly engaged in the domain of application satellites. Facing the growing political and economic importance of space activities, European governments were involved in long and painful discussions about the possible definition of a coherent space policy for the Old Continent, trying to find a compromise between conflicting national interests. In 1973 this compromise was finally agreed on, starting a process which led in 1975 to the birth of the European Space Agency (ESA), out of the ashes of ELDO and the wealth of ESRO.[6]

In this context it was hardly possible for ESRO to approve new satellite projects in this period, in spite of several mission definition and feasibility studies performed after suggestions from the European space science community. The time was not wasted, however, and we can consider these four years a period of maturation of ESRO's scientific programme. Three elements contributed to this maturation process. Firstly, with the successful launching of three satellites and the development of six new spacecraft, four of which launched within the period we are considering, ESRO acquired invaluable experience and proved to be a reliable organization. This was not of minor importance in the positive outcome of discussions on European space policy. The second element regards the place of

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[5] The definition and early development of ESRO's scientific satellite programme up to mid-1969 is dealt with in Russo (1992a), (1992b) and (1992c), and in Krige (1992a).

[6] ELDO is the acronym for European Launcher Development Organization: its "sad parable" is described in De Maria & Krige (1992).

the scientific programme within ESRO's new engagement in the application field. While the budget for the scientific programme was dramatically reduced in the period we are considering, this programme was made mandatory in the new institutional setting and the money finally started to flow from member states continuously and predictably. Long-term planning became "a rational exercise" as it had never been before. Finally, the third element of the maturation process, the one that will constitute the main thread of this paper, regards the definition of a scientific policy. ESRO's policy makers definitely abandoned the illusion that the Organization could actually pursue the "book of dreams" that the European space scientists had written in the *Blue Book*, and made an important effort to discuss guidelines and priorities, on the basis of the financial and technical resources available and taking into account the parallel development of national space programmes in Europe and the United States.[7]

Following this thread, this paper is organized in three main parts. In the first we will review the main features of the two satellite projects approved by the ESRO Council in July 1969, namely COS-B and GEOS. These were the last to be approved in the institutional framework established by ESRO's founding fathers and represented a cornerstone for the following evolution of the Organization's scientific programme. In the second part, we will analyse the discussions within the European space science community which led to the important policy statement issued by ESRO's Launching Programme Advisory Committee (LPAC) in early 1970. The relevant aspect of this policy definition was the recognition that only a limited number of scientific fields could be included in ESRO's scientific programme and a choice had to be made: magnetospheric physics and high energy astrophysics were included in this number with high priority, while UV stellar astronomy, solar physics, and planetary science were definitely ruled out. As a consequence of this decision, the X-ray satellite project HELOS was recommended in 1971 by the LPAC but, pending the outcome of the political discussions among ESRO's member states, its eventual inclusion in the Organization's programme was not even discussed by the Organization's governing bodies. The latter, however, did approve LPAC's other recommendation

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[7] The so-called *Blue Book* is the original programme of ESRO as approved by the European Preparatory Commission for Space Research (COPERS) in October 1961: Russo (1992b).

that ESRO should cooperate in the NASA/UK project *International Ultraviolet Explorer* (IUE). In the third part we will report on the important "Package Deal" agreed on by the ESRO Council in December 1971, which formally established application satellite programmes, and then we will discuss the choice of ISEE-2 and *Exosat*, the coherent conclusion of four years of scientific discussions and feasibility studies.

COS-B AND GEOS

We have discussed in detail elsewhere the decision-making process leading to the choice of COS-B and GEOS in ESRO's satellite programme.[8] It must be recalled here that this choice implied the rejection of the UVAS project, a space observatory for ultraviolet astronomy strongly advocated by the same groups which had been involved in the ill-fated *Large Astronomical Satellite* (LAS). This decision, therefore, represented a new blow to the expectations of European stellar astronomers interested in space research and, at the same time, it set the stage for the eventual emergence of magnetospheric science and high energy astrophysics as the leading fields in ESRO's scientific satellite programme.[9]

COS-B was an observatory-type satellite whose mission was the study of the extraterrestrial gamma radiation with energy above about 30 MeV. The scientific payload was provided by a group of laboratories, calling themselves the *Caravane Collaboration*, who built the different parts of the instrument (Table 1). The heads of the groups providing the payload constituted the Steering Committee responsible for the scientific direction of the project and for the publication of its results. An important aspect of this project is that ESTEC's Space Science Department (SSD, former ESLAB) was a member of the collaboration and had the responsibility for integration and management: this was the first time that ESRO's in-house research laboratory was significantly involved in a major satellite project

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[8] Russo (1992a). The scientific aims and technical specifications of the two satellites by the time of their launch are described in ESA *Bulletin* No. 2 (August 1975) and No. 9 (May 1977), respectively.

[9] For the history of the LAS see Krige (1992a). While UVAS was the main competitor of COS-B and GEOS in the final decision, we should recall that another project was discussed in the same circumstance, namely a fly-by mission to the planet Mercury. For all this see Russo (1992a)

and this affected the further evolution of the laboratory, making it a recognized scientific institution. The satellite was successfully launched in August 1975 and it provided a continuous flow of useful data until April 1982, when the instruments on board were switched off because of the definitive deterioration of the main detector.

GEOS was a geostationary satellite whose scientific mission was the study of physical phenomena in the magnetosphere by integrated measurements of particles, fields and plasma. Unlike COS-B, GEOS was a multi-experiment satellite, whose scientific payload was made up of 7 different instruments provided by 10 European laboratories. Because of its unique orbit and the sophistication of its payload, GEOS was selected as the reference spacecraft in the world-wide "International Magnetospheric Study" (IMS). The satellite was launched in April 1977 but, as a result of a launcher malfunction, the planned geostationary orbit could not be attained. The launch of the refurbished qualification model was then approved in December 1977 and successfully executed in July 1978. The satellite's operations were terminated in June 1982.

COS-B and GEOS were ESRO's second generation satellites, after the greatly curtailed ESRO, HEOS and TD programmes, and they were quite different from each other, both in their scientific mission and in their overall conception. COS-B was the first ESRO/ESA single-experiment satellite and this implied that the success of the mission depended on a close coordination between the different people and institutions responsible for the development of the spacecraft and the payload. While in multi-experiment satellites the failure of one experiment did not jeopardize the success of the mission, in the case of COS-B a good performance of all the different parts of the satellite and its payload was the *sine qua non* for the fulfilment of the scientific aims. The actual implementation of the project, however, was based on ESRO's standard practice that the scientific payload should be provided by external laboratories which depended on separate funding, expressed different scientific cultures and worked in different institutional contexts. The *Caravane Collaboration* kept scientific responsibility for the mission and the property of the data, which represented the standard for an "experiment" rather than for an "observatory". While not a particularly sophisticated spacecraft from the technical point of view, COS-B was, for all these reasons, very challenging from the point of view of the management. This

was complicated by the fact that ESTEC's SSD was at one and the same time responsible for building a part of the instrument and for the integration of the payload. Thus the problem of how to share the responsibility for the scientific supervision over the experiment between the scientific collaboration as a whole and SSD's scientists became a matter of continuous negotiation. The organization and management of COS-B in the different phases of development of the project was a matter of experimenting and testing by itself, the results of which significantly affected the further evolution of scientific satellite management in ESA. In the words of R. Gibson, ESA Director General when COS-B was launched:

> [It was not] always easy to develop a management scheme for the payload which had to be established by mutual and voluntary agreement between ESRO and the members of the payload collaboration, particularly as ESRO was not financing the payload. [...] The Organisation has also drawn certain conclusions from this experience, such as that for observatory satellites ESA hardware financing is a must. This philosophy has been adopted for the EXOSAT payload.[10]

GEOS, on the contrary, was conceived like ESRO's first generation satellites, namely as a broad scientific mission to be accomplished by a set of experiments chosen among proposals coming from the scientific community and integrated into the payload. In this case, however, owing to the peculiarity of the satellite's scientific mission, the problem of close cooperation among the different experimenters, as well as between them and the scientific community at large, presented itself in more urgent terms than previously. While the experiments in previous ESRO satellites were relatively independent from one another and each group dealt with its own data autonomously, the GEOS experimenters from the very beginnning discussed ways to achieve the maximum scientific value from the satellite and defined common modes of payload operation and data handling. They also established contacts with other scientists through a Committee for Co-

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[10] R. Gibson's Introduction to *COS-B Special*, *ESA Bulletin*, **2** (August 1975), p. 4.

ordination of Observers associated with GEOS (CCOG), created in 1972 on the initiative of a number of eminent European scientists.[11]

The choice of the payload composition for GEOS

In order to organize in the best possible way the scientific programme of the newly approved geostationary satellite, ESRO organized a 3-day colloquium in Lyngby, near Copenhagen, in mid-October 1969. Here it was stressed that it was opportune to achieve an integrated scientific programme, with related experiments being carried out by ground-based, balloon-borne or rocket-borne instruments. Immediately following the colloquium, the three interested scientific Working Groups ION, COS and PLA held a joint meeting in order to define the mission objectives and to draft a letter of invitation for experiment proposals.[12]

This was a very delicate passage. After the long and controversial decision-making process regarding COS-B and GEOS itself, it was clear that the time when any scientific group interested in space research could hope to get a share in one of ESRO's scientific satellites was over and GEOS appeared to many as the last chance. At the same time, the peculiarity of the orbit made GEOS a spacecraft of great scientific interest for many research fields, and much attention had to be devoted to obtain the best results from it. In fact, the study of the magnetosphere and its phenomena was typically a scientific domain created by the advent of space research, and it spread over several sectors of the space science community. By probing this "little backyard universe", as the magnetosphere came to be called, geophysicists wanted to pursue further their investigation of the structure of the earth's magnetic field; for ionosphere physicists it was of great interest to study how particles and waves travelling along the magnetic lines determined ionospheric phenomena; cosmic ray physics was also involved, as the shape and

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[11] ESRO, *General Reports* 1972 and 1973; *Annual Report*, 1974.

[12] The report on the meeting (17/10/69) is in LPAC/55, 10/11/69 and the conclusions are presented in LPAC/57, 28/10/69. The meeting followed separate meetings of the three groups held earlier on the same day, whose reports are ION/80, 19/12/69; COS/46, 20/2/70; and PLA/62, 4/12/69 respectively. The three groups were responsible for advising the LPAC on ionospheric research (ION), cosmic rays (COS) and planetary science (PLA). Three other groups existed, responsible for atmospheric research (ATM), stellar astronomy (STAR) and solar astronomy (SUN). The structure and functions of LPAC's scientific advisory groups are discussed in Russo (1992b).

structure of the magnetosphere is strongly affected by energetic particles from the sun; finally, the magnetosphere was a sort of natural laboratory for plasma physics studies.[13]

After long discussions, the purpose of this mission was carefully defined as follows:

> To make integrated scientific studies of the distribution of thermal plasma, energetic particles, fields and waves, by means of a satellite in a geosynchronous or geostationary orbit. All types of experiment, however, for which this type of orbit is appropriate will be considered for inclusion in the spacecraft.[14]

Through careful wording the LPAC eventually specified that magnetospheric and interplanetary studies would be considered on the same basis; that while priority should be given to experiments for which a geostationary orbit was advantageous, other types of experiment would be considered for inclusion in the payload "if they are of exceptional value or significance;" that the study of energetic particles was included in the mission but with the exclusion of galactic cosmic rays; that the orbit should be defined as "geostationary" but that "experimenters who would prefer a geosynchronous orbit would have to justify their requirements, taking into account the penalties which might result."[15]

Two important points were stressed by the LPAC, that represented a novelty with respect to previous ESRO's practice. The first was that the experimenters were advised that they would be actively engaged in managing and funding data processing, and that each experimenter would be required to communicate his processed data to the others. GEOS, in fact, would provide an enormous potential output of data, about 200 times as much as current ESRO satellites, and it was desirable to reduce the Organization's workload in this field.[16] The second was the

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[13] For an overview on the discovery and early studies of the magnetosphere, see Newell (1980), pp. 172–186. The definition "little backyard universe" is in Knott (1977), p. 12.

[14] LPAC/57, 28/10/69, p. 1.

[15] LPAC, 29th meeting (13/11/69), LPAC/63, 12/1/70, pp. 7 and 11. Possible orbits are discussed in MS/64, rev. 1, 11/11/69.

[16] It is interesting to remark in this respect that the Director General H. Bondi stressed the fact that "European experimental groups, to date, did not have sufficient experience to handle the flood of data that would be derived from this satellite." LPAC, 32nd meeting (15–16/6/70), LPAC/88, 24/8/70, p. 4.

endorsement of a solicitation from the Danish physicist B. Peters, aimed at fostering cooperation among groups participating in the project.[17] For this a two-stage procedure was defined for the submission of experiment proposals. In the first stage, groups wishing to participate either in the hardware or in the data analysis for a specific experiment were to write a letter of intent, to be circulated in order to enable other groups to become acquainted with the existing possibilities and to stimulate the start of cooperative programmes. After this preliminary step, definite experiment proposals had to be submitted.

By mid-January 1970, 28 letters of intent had been received, including 35 experiment proposals. Moreover, several groups expressed an interest in participating in the scientific programme of GEOS by rocket, balloon and ground-based experiments. Further negotiations among all interested groups led to the submission, by the end of March, of 31 experiment proposals that were classified into 10 fields: low-, medium-, and high-energy particles, ion composition, plasma experiments, DC electric fields, DC magnetic fields, electric and magnetic wave fields, Lyman-α emission, beacon experiment. Two experts for each field were appointed as referees and their reports were then discussed by a panel of experts, chaired by the British physicist H. Elliot, that finally submitted its conclusions to the LPAC.[18]

It required a long discussion in the LPAC in order to analyse the panel's recommendations as well as the referees' reports when any inconsistency was present. As a result the recommendations of the panel were generally accepted and an integrated payload was defined, including 9 experiments in 7 fields of study (Table 2). The LPAC in particular endorsed the panel's suggestion to exclude the beacon experiment and studies of high-energy particles and Lyman-α emission;

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[17] Peters, on behalf of the Danish delegation, had submitted a written statement on this subject to the STC at its 23rd meeting (22/10/69), ESRO/ST/MIN/23, 22/1/69. The matter had been widely discussed by the COS group at its 23rd meeting (17/10/69), COS/46, 20/2/70.

[18] The procedure for the selection of the GEOS payload was agreed at the 31st meeting of the LPAC (27-28/2/70), LPAC/73, 3/4/70. The initial 35 proposals are presented in LPAC/66, 26/1/70, and add. 1, 28/1/70. The following 31 proposals are presented in GEOS/4, 27/5/70. Reports of the referees are in the series of documents GEOS/7-38. The panel of experts consisted of H. Elliot (chairman), R. Gendrin, G. Haerendel, N. Herlofson, J.W. King, G. Pfotzer, J.J. Quenby, J. Sayers. The panel held two meetings, on 20 April and 30 April - 2 May 1970, whose reports are GEOS/1, 14/5/70, and GEOS/2, part I-III, 27/5/70 - 5/6/70. The panel's final report is GEOS/3, 28/5/70. Both the conclusions of the Panel and those of the referees are summarized in LPAC/83, 11/6/70.

it decided on the contrary to include experiment S-303 to measure ion composition, a field that the panel had not recommended for the GEOS mission.[19] This payload composition was eventually endorsed by the STC even though, regarding experiment S-328, the French delegation wanted to reaffirm its opposition to development of payloads by ESLAB.[20]

WORKING OUT A SCIENTIFIC POLICY

Just after the decision on COS-B and GEOS, the LPAC's membership was partially renewed by the STC. J. Blamont and C. de Jager were replaced by the Swiss physicist J. Geiss and the Danish astrophysicist B. Strömgren, who joined B. Hultqvist, R. Lüst and G. Occhialini in the Committee (Table 3).[21] The new LPAC was asked by the Director General H. Bondi "to consider the problem of ESRO's long-term scientific policy in order to enable ESRO to make a careful selection of new feasibility studies to be initiated on future projects."[22]

As a matter of fact, the complex affair of the choice of the satellite projects for the second phase of ESRO's scientific programme had shown that the problem of the Organization's long-term scientific policy deserved fresh consideration. Several factors in fact had to be considered before undertaking any feasibility study on projects to be realized in the second part of the 1970s. First of all it was obvious that budgetary limitations would not allow ESRO to carry out satellite projects in all fields of space science: the Organization had to make choices about the research fields in which it wanted to concentrate its efforts. Secondly, ESRO's satellite programme had to be based on a few, well-phased projects with a well-defined scientific mission and an integrated payload. This implied the definition for each project of a clear scientific leadership to deal with the building of the payload, the observation programme and data handling. Thirdly, the definition of ESRO's scientific programme required a large amount of coordination with the

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[19] LPAC, 32nd meeting (15-16/6/70), LPAC/88, 24/8/70. LPAC's recommendations are in LPAC/86, 17/6/70.

[20] STC, 26th meeting (14-15/10/70), ESRO/ST/MIN/26, rev. 1, 23/11/70, p. 4.

[21] STC, 22nd meeting (19-20/6/69), ESRO/ST/MIN/22, 29/7/69, p. 6. The list of candidates presented by ESRO's Director General also included H. Elliot and B. Gregory.

[22] ESRO/ST/330, 10/10/69, p. 1.

member states' national policies and with NASA's, both in the light of eventual collaboration and to avoid wasteful overlapping. Fourthly, as ESRO was going to be involved in application satellite programmes, some kind of coordination had to be defined, from the technological and managerial viewpoint, between this new field of activity and the scientific programme. The case of GEOS was an example of a scientific satellite whose technological implications (platform, telemetry, tracking stations, and so on) were relevant for the telecommunication satellite programme, also based on the realization of a geostationary satellite. Finally, no less important was the problem of defining selection procedures which avoided what the French delegation at the STC called "an unhealthy situation," namely that "the Committee charged with making the selection from amongst the various proposals was composed of scientists who might be personally involved in preparation of the proposals."[23]

Following the Director General's request, the LPAC set up two panels: a Geophysics Panel, chaired by A.P. Willmore, and an Astrophysics Panel, under the chairmanship of C. Dilworth (Tables 4a and 4b). The former was to cover research in geophysics and planetary science, including studies of the neutral atmosphere, the ionosphere, the magnetosphere and the solar wind, as well as studies of the planets and interplanetary matter. The latter was to cover research in solar and stellar astronomy, cosmic rays and cosmology. These two panels held several meetings between August and December 1969, with the participation of several invited experts, and their reports were presented to the LPAC in January 1970. I will describe them separately.[24]

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[23] STC, 22nd meeting (19-20/6/69), ESRO/ST/MIN/22, 29/7/69, p. 4. The comment was on the choice of COS-B and GEOS.

[24] The terms of reference of the two panels are in the annex of ESRO/ST/330, 10/10/69 and also in LPAC/41, 8/9/69. The membership is *ibidem*. The Geophysics Panel met three times, the summary reports being LPAC/42, 22/8/69; LPAC/44, 4/11/69; and LPAC/53, 2/12/69. The Astrophysics Panel met 4 times, their summary reports being LPAC/46, 22/10/69; LPAC/52, 9/1/70; LPAC/54, undated; and LPAC/64, 13/1/70. The two panels' final reports to the LPAC are LPAC/68, 27/1/70, and LPAC/69, 9/1/70, respectively.

The Geophysics Panel

The first point made clear by the Geophysics Panel was that ESRO should exclude planetary missions and missions aimed at studying the solar wind and the interplanetary medium at great distance from the earth:

> They are necessarily expensive missions partly because of the large launcher cost and partly because of stringent demands on the spacecraft which result from the long mission duration, large transmission distance and variations in the solar constant of the spacecraft.[25]

According to the Panel, it was impossible for ESRO to sustain a healthy scientific programme in these fields with the limited financial and technical resources available. Moreover, as American activity was rather strong and was expected to undergo substantial expansion in the future, "ESRO would experience strong competition with unequal resources." The Panel, however, did not exclude planetary studies if these could be pursued by a small earth-orbiting optical telescope specially devoted to the observation of planets.

If the regions far away from the earth were excluded for financial reasons, those nearest the earth's surface were excluded for lack of real scientific interest. The Panel in fact agreed that studies of the neutral atmosphere and of the ionosphere at mid-latitudes should be omitted from the ESRO programme, as the former could be pursued by national sounding rocket programmes or in the framework of the forthcoming ESRO's meteorological satellite programme while the latter could not receive significant improvement by additional future satellites.

So there remained the wide domain of magnetospheric studies, for which ESRO's resources were sufficient to establish a viable programme and whose scientific interest was worth such an effort. Even though it was recognized that the exploratory content of this field of study was not so great, after the results obtained over the previous decade in the US and the Soviet Union on the structure and properties of the magnetosphere, nevertheless, by experiments in the magnetosphere, it was possible to carry out studies in plasma physics under

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[25] LPAC/68, 27/1/70, p. 5.

extreme conditions, a branch of physical research of great interest and wide applicability both on the earth and in the skies:

> In addition to being interesting in itself as an unusually rich branch of physics, the physics of collisionless plasma has the added attraction of being a key subject in thermo-nuclear research. This circumstance has, in recent years, led to remarkable progress in plasma technology, that has greatly improved the basis for laboratory simulation of cosmic phenomena. Far from making space plasma experiments unnecessary, such improvements (which can be expected to continue) will make it increasingly fruitful to combine laboratory experiments and space observations in the effort toward better understanding of the physics of collisionless plasma.[26]

In conclusion, as regards the fields included in its terms of reference, the Panel recommended that ESRO should concentrate its scientific satellite programme on plasma physics studies in the magnetosphere and on astronomical observations of the planets. Studies of the polar ionosphere and nearby interplanetary space by small satellites could be undertaken only if in support of the magnetospheric programme. It was agreed not to explicitly award priority to either of the two recommended research fields, but a wide majority in the Panel thought that higher priority should be given to magnetospheric studies.

The Astrophysics Panel

The Astrophysics Panel had a more difficult task. The difficulty arose from at least two factors. The first regarded the research fields in the Panel's terms of reference, which included the three broad categories of cosmic rays (including celestial X and gamma rays but excluding solar radiation), stellar astronomy (including visible, infrared and ultraviolet radiation), and solar physics (including all corpuscular and electromagnetic radiation from the sun). A survey among the

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[26] LPAC/68, 27/1/70, p. 11. It should be recalled that one of the member of the Panel, the Chairman of the ATM Group U. von Zahn, protested against the priority given to magnetospheric studies because "while the main emphasis should be placed in ESRO on the exploration of space, a choice was being made of a field or research of non exploratory character." LPAC/53, 2/12/69, p. 4.

European scientific community had shown that there was roughly an equal number of groups interested in each of these fields and important results were to be expected from the use of satellite instrumentation of ever increasing sophistication. Moreover, the very possibility of definite discipline classification was made difficult in a phase which saw the emergence of a new discipline, high energy space astrophysics, based on the use of physical techniques to investigate astronomical objects. In this situation, the possibility of excluding some research field, as had been done by the Geophysics Panel, or even to establish priorities, was definitely out of the question.[27] The second difficulty derived from the consideration of NASA's post-Apollo programmes of manned space stations, expected to be in orbit by the end of the 1970s and for which Europe's collaboration of was urged. These stations would provide splendid opportunities for scientific research in the fields covered by the Panel and therefore the various scientific objectives had to be assessed and scheduled in the light of the facilities eventually available on the space stations. In this context, a new question arose, namely ESRO's role and responsibility in the building and management of instrumentation to be placed in NASA's spacecraft and space stations in the framework of ESRO/NASA cooperation. In the event, the Astrophysics Panel decided to follow a different path from that of the other panel: it agreed not to make selections or to establish priorities but rather to discuss the scientific interest of the various research fields, stressing that it was up to the scientific community, through ESRO's advisory Working Groups, to give advice about the choice of future projects.

Underlying the discussions in the Astrophysics Panel there was the ongoing competition between astronomers and cosmic ray physicists, the former advocating large and sophisticated space telescopes for high resolution studies of the sun and other stars in the UV region, the latter being more and more interested in developing satellites devoted to high energy astrophsyics (i.e. X- and gamma-

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[27] An updated statistics of European groups interested in ESRO's programmes was presented at the 2nd meeting of the Astrophysics Panel (20-21/10/69), LPAC/52, 9/1/70. Slightly different figures had been presented earlier at the second meeting of the Geophysics panel (1-2/9/69), LPAC/44, 4/11/69. Besides the three fields cited above two others were considered by the Astrophysics panel: radio astronomy and fundamental physics. About the growing role of physicists in the traditional domain of astronomers see Hirsh (1983), in particular ch. 6.

ray astronomy).[28] In this competition, astronomers had the advantage of being in the position to claim their turn in using ESRO resources, after the misgivings felt by the astronomical community in relation to the abandonment of the LAS, UVAS and TD-2 projects. On the other hand, they suffered a weakness deriving from three factors. The first, and more immediate, was that their projects were on the borderline of ESRO's financial resources, and often they required collaboration with NASA or even the use of NASA's spacecraft. Secondly, their scientific objectives were in an area well covered by the American OAO (Orbiting Astronomical Observatory) and OSO (Orbiting Solar Observatories) programmes, which were to be followed up by more powerful missions, including manned stations. Finally, such projects were in competition with the interests and expectations of astronomers relying on ground based telescopes, who also advocated ever more powerful instruments.[29] As to the high energy astrophysics community, they certainly had the advantage that their projects could fit well into ESRO's medium-satellite programme but suffered from one serious drawback. In fact, they had already obtained the gamma-ray satellite COS-B while, in the X-ray astronomy field, they lacked a project that could successfully compete with the vigorous American programme: NASA's first Small Astronomy Satellite (SAS-A), scheduled for launch in late 1970, was entirely devoted to X-ray astronomy, and an ambitious programme of large High Energy Astronomy Observatories (HEAO) was being approved.[30]

The Panel's conclusions suggested a programme for the 1970s articulated in three phases. In the first half of the decade, when no new satellite launches would be available, the programme was to consist of stabilized sounding rockets, essentially devoted to ultra-violet and X-ray astronomy. After 1975 a small- and medium-size satellite programme was to be defined whose scientific objectives did not require the facilities of the space stations or would be impossible with the space stations. The third component of the programme was the preparation of

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[28] This point has been discussed by Dilworth (1992).

[29] In this period the European astronomical community was involved in plans and discussions on the envisaged European Southern Observatory (ESO), a large facility to be built in Chile. See, in this respect, Golay (1992).

[30] SAS-A was renamed *Uhuru* after launch and provided the first catalogue of celestial X-ray sources: Hirsh (1983).

experiments to be carried out by the facilites of the space stations, for which "ESRO should offer to European experimenters not only coordination and management, but also basic facilities."

With respect to the various research fields, the Panel's report pointed out that, after the negative outcome of the UVAS and the TD-2 affairs, a larger expectation existed among the European astronomical community for satellite projects devoted to stellar astronomy and solar physics. As to the former, the report recalled that "the need for ultraviolet observations has been stressed by European stellar optical astronomers for many years, particularly in the design studies carried out for the LAS and the UVAS." It then continued:

> If it appears that such a facility is outside of ESRO's financial possibilities, it might be quite appropriate to make use, on a cooperative basis, of the OAO vehicle developed by NASA. Scientific aims and basic instrumentation may remain identical to what has been proposed for the UVAS, thus making use of the feasibility study work already carried out by ESRO on the subject.[31]

The Panel also recommended that ESRO should propose to NASA a joint project for a space astronomical observatory to fill the gap between the OAO series and the facilities aboard the manned space stations. When more information on the latter would be available, ESRO was to provide facilities to enable European astronomers "to put auxiliary equipment at the focus of large, stabilized, light collecting devices."

As to solar research, two types of projects were presented, which seemed of particular interest for European scientists. The first was a satellite to study high energy plasma phenomena (flares) in the solar atmosphere by simultaneous measurements in a wide spectral range, from extreme ultraviolet to submillimeter, with good angular, spectral and temporal resolution. This kind of project, in the Panel's opinion, seemed to be "within the reach of European technology and the European scientific interest and capacity." The second project, on the contrary, envisaged cooperation with NASA to build a solar space observatory to study the solar atmosphere with angular resolution better than 0.2".[32]

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[31] LPAC/69, p. 5-6.

[32] LPAC/69, p. 8.

Against these major astronomical projects, cosmic rays and X- and gamma-ray astronomy (the physicists' domain) appeared with a low profile in the Panel's report. About cosmic ray studies it was recalled that much could be done by balloons, "satellites being necessary for particular experiments requiring either long and continuous observation times, or complete freedom from the earth's magnetic field." Two such lines of investigation were indicated: the search for anti-nuclei and a detailed investigation of the chemical and isotopic composition of the cosmic radiation. As to X-ray astronomy, the report limited itself to recalling the projects under development and then concluded:

> However, it is certain that X-ray studies will, in the future, require instrumentation of ever increasing power and complexity and the Panel felt that European experimenters might profitably concentrate on developing, over the next few years, sophisticated X-ray detection systems so that they are available to take advantage of the facilities provided by the manned space stations.[33]

No less generic was the presentation of gamma-ray astronomy: in the field of high energies (above 30 MeV) ESRO was developing the COS-B project while, in the low-energy range (0.3 to 10 MeV), much more sophisticated experimental techniques were required.

Besides these "classical" research fields, others were discussed as eventual new terrains for space experiments. A field "adopted enthusiastically by the Panel" was that of fundamental physics, namely the application of space technology to the study of phenomena involving fundamental laws and principles of physics. Two examples were put forward in particular, both aiming at testing gravitation theories. One was an experiment on the space-time metric, involving the timing of the passage of a laser signal to the earth from a satellite in orbit beyond the sun. The other concerned the detection of gravitational waves in the quiet conditions afforded by satellites.[34] Other research fields were put in a more distant future, such as infrared astronomy (for which a programme of technological research was recommended); optical astronomy (for which a long

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[33] LPAC/69, p. 5.

[34] LPAC/69, p. 9. A preliminary mission definition study for a space experiment on the geometry of space-time had already been performed, following a proposal of J. Blamont: LPAC/48, 15/10/69.

focal telescope on a manned space station was suggested, with the aim of measuring accurately the orbit of a large number of binary stars and then obtaining a much better knowledge of stellar masses); and radio astronomy (for which the possibility was envisaged of a long wavelength radio telescope on the moon, or an extension to long-baseline interferometry using a geostationary satellite).

The LPAC's policy statement of February 1970

The reports of the Geophysics Panel and Astrophysics Panel were submitted to the LPAC in January 1970 but the Committee agreed that, before arriving at a definite statement on ESRO's future scientific policy, the two reports should be further discussed by the six scientific Working Groups.[35] Of course, the outcome of these discussions did not make the LPAC's task easier. Commenting on the Geophysics Panel's report, the ION group objected to the principle of establishing a negative priority list and argued that the Panel's guidelines should be used only for the major projects and should not cover areas in which important missions could be carried out by the use of small satellites. The PLA group stressed that new information from the United States showed that inexpensive planetary missions were possible and suggested studying the feasibility of a Venus orbiter. The STAR group expressed its concern for the fact that so much emphasis was placed on the space stations, whose availability in the near future was still uncertain, and recommended a satellite flying instrumentation similar to the UVAS type to carry high resolution studies. The COS group stressed the importance of X- and gamma-ray astronomy and of studies on the isotopic and chemical composition of cosmic rays. This group also gave top priority to the study of neutrons and charged particles from the sun, a research area not included in the Astrophysics Panel's report, and placed the study of the magnetosphere rather low in its list of priorities, contrary to the recommendations of the

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[35] LPAC, 30th meeting (14/1/70), LPAC/70, 3/2/70. The the two Panels' reports were discussed at the following meetings of the scientific Working Groups: ION, 28th meeting (26-27/1/70), ION/84, 17/2/70; PLA, 16th meeting (6/2/70), PLA/65, rev. 1, 23/3/70; STAR, 15th meeting (11/2/70), STAR/65, 25/2/70; COS, 24th meeting (19/2/70), COS/50 [missing in the files]; SUN, 14th meeting (4/2/70), SUN/40, 23/2/70; ATM, 16th meeting (12/2/70), ATM/49, 8/4/70. The comments of the various groups are reported in ION/83, 23/2/70; PLA/64, 19/2/70; STAR/64, 23/2/70; COS/48, 23/2/70; SUN/38, 16/2/70; ATM/48, 19/2/70.

Geophysics panel. Finally, the COS group recommended overriding priority to the field of fundamental physics, should a mission in this domain prove feasible. The SUN group stressed the importance of having an ESRO solar satellite to bridge the gap between the end of the NASA OSO programme and the space station projects. The ATM group strongly complained against the elimination of atmospheric research.

It finally required two days of lively discussions in the LPAC to arrive at a definite statement about ESRO's future scientific policy. The chairman of the Council, H. van de Hulst, also attended the meeting, together with an important delegation of ESRO's directorate (the Director General H. Bondi, the Director of Programmes and Planning J.A. Dinkespiler, and the Director of ESTEC's Space Science Department E.A. Trendelenburg), and with C. Dilworth and J.W. Dungey on behalf of the Astrophysics Panel and the Geophysics Panel respectively.

The main issue was again UV stellar astronomy and the pressure from the astronomical community to have a serious involvement of ESRO in the field. B. Strömgren informed the LPAC of a letter he had received from the chairman of the STAR group about "the concern felt by astronomers at the scarcity of optical astronomy in ESRO's programme." The group felt that better communication was required between the LPAC and the astronomical community and urged that investigations should be started "for the use of an orbital observatory to take advantage of the work already undertaken [for UVAS]." Strömgren himself, however, aknowledged that "this was an area in which competition was involved," and that the opportunity of a UVAS-type project should be assessed taking into consideration the American programme. According to chairman Lüst the problem presented itself in the following terms:

> The LPAC should demonstrate a) whether it felt ESRO should have, besides a sounding rocket programme, satellite activity in the UV wavelength range, which would mean that a substantial percentage of the budget should be allocated for this purpose in the future; and b) whether such activity would involve ESRO's starting a medium-sized satellite like UVAS with later modifications. On the other hand, consideration should be given as to whether it would be better to link this type of programme to the space station on the lines that ESRO

might build certain equipment, e.g. a telescope, for use on the station.[36]

It was a matter of scientific policy, of course, that had to confront the financial reality. This was presented by Dinkespiler who provided the meeting with a tentative launching programme of scientific satellites for the second half of the 1970s, on the basis of an envisaged budget of 30–33 MAU per year (Table 5). Dinkespiler's table was obviously oecumenical: it showed how it was possible to include in ESRO's satellite programme all technical options, namely one large satellite project (50 MAU in 5 years), 2 medium sized projects (32 MAU in 4 years), 3 small near–earth orbiting satellites (9 MAU in 3 years), and 1 highly eccentric orbit satellite (16 MAU in 3 years).

The LPAC's decision went into another direction. Concluding the discussion, in fact, the Committee excluded large satellite projects from the ESRO programme and stated that "with the presently foreseen budget for scientific spacecraft [...], it would be possible to perform in the five–year period 1975–80 three medium–sized satellite projects and three to five small satellite projects." As regards the contents of the programme, four research fields were to be given primary consideration according to the LPAC, namely:

a) fundamental physics, with some priority given to experiments to test gravitational theories;
b) plasma physics investigations in the magnetosphere and coordinated studies in the surrounding interplanetary medium and in the polar ionosphere by means of GEOS–type, HEOS–type and small near–earth satellites;
c) high energy astrophysics projects in the X–ray and low energy gamma–ray regions;
d) special cosmic ray studies such as the determination of elemental and isotopic abundances and the measurement of solar neutrons and charged particles.

The LPAC's policy statement, as we see, was consistent with the recommendations of the Geophysics Panel while, regarding the other Panel's controversial issues, it definitely endorsed the arguments of the advocates of high energy astrophysics and cosmic rays. In fact, the most important element in the LPAC's policy statement was that it explicitly excluded stellar UV astronomy and

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[36] LPAC, 31st meeting (27–28/2/70), LPAC/73, 3/4/70, pp. 10 and 11.

solar high resolution astronomy from ESRO's satellite programme, confining these fields to rocket experiments. In the opinion of the LPAC, "it would be inopportune to launch unmanned satellites at dates so close to those when the [space] station begins to work." Preparation for eventual participation in the NASA manned space station programme was recommended but it was made clear that "the funds for a major European participation in the development of the manned space station programme will be provided in addition to the currently foreseen ESRO space science budget." Finally, as regards planetary missions, the LPAC agreed with the Geophysics Panel that ESRO could not compete in this field with the programmes pursued in the USA and USSR. Even in this case it was specified that any eventual participation in a cooperative programme with NASA would require additional resources.[37]

The LPAC decided that its report should not be submitted to the approval of the STC and the Council. It was agreed, however, that the policy statement contained in it should provide the LPAC with definite guidelines for future discussions and recommendations, and ESRO's Directorate of Programmes and Planning with a general framework for next feasibility studies. These same guidelines, stressed the LPAC, "could be of help to European experimenters in defining the direction of their space activities and might assist in the definition of scientific policies in national space programmes and in particular in the orientation of the work of institutes."[38]

Ten years after the *Blue Book*, this was the first time that the representatives of the scientific community involved in ESRO had tried to define a clear scientific policy, based on a set of priorities and on the exclusion of some scientific areas and technical options. Even though not formally endorsed by ESRO's governing bodies, this policy did aim at shaping the further development of the scientific programme of the Organization, with the ambition of establishing guidelines for the whole of European space science. In this respect it is important to remark that

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[37] LPAC/80, 22/5/70, pp. 2 and 4. This is the first draft of the LPAC's *Report on future policy for the scientific space programme of ESRO*. The first two chapters of this document report on the activity of the Geophysics Panel and of the Astrophysics Panel and on the final recommendations of the LPAC. The various research fields are then reviewed in the following chapters. The draft was slightly amended at the 32nd LPAC meeting (15–16/6/70), LPAC/88, 24/8/70, and the final report was eventually circulated in June in the form of a booklet.

[38] LPAC/80, 22/5/70, p. 3.

in the new organizational framework established after the Bannier Report, the LPAC became an advisory body of the Director General, who eventually reported to the STC. And in fact the LPAC's policy definition made explicit reference to the activity of ESRO's new Directorate for Programmes and Planning, created in 1968 after the recommendations of the Bannier Report, whose task was that of "elaborating a long term-policy, and initiating its execution, on the basis of thorough analysis of the past and a sound and wide-ranging knowledge of space activities, programmes and capabilities in Europe and throughout the world." In this capacity, the Directorate of Programmes and Planning was the office responsible for the execution of mission definition and feasibility studies and for providing the European space science community with all information about the status and perspectives of the space programmes in the world. It represented the LPAC's immediate interlocutor within the ESRO top management.[39]

Reaching maturity, ESRO could no longer remain a service organization for any kind of project emerging from the competing interests within the scientific community. Thirteen years after the beginning of the space era, the general framework of worldwide space research appeared clearly defined; the European space science community had definitely got over its infancy; and ESRO could now rely on a more predictable, though limited, set of financial, technical and human resources. It was possible and necessary for the Organization to plan its long-term programme on a more secure base, and the LPAC felt it had to play its part.

If we look at the LPAC's policy statement of February 1970 a few considerations are called for about its most important aspect, namely the exclusion of solar and stellar astronomy from the ESRO satellite programme. This was not an obvious nor a painless choice. In fact, it mortified one of the most important sectors of the space science community and excluded research fields in which the use of space technology had stimulated a dramatic breakthrough in scientific knowledge. The decision to limit solar and stellar astronomy in the ultraviolet to the sounding rocket programme was actually a political as well as a scientific choice, whose rationality derived from three main factors. The first was the

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39 The quotation is from ESRO, *General Report*, 1967, p. 5. Among the terms of reference of the Director for Programmes and Planning, there was that of providing the secretaries of the STC and the LPAC.

consideration of the American effort in these fields. In spite of their great scientific importance, the LPAC felt that a major effort of ESRO in any of them could not be justified since the knowledge obtained would probably not be unique.[40] Rather than committing a substantial fraction of ESRO's limited resources to such fields, the LPAC felt that it was better to foster collaboration with NASA in the space station programme.

The second factor regards the the weakness of the astronomical community *vis à vis* the space programmes, what prevented them from working out good projects and lobbying efficiently through ESRO's policymakers. Even considering NASA's activities, in fact, European astronomers could still claim their past experience in designing the LAS and UVAS projects and could certainly advocate the expediency of a European undertaking in stellar astronomy or solar physics. The NASA's space station programme was far from being established on a firm financial and institutional frame and the field was wide enough to allow a niche where important original results could be obtained by a European satellite. ESRO's financial resources did not in fact exclude this possibility while still leaving enough money for other projects, as Dinkespiler's table showed. Most stellar astronomers and solar physicists were, however, mainly interested in the development of ground based facilites and they lacked the scientific culture and technical expertise required for developing important space projects. The few groups interested in space research which had contributed to the first ESRO satellite payloads were engaged in national or multinational projects outside ESRO's programmes and could not viably support a new major undertaking.[41]

Finally, if we are to understand the reason for a political defeat, we have to consider the winners. These were the two main physicists' communities involved in space research: those interested in the earth's space environment and those interested in high energy astrophysics, i.e. those who had advocated and benefited from the choice of GEOS and COS-B. The former looked at the magnetosphere as the new frontier of geophysical research, with a large variety of experimental possibilities; the latter were colonizing a new and promising field, where experimental techniques borrowed from physical research could be successfully

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[40] This point was made clear in the LPAC's report LPAC/80, 22/5/70, pp. 17-18.

[41] This point has been discussed by Golay (1992) with regards to stellar astronomy and by de Jager (1992) with regards to solar physics.

implemented for studies of high energy phenomena in astronomical objects. The COS-B project had provided them with an instrument devoted to high energy gamma rays; now, just when the LPAC was discussing its policy definition, they received a valid suggestion for an X-ray satellite project: it was too late for discussing it in the Astrophysics Panel meetings but still in time to affect the LPAC's decisions. In fact reporting to the LPAC on the results obtained by the X-ray Mission Definition Group set up a few months before in ESRO, J. Collet informed the Committee that it seemed possible to carry out localization of X-ray sources in the arc second range by using the lunar occultation method with an HEOS-A2 type satellite, to be compared with the arc minute accuracy attainable with SAS-A. Finally there was a project that could compete on equal footing with the American important programme, and indeed, as soon as she heard this statement, C. Dilworth was ready to underline that "the Astrophysics Panel and COS Group reports would be modified by this information." It is quite evident that the information did affect the LPAC policy statement, as the field of X-ray astronomy was given high prority in spite of the low profile it appeared in the Astrophysics Panel's report. The competition was starting again and the various scientific interests were ready to take sides.[42]

The definition of a new structure of the scientific Working Groups

Following the policy statement of February 1970, the LPAC considered whether the structure of the existing scientific Working Groups should be modified in order to be streamlined towards the research fields which had been recommended for the future ESRO satellite programme.[43] Three aspects had to be considered. The first regarded the evolution of the scientific fields involved in space research. The existing ION Group, for example, was no longer interested only in "ionospheric and auroral phenomena" but had in fact taken over responsibility for discussing scientific projects falling into a much wider domain, covering the whole of solar-terrestrial phenomena (magnetosphere, solar wind

[42] LPAC, 31st meeting (27-28/2/70), LPAC/73, 3/4/70, p. 9. This was the first reference to what was to become first the HELOS (High Energy Lunar Occultation Project) project and then *Exosat*. The origin of this project is discussed by Dilworth (1992).

[43] LPAC, 33rd meeting (1-2/10/70), LPAC/92, 23/11/70. Relevant documents on development of this issue are LPAC/95, 25/11/70; and ESRO/ST(72)8, 11/1/72.

and interplanetary medium). Similarly, the COS Group, whose original terms of reference included "cosmic rays and trapped radiation", no longer had members representing radiation belt physics and its main interest was now not so much in cosmic rays as in the high energy range of astrophysics. The second aspect regarded the evolution of ESRO's scientific policy, after the LPAC's policy statement. It appeared, for example, that the work load of the PLA and ATM Groups would not be very large in the future, while some merging of the SUN and STAR Groups seemed advisable to cover the field of low energy astrophysics. At the same time, because of the emphasis laid on the importance of fundamental physics studies, a new Working Group on this subject was recommended. The third aspect regarded the delicate issue of the relationship between ESRO and its scientific customers, the European space scientists. A reduction in the number of scientific groups implied in fact that fewer scientists would be involved in discussions about ESRO's scientific programme, thus reducing goodwill and support for ESRO in the member states. In other words, the role of the Working Groups was to be viewed from two different angles: (a) obtaining the best advice on scientific matters within the framework of ESRO's overall policy; (b) keeping the European space science community together.

The LPAC eventually decided to postpone a decision on the change in the structure of the existing scientific Working Groups as, after the dramatic failure of the November 1970 session of the European Space Conference and the start of new negotiations among ESRO's member states, the very size and nature of the future scientific programme was under discussion at the political level. The Committee, however, did agree to set up a Fundamental Physics Panel, under the chairmanship of H. Bondi.[44]

The issue was taken over again by the LPAC in September 1971, following a solicitation by the STC.[45] By that time fresh information was available about the proposed reduction in the funding of the scientific satellite programme as well as about the elimination of the sounding rocket programme. As a consequence, the Committee agreed that the newly created Fundamental Physics Panel (FFP)

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[44] LPAC, 34th meeting (10-11/12/70), LPAC/96, 15/1/71; 36th meeting (28-29/4/71), LPAC/110, 30/8/71.

[45] LPAC, 37th meeting (28-29/9/71), LPAC/119, 15/11/71; STC, 28th meeting (18/5/71), ESRO/ST/MIN/28, 30/6/71.

should remain as an advisory body of the LPAC and that two new Working Groups should replace the existing six: a Solar System Working Group (SSWG) to cover solar physics, geophysics, solar-terrestrial relations and planetary physics; and an Astrophysics Working Groups (AWG) to cover stellar astronomy, X- and gamma-ray astronomy and cosmic rays. Each Working Group was to have approximately 15 members, to be elected by the LPAC with a gradual build-up, and a rotation of members every 3 years. All fields of space research were thus formally maintained in the working group structure; this however was made much more coarse-grained and the number of scientists involved was reduced by roughly 50 %. The chairmen and vice-chairmen of the groups were to be approved by the STC after nomination by the LPAC. Eventually, G. Haerendel, from the Max-Plank-Institut für Extraterrestrische Physik in Garching, was nominated Chairman of the Solar System Working Group, and C. de Jager, from the Utrecht Observatory, was nominated Chairman of the Astrophysics Working Group. A. Dollfus (Paris-Meudon Observatory) and L. Scarsi (University of Palermo) were their respective deputies. The new structure came into effect on 1 February 1972, at which time the existing Working Groups were disbanded (Table 6).[46]

LPAC'S FIRST RECOMMENDATION: HELOS AND SAS-D (IUE).

In June 1970 the LPAC started to discuss the choice of ESRO's future satellite projects, to follow COS-B and GEOS in the second half of the 1970s. Three mission definition studies had been completed, all fitting within the LPAC's policy definition and devoted respectively to: (a) a space experiment on gravitation theories; (b) an X-ray astronomy satellite; and (c) a series of small standard magnetospheric satellites.[47]

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[46] LPAC, 38th meeting (9/11/71), LPAC/122, 20/12/71. STC, 30th meeting (25/1/72), ESRO/ST/MIN/30, 17/2/72.

[47] LPAC, 32nd meeting (15-16/6/70), LPAC/88, 24/8/70. These studies are presented in LPAC/75, 8/4/70; LPAC/76, rev. 1, 23/7/70; and LPAC/77, 25/5/70; respectively. At the meeting a study on the possible launching of a second GEOS was also discussed. This option was discarded at the following LPAC meeting, where the three main projects were discussed in detail: LPAC, 33rd meeting (1-2/10/70), LPAC/92, 23/11/70.

The X-ray astronomy satellite appeared the most promising project. A Mission Definition Group (K. Pounds from Leicester University, R. Rocchia from Saclay, P. Sanford from Imperial College, and J. Collet and R. Pacault from ESRO) had studied the matter, considering only projects not involving very advanced technology such as highly accurate stabilization, and remaining within the general range of small- or medium-sized projects. After considering the experiments already envisaged on X-ray astronomy on four other satellites to be launched in the near future (the American SAS-A, the European TD-1, the British UK-5, and the Japanese COSRA), the group concluded that the main aim of a subsequent ESRO mission should be the precise determination of the position and geometric shape of X-ray sources, with an accuracy of a few arc sec. This could be achieved by a lunar occultation method with a spacecraft in a highly eccentric orbit. They envisaged a detector sensitive to photons within the energy range 0.3 to 20 KeV as the main component of the scientific payload of such a satellite, whose orbit would allow the scanning of approximately 30 % of the sky, covering about 40 % of X-ray sources presumably known at the time of launch.

The COS group, chairwoman C. Dilworth reported, had expressed its endorsement of the project and the LPAC also showed considerable interest in it, recommending that a feasibility study should be carried out "with all possible speed." The LPAC also urged that a note on this project should appear in *Nature* and that a survey should be made in order to identify the scientific groups in Europe potentially interested in it. Finally, two other members were recommended in the membership of the Mission Definition Group: J. Bleeker from Leiden University and J. Trumper from the Max-Planck-Institut in Garching. The group could also take advantage of the advice of C. Dilworth.[48]

A well-defined and properly timed project, a widespread interest among an influent sector of the scientific community, and a dedicated group of scientists were thus established for the X-ray satellite project, which eventually came to be called HELOS, an acronym for Highly Eccentric Lunar Occultation Satellite. The COS group and its chairwoman C. Dilworth, in particular, felt a sort of moral obligation for supporting the X-ray satellite, after their recommendation of the

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[48] Collet *et al.* (1970). COS group, 25th meeting (5/6/70), COS/53 [missing in the files].

pure gamma-ray satellite COS-B against the alternative project COS-A, which included both a gamma-ray and an X-ray experiment.[49]

As regards the two other studies, the space experiment on gravitation theories and the small magnetospheric satellites, the former was certainly the more interesting from the scientific point of view (it aimed at testing a fundamental physical law) and the more challenging from the technical point of view (it required the development of a heliocentric probe, with an extremely accurate clock and a very sensitive accelerometer on board). It was clear, however, that the realization of such a mission required a good deal of advanced scientific and technical studies and the LPAC recommended keeping on this studying and looking into NASA's possible interest in collaborating on such a project.

Finally, as could be expected, the launching of small standardized satellites for magnetospheric studies was advocated by the ION Group, which stressed the widespread interest in the project among European scientific groups as well as the possibility of relating the small satellite programme to the GEOS mission.[50] Two types of mission were considered, one based on the use of highly eccentric orbit satellites and the other on satellites in circular orbits in the altitude region between 300 and 3000 km. In the first case, three groups of scientific objectives were suggested: studies of the polar region at high altitude, studies of magnetospheric dynamics, and studies of plasma physics. In the second case, it was suggested that two satellites should be operating at the same time, with experiments aiming at high latitude studies of the coupling between the magnetosphere and the ionosphere.

In the event, the LPAC was called to discuss one more project, namely the offer by NASA to have ESRO's collaboration in the development of SAS-D, a space telescope for UV astronomy scheduled for launching in 1974/75. This was only an adaptation of the UVAS package to an explorer-type satellite injected into a geosynchronous orbit, and the project in fact was to be realized by a collaboration between the American space agency and the UK group which had

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[49] Russo (1992a). When recommending COS-B against COS-A, in March 1969, the COS group had urged that a satellite project devoted solely to X-ray astronomy should be studied by ESRO.

[50] ION Group, 28th meeting, (26/27/70), ION/84, 17/2/70; 29th meeting (5/6/70), ION/90, 26/10/70. The interest of the scientific community is documented in ION/81, 9/1/70 and add. 1, 13/1/70.

designed both the LAS and UVAS. ESRO's possible participation was envisaged in the provision of a ground station to monitor the satellite on this side of the Atlantic and/or in the design and development of some sub-system of the satellite. For a total cost of no more than 2 to 4 MAU, the European astronomical community would thus be offered observational time of the order of one third of the total observational time. This possibility, LPAC member B. Strömgren reported, generated "enthusiasm (...) among scientists who are worried about the future of UV astronomy in Europe." In their opinion, in fact, "the proposed astronomical rocket experiments would not be sufficient if one wanted to prepare for the phase when European experimenters would have access to the Post Apollo Programme" and the participation in the SAS-D programme would satisfy just such a need. The LPAC accepted the plea: it in fact expressed its great interest in the project and urged ESRO to further investigate the possibility of cooperation with NASA in the SAS-D project. The Committee was aware, of course, that this could appear to be in contradiction with its own policy statement and it thus stressed that this policy did not exclude but rather hoped for a financially feasible involvement in UV astronomy in preparation for eventual participation in the manned space station programme.[51]

The time of decision for the LAPC came at the end of April 1971, when the feasibility studies for the various projects were available. The main decision regarded the choice between the magnetospheric project and the X-ray astronomy project HELOS. Whatever the choice made between them, it was possible in addition to undertake a smaller project to be selected between participation in the NASA SAS-D project and the establishment of a study and laboratory programme to prepare a space experiment on gravitation theories.[52]

Three different options had been studied for the magnetospheric project: a highly eccentric magnetospheric satellite (HEMS), to be launched by the ELDO

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[51] LPAC, 33rd meeting (1-2/10/70), LPAC/92, 23/11/70, p. 10. Information on the possible ESRO participation in the SAS-D programme is in ESRO/C/480, 23/11/70.

[52] LPAC, 36th meeting (28-29/4/71), LPAC/110, 30/8/71. This document is divided into two parts with different page numbering, the first for the open meeting, with the chairmen of the scientific groups, the second for the restricted meeting, with only LPAC members, the chairman of the STC (Lüst) and a limited ESRO staff. The result of feasibility studies are presented in LPAC/103, 16/4/71 (near earth magnetospheric satellites); LPAC/104, 16/4/71 (highly eccentric magnetospheric satellites); LPAC/105, 2/4/71 (HELOS); LPAC/108, 26/4/71 (SAS-D); and LPAC/109, 21/4/71 (gravitation theories).

Europa II or the NASA *Thor Delta* vehicle, and two near earth magnetospheric satellites (NEMS), to be launched by the French *Diamant-BC* and the British *Black Arrow* respectively. Reporting on the recommendations of the ION group, its chairman J.W. King explained that a series of satellites would not be necessary to achieve the scientific aims and emphasized rather the need to have correlated measurements from another satellite at the time of GEOS as part of the International Magnetospheric Study. According to the ION Group, first priority had to be given to the HEMS project while the NEMS projects should be considered as second choice.[53]

The ION group's endorsement of the magnetospheric project was not coupled with that of the COS group. On the contrary, the latter, represented at the LPAC meeting by its chairwoman C. Dilworth, criticized the lack of clear scientific aims in the proposed magnetospheric missions. Not surprisingly, the group strongly recommended the X-ray mission, which they considered "an important and advanced tool in X-ray astronomy, with possible future application in the low energy gamma ray field."[54]

The strength of HELOS derived from two main factors, one scientific and one institutional. From the scientific point of view the project had the advantage of the lunar occultation method, which allowed the precise determination of the position of X-ray sources and the measurement of their fine structure and angular dimensions with high accuracy. This was a very important characteristic since the launching of the satellite was planned after that of SAS-A, which was to produce the first large scale survey of the X-ray sky, and before the launching of the first High Energy Astrophysics Observatory (HEAO), a family of second generation satellites for X-ray astronomy whose pointing accuracy, however, was expected to be one order of magnitude lower than that of HELOS.

As to the institutional aspects, HELOS was an observatory-type satellite like COS-B but with one significant difference with respect to the latter, namely that ESRO was to be responsible for funding both the spacecraft and the scientific

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[53] ION Group, 31st meeting (29/3/71), ION/103, 6/4/71. In addition to these three projects, a feasiblity study had also been carried out on a smaller near earth satellite to be launched by the less powerful *Diamant B* launcher. The ION group, however, considered that this option would not be able to fulfil the envisaged scientific objectives.

[54] COS Group, 28th meeting (26-27/4/71), COS/60, 11/6/71, p. 13.

package. HELOS was thus to be the first ESRO project for which the Organization would bear the financial cost of the experiment and the satellite would become a real observatory-like facility: the whole of the European scientific community working in X-ray astronomy would be interested in its performance, would be involved in its scientific management, and would have access to its data. If HELOS was approved, ESRO's J. Ortner pointed out, "it was intended to expand the Mission Definition Group to include representatives of all institutes actively engaged in X-ray astronomy, in order to define the scientific payload in the best possible way."[55] In conclusion, while the magnetospheric project still placed itself in the early tradition of ESRO's satellites - a loose scientific mission in a well-established research field, to be fulfilled by a collection of experiments provided by different laboratories - HELOS was definitely in the new tradition inaugurated by COS-B - a space observatory in a new and dynamic exploratory field, requiring the unitary effort of an important sector of the space science community.

Last but not least, it must be recalled that behind HELOS there was the support of the same coalition which had determined the succes of COS-B (Occhialini's Milan group with Dilworth, Lüst's Münich group with Trumper, van de Hulst's Leiden group with Bleeker), with two important additions: ESTEC's Space Science Department, where the involvement in COS-B had produced the establishment of a lively research programme in high energy astrophysics, and the British X-ray group at Leicester University (K. Pounds), which had lost the possibility of flying its X-ray instrument in COS-A and now wanted to seize the new opportunity.

If the alternative between the magnetospheric project and the HELOS project required the most important choice, another decision had to be taken by the LPAC, namely whether to recommend ESRO's cooperation in the NASA/UK SAS-D project or to recommend a laboratory research programme to prepare a space experiment on gravitation theories. Regarding the former, the suggested

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[55] LPAC/110, p. 7. This aspect of the HELOS mission was emphasized at the COS group meeting which recommended it. The LPAC had discussed at length the financing of scientific experiments for ESRO satellites at its 33rd meeting (1-2/10/70), LPAC/92, 23/11/70, and it had agreed that, for large projects, consisting of one or two large experiments, there would be a great advantage if ESRO funded the scientific payload.

form of cooperation was the development by ESRO of a ground station in Europe, including a set of antennae and a dedicated computer, at an estimated cost of around 3 MAU. This solution would give European astronomers full scientific control of the observational time allocated to them, namely some 40 per cent of the total, equally shared between ESRO and the UK. As regards the space experiment on gravitation theories, studies carried out in industry and scientific institutes had confirmed "the real gain one could expect from a complex space experiment entirely and exclusively devoted to tests of gravitation theories."[56] The proposed mission foresaw the use of a spacecraft in heliocentric orbit to measure the coefficients of the space-time tensor with the highest accuracy possible. Owing to the great technical complexity of the project, however, a vigorous programme of laboratory research was required in order to demonstrate its feasibility and to permit assessment of its cost.

ESRO's involvement in the SAS-D project was strongly recommended by the STAR group, represented at the meeting by its chairman L. Houziaux, who was also ESRO's representative in the SAS-D Working Group. For the STAR Group, ESRO's participation in the SAS-D project represented "a unique opportunity to satisfy the European UV community at a very attractive cost." The group's resolution then concluded on a note of victimization:

> Rejection of the offer by NASA would deprive the European astronomical community of the immeasurable benefits from the large capabilities offered by SAS-D. With the TD-1 instruments being the only sources of astrophysical information from satellites, the European community would be placed at a major disadvantage with regard to its American counterpart. [...] It is felt that the expenditure required for participation in the SAS-D project is not excessive in respect of what has been requested for, and given to, astronomy.[57]

It was eventually the task of the restricted meeting of the LPAC to issue a final recommendation about the choice of ESRO's next scientific satellite projects. Not surprisingly these were HELOS and SAS-D. Even though we do not find in the minutes any explicit reason for the choice of HELOS, they can be easily inferred

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[56] LPAC/109, 21/4/71, p. 3.

[57] LPAC/110, p. 10. STAR, 27th meeting (27/4/71), STAR/72 [missing in the files].

from what has been said before. We can just recall four main aspects: (a) it was a well designed project, with a clear scientific objective and with strong support from an influential sector of the scientific community involved in ESRO's programmes; (b) it allowed European scientists to play a significant role in the promising field of X-ray astronomy even in tha face of NASA's important effort; (c) following COS-B, it gave coherence to ESRO's scientific programme in the field of high energy astrophysics; (d) it would be the first truly ESRO satellite.

The choice of HELOS excluded, for financial reasons, the possibility of adopting the magnetospheric project recommended by the ION group but it did allow ESRO's participation in the NASA SAS-D programme. The LPAC recognized the great rewards in observation time for European astronomers that would be obtained by this participation and strongly recommended it. No decision, on the contrary, was taken on the laboratory programme for the space experiment on the gravitation theories, pending the views to be expressed by the newly established Fundamental Physics Panel.

In the event, owing to the political difficulties described in the following section, only the possible participation in the SAS-D project was put forward to the STC. It was easily approved and the STC also recommended that, besides providing a ground station at a cost of about 3 MAU, ESRO should contribute to the spacecraft hardware up to a maximum of 1 MAU.[58] In July 1971 the Council finally approved this recommendation and the project then came to be called *International Ultraviolet Explorer* (IUE). We can notice a sort of irony in the circumstance that the first new ESRO project approved after the LPAC's policy statement was in fact in a field that was excluded in that very statement.[59] The IUE satellite was launched in January 1978 into a geosynchronous orbit and, after commissioning, it was operated for 8 hours each day from ESA's Villafranca

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[58] STC, 28th meeting (18/5/71), ESRO/ST/MIN/28, 30/6/71. See also ESRO/ST(71)9, 12/5/71 and ESRO/ST(71)10, 7/5/71. The STC's endorsement was taken with the sole abstention of Spain, who pressed to have the ESRO tracking station for GEOS and SAS-D in her territory. Eventually, the ground station was built at Villafranca, near Madrid, and ESA also contributed the deployable solar-cell array of the spacecraft.

[59] Council, 43rd session (13-14/7/71), ESRO/C/MIN/43, 14/12/72. Information to the Council was provided in ESRO/C(71)34, 2/7/71. The IUE project is described in ESRO/ELDO *Bulletin*, **18** (May 1972), pp. 13-17.

station, near Madrid, from which European astronomers could carry out their observations just as in the case of a ground observatory.

THE 1971 CRISIS AND THE "FIRST PACKAGE DEAL"

Notwithstanding the LPAC's discussions and recommendations, there was no question for ESRO, in that spring of 1971, deciding on the start of a new major satellite project. In fact, just a few months before, in November 1970, the latent crisis which afflicted European cooperation in space had erupted dramatically at the fourth session of the European Space Conference (ESC). On that occasion, ESRO's *General Report* informs us, "the disunity between the countries favouring a 'coherent policy' including an independent European launcher effort and the others reached such a magnitude that the meeting broke up."[60] As a consequence, all plans for a unified European space organization that for two years had dominated discussions receded dramatically and the very future of Europe collaboration in space appeared rather grim. Denmark and France went so far as to denounce the ESRO Convention in order not to incur financial obligations extending beyond the first eight-year period. Given this situation, it was impossible for the Organization to embark on a new programme and even the projects under development had to be delayed.

Facing the failure of the ESC meeting, ESRO Member States agreed that their delegations to the Council should negotiate further among themselves, leaving aside the problems which had led the ESC to deadlock. In spite of difficulties and setbacks, in fact, ESRO had proved to be sufficiently reliable and successful in its work; it had acquired maturity and competence in managing industrial development contracts; and it had established a firm basis for the development of application satellites, which increasingly appeared to be the true political and

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[60] ESRO, *General Report*, 1970, p. 9. The European Space Conference (ESC) had been convened for the first time in December 1966, with the aim of discussing and defining a coherent European space policy, including scientific research, application satellites and launcher development. The fourth session of the ESC was convened in Brussels in two separate meetings, on 22-24 July and 3-5 November 1970. The issue of the European launcher was the hottest of several controversial issues which shook the discussions of ESC delegations. A detailed analysis of the political and institutional aspects of this crisis will be developed in a subsequent report in this series. See, however, McDougall (1985) and Krige (1992b).

economic *rationale* for European co-operation in space.[61] The new Chairman of the ESRO Council, the Italian physicist G. Puppi, who had been the Chairman of the ESC's Committee of Senior Officials, was given the task of negotiating a proper compromise in order to drive the Organization, as smoothly as possible, to its new role in the application field and, at the same time, to offer European space policymakers a new ground for negotiations. After one full year of intense negotiations, the compromise was worked out and it became known as the "First Package Deal."[62]

From the point of view of this paper, the main aspect of the 1971 package deal is that ESRO definitely abandoned its role as an Organization solely devoted to scientific research and undertook application satellite programmes on telecommunications, aeronautical communication, and meteorology. The dramatic rise of importance of these application programmes can be appreciated if one considers that for the years 1972, 1973 and 1974 they were to be provided for at a cost of 22.8 MAU, 48.5 MAU and 63.4 MAU respectively, eventually reaching an annual level of resources of not less than 70 MAU in the period 1975-1980. In comparison, the budget for the scientific satellite programme for 1972, 1973 and 1974 was fixed at 41.7 MAU, 36.0 MAU, and 31.7 MAU respectively, eventually reaching a minimum level of 27 MAU in the years 1975-1977.[63]

As a consequence of this re-orientation, the Council decided to eliminate the sounding rocket programme and to terminate the scientific activities in ESRIN by 1973. The Kiruna launching range (ESRANGE) was taken over by Sweden under an appropriate protocol while, in order to smooth Italian protests, it was eventually decided that ESRIN should become the new seat of the Documentation Service.[64] Further economies were effected in the scientific programme by postponing the start of the development contracts for the COS-B and GEOS projects, by

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61 "Statement by the Director General" at the 35th session of Council (22/12/70), ESRO/C/483, 18/12/70.

62 Council, 44th session (20/12/71), ESRO/C/MIN/44, 6/1/72. The Council resolution with the agreed on "package deal" is reported in ESRO, *General Report*, 1971, p. 129-132, and in *ESRO/ELDO Bulletin*, **17**, Feb. 1972, p. 6-11.

63 The figures are taken from G. Puppi's and A. Hocker's comments to the Council resolution of December 1971, *ESRO/ELDO Bulletin*, **17**, February 1972, pp. 11-14 and 14-19.

64 ESRIN, ESRO's Space Research Institute, was located in Frascati, near Rome.

deferring new projects, and by limiting future scientific satellites launchings to one about every two years.

The 1971 package deal marked "the beginning of a new period in the life of ESRO."[65] The Organization was definitely transformed into a space agency mainly devoted to application satellites with just a minor fraction of its jobs and funds devoted to science. As a matter of fact, during the laborious negotiations which led to the compromise, "the whole scientific programme was put in some doubt", according to the chairman of the STC.[66] In the first draft of Puppi's package deal, it was suggested that the scientific programme should be made optional from 1974, a position strongly supported by France, and only with a drastic reduction of funds had it been finally agreed to keep it mandatory. The sum of 27 MAU, however, fell quite short of the scientists' expectations. In fact, in the hottest phase of negotiations, both the STC and the LPAC had approved a statement in which, on the basis of some statistics on the number of scientific groups active in space research in Europe, it was argued that ESRO should launch one medium-sized satellite per year. The statement concluded that "the minimum level of funding required for a truly viable scientific satellite programme lies between 43 and 47 MAU."[67]

It is against this background that we shall consider the evolution of discussions and decisions about ESRO's scientific satellite programme.

Choosing ESRO's new satellite projects: ISEE-2 and Exosat

The agreement reached in the ESRO Council foresaw that the development contract for the next scientific satellite project should start not later than January 1975, which implied that a decision had to be taken in 1973. The decision-making process thus started again.

In the course of 1972, three projects were studied in detail by the Directorate of Programmes and Planning. The first was the HELOS project, under study for

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65 ESRO, *General Report*, 1971, p. 9.

66 STC, 28th meeting (18/5/71), ESRO/ST/MIN/28, 30/6/71, p. 2.

67 LPAC, 36th meeting (28-29/4/71), LPAC/110, 30/8/71, p. 2-3 of the restricted session; STC, 28th meeting (18/5/71), ESRO/ST/MIN/28, 30/6/71, Annex 1; also in ESRO/ST(71)10, 7/5/71, p. 2-3.

two years and already recommended by the LPAC. Further studies demonstrated that the spacecraft's pointing system, designed to achieve good lunar occultation of sources, also assured the possibility of making observations in any celestial direction. Moreover, the satellite's design made it possible to study temporal variations in the intensity of X-ray emissions from discrete sources in a range between a few tens of microseconds and a few tens of hours. The conception and objectives of the HELOS mission were discussed in a colloquium organized at ESRIN in May 1972 and by the end of the year the scientific objectives and model payload of the satellite had been fully defined.[68]

The two other projects involved cooperation with NASA, more and more a necessity for ESRO after the reduction of the scientific programme budget. The first project envisaged the launch of two satellites into adjacent orbits for the study of small scale spatial and temporal variation in magnetospheric plasma and solar wind. This project, originally called IMP-K/K' and then renamed IMP-M/D (Mother/Daughter), had been discussed for the first time during a joint ESRO/NASA programme review meeting, held in Washington in early February 1971.[69] Subsequently, following further discussions between ESRO and NASA and a preliminary study of an ESRO Mission Definition Group, the COS and the ION groups jointly agreed to recommend that ESRO should undertake the project with NASA by supplying the "daughter" satellite, and the LPAC requested a feasibility study.[70]

The two space organizations eventually defined a selection procedure for the payloads of both satellites, which foresaw the possibility that American experiments might be included in the European satellite and viceversa. This was an important innovation for ESRO, whose satellite payloads had been reserved till

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[68] ESRO, *General Report*, 1972, pp. 106-107. The proceedings of the symposium are in *X-ray astronomy in the near future*, ESRO SP-87, Noordwjik 1972.

[69] This meeting (1-2/2/71) is reported on in LPAC/107, 17/3/71. The acronym IMP stands for Ionospheric and Magnetospheric Physics.

[70] LPAC, 37th meeting (28-29/9/71), LPAC/119, 15/11/71. The report on the joint COS/ION meeting (14/9/71) is ION/108, 2/11/71 and the resolution passed at the meeting is in ION/106-COS/62, 15/9/71. In this resolution, it was made clear that the inclusion of the project in the ESRO programme was recommended, "provided that the missions already approved by the LPAC are not jeopardized." This reflected the COS Group's concern that the IMP-M/D project should not compete with HELOS: COS Group, 29th meeting (14/9/71), COS/63, 3/11/71. Document MS/282, 15/9/71, is a presentation of the project at this stage.

then to European scientists. Another important aspect of the agreement was that, following the usual NASA procedure but contrary to ESRO's standard procedure, an announcement of flight opportunity, based on the mission definition, would be sent out and experiment proposals discussed before the mission was actually approved.[71] The IMP-M/D project was then discussed in May 1972 at a colloquium in ESRIN and, by the end of the year, the selection procedure had been completed and the payloads of both satellites definitely approved.[72]

The last project was a spacecraft to be injected into an orbit around the planet Venus. Preliminary studies on a possible low-cost mission to Venus had already been made by ESRO in 1971, compatibly with the LPAC policy statement which excluded planetary exploration for budgetary reasons but did allow for re-consideration of this issue if a significant cost reduction proved possible.[73] The envisaged solution was a Venus orbiter based on a spacecraft whose size and cost would be of the order of that of GEOS. Subsequently, following a joint ESRO/NASA meeting on future space science co-operation, held in Washington on 18 April 1972, it was decided to link this project to NASA's Pioneer Venus programme. The project foresaw that NASA should provide the basic spacecraft (the so-called "space bus"); ESRO would then transform it into an orbiter by the addition of a suitable motor and be responsible for the integration of the scientific payload and the testing of the satellite; finally, the spacecraft would be delivered to NASA for launching on a *Thor Delta* vehicle. A joint ESRO/NASA committee eventually worked out the scientific objectives of the mission and defined a model payload.[74]

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[71] LPAC, 38th meeting (9/11/71), LPAC/122, 20/12/71; STC, 30th meeting (25/1/72), ESRO/ST/MIN/30, 17/2/72. The terms of the agreement are described in LPAC/120, 2/11/71 and in ESRO/ST(25), 29/11/71.

[72] The agreed payload composition of both satellites was presented in LPAC/147 + addendum, 13/12/72, and it was approved by the LPAC at its 44th meeting (15/12/72), LPAC(73)2, 23/1/73. Besides the two IMP-M/D satellites, a third ("heliocentric") NASA spacecraft was contemplated, with correlated experiments on the solar wind undisturbed by the presence of the Earth. Some of the instruments of this spacecraft were also to be provided by European scientific groups.

[73] A mission definition study for a low cost Venus orbiter was requested by the PLA group after the LPAC's policy statement: 18th meeting (2/7/70), PLA/69, 18/8/70; 19th meeting (25/9/70), PLA/71, 20/11/70.

[74] The report on the ESRO/NASA meeting, by LPAC's chairman J. Geiss, is in LPAC/127, 9/5/72. The project was then discussed at the second meeting of the Solar System Working Group

When the LPAC was finally called to issue its recommendation on the choice of ESRO's new satellite projects, the scientific importance of the event could not be underestimated. It came as much as four years after the choice of COS-B and GEOS, and from that time onwards the aims and scopes of the Organization in the wider context of European space activities had undergone significant changes, of which the dramatic reduction of the scientific budget was certainly not the least important. It was clear that the new decision would have a major impact on the overall development of space research in Europe, on the relationship between ESRO and NASA, and on the public image of ESRO's undertakings. In fact, the event was given all the official prominence it deserved. The three projects were first discussed in a two-day symposium, held at ESRIN, on 26-27 February 1973, attended by about a hundred scientists from all over Europe. The symposium was then followed, on 28 February, by meetings of the Astrophysics and Solar System Working Groups and of the Fundamental Physics Panel, whose conclusions were reported to the LPAC. Finally, on 28 February and 1-2 March, the LPAC itself held its meeting and, in a restricted session, issued its final recommendation to the Scientific Programme Board (SPB), the body that had replaced the STC in the new organizational structure of ESRO, which took into account the Organizational involvement in application satellite programmes.[75]

As usual in the case of major LPAC's decisions, the choice involved scientific, financial and political aspects. Each of the three projects under discussion was recognized in fact as being "fully worthy of adoption by ESRO." Financial limitations, however, made it impossible to recommend simultaneous adoption of all three, because this would have unduly delayed the date of the next decision for another four years. By appropriate phasing, however, it was possible for ESRO to

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(15/5/72), SOL/4, 21/8/72, and a feasibility study was requested by the LPAC at its 40th meeting (16/5/72), LPAC/128, 23/6/72.

[75] LPAC, 46th meeting of the (28/2-2/3/73), LPAC(73)11, 21/3/73. The three projects at this stage are described in ESRO/PB-S(73)2, 13/3/73 (Venus Orbiter); ESRO/PB-S(73)3, 9/3/73 (HELOS); and ESRO/PB-S(73)4, 9/3/73 (IMP-M/D). The programme of the Frascati symposium is in LPAC(73)8, 24/1/73, and its attendance is in MS(73)10, 14/3/73. The conclusions of the Astrophysics and Solar System Working Groups and of the Fundamental Physics Panel are attached to the minutes of the LPAC meeting. The LPAC's recommendation to the SPB is also attached; it was eventually presented to the SPB with the code number ESRO/PB-S(73)1, 8/3/73. It must be remarked that the minutes of the LPAC meeting do not report at all on the discussion which led to the conclusion presented in this document.

realize two projects, the first to be started in 1974 and the second in a later year. Therefore, the first problem the LPAC had to confront was whether to recommend simultaneous adoption of both or to choose one now and delay the decision on the second project to some later time. The issue was debated at length and eventually it was agreed that two projects ought to be adopted contextually, the main reason being that ESRO should remove all uncertainty about its future plans and "leave no doubt in the minds of national authorities and of the scientific community of its determination to carry out a good scientific programme." Moreover, by adopting two projects, the interest of potential experimenters in the second project would be fully retained, giving them ample preparation time to optimize the scientific package. In the opinion of the LPAC, all these aspects compensated the disadvantage deriving from the frustration of many other scientists who would be "painfully aware that three years will elapse before they get another chance on a European space vehicle."[76]

Then came the problem of which two projects out of the three on the table should be recommended for adoption, a choice that involved at least three kinds of consideration. The first of course regarded a comparison between the three projects from the viewpoint of their scientific interest and the degree of support they received from the scientific community. From this point of view HELOS was certainly the best placed: this was in fact a satellite based on an original concept proposed by European teams, whose scientific mission pertained to a new and dynamic research field, and that had been under study since a long time. The project had been strongly recommended by the Astrophysics Working Group, as could be expected, and also the Fundamental Physics Panel had given it top priority, on the motivation that "it will help to answer questions of fundamental significance in gravitation and cosmology as well as many problems of astrophysical importance."[77]

As to the other two projects, which pertained to the interests of the Solar System Working Group, this had concluded that they were both scientifically valuable and that "a grouping together of the two projects would constitute a

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[76] ESRO/PB-S(73)1, pp. 2-3. This document (as well as the minutes of the LPAC meeting) inform us that this was a "majority opinion" in the LPAC but it is silent about the actual position of individual LPAC members.

[77] LPAC(73)11, annex V.

balanced programme and serve a wide section of the scientific community."[78] The Group carefully avoided to award priority to either of them, and in fact this was a very delicate issue. On the one hand, participation in the IMP-M/D project was consistent with the LPAC's policy statement and would usefully complement the GEOS mission, thus meeting the interests of a sector of the European space science community that had had a leading role in the development of ESRO's scientific programme. On the other hand, the Venus Orbiter would provide ESRO and European scientists with a unique opportunity to enter the fascinating field of planetary exploration at low cost. According to the Working Group, the number of scientific groups eventually involved in the project was estimated to be not less than 25 and the Venus mission would foster new lines of research by bringing diverse disciplines together.

The second consideration regarded ESRO's relationship with NASA, a complex relationship that involved both partnership in joint projects and "friendly competition."[79] While HELOS was a pure ESRO project, both the Venus Orbiter and the IMP-M/D mission were cooperative projects and, in fact, this was the first time the two agencies were involved in such an important collaboration. The status of the two projects on the other side of the Atlantic was different, however. The IMP-M/D mission had already been approved by the top NASA management and by the President's Office for Management and Budget, and it was on the way to obtaining congressional approval. Moreover, payloads for both satellites and for the associated NASA's Heliocentric spacecraft had already been decided by a joint ESRO/NASA screening procedure. Therefore it seemed likely that if ESRO approved its part of the project (i.e. the Daughter satellite), there was little risk that it might be cancelled by U.S. authorities at a later date. The situation was different for the Venus Probe: ESRO in fact had received word from NASA that, because of its tight budget situation, this project could not start in 1974, and it was still uncertain whether it could be included as a new start in 1975. In this case too a positive decision by ESRO could affect the eventual course of action in the U.S. but the risk was not negligible that the project might be cancelled in the future, as a consequence of negative decisions in the United States.

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[78] LPAC(73)11, p. 4.

[79] ESRO/PB-S(73)1, p. 5.

Finally, the problem of timing played an important role, as ESRO was to start its new satellite project in 1974. The Venus Orbiter, even if adopted, could not start so soon, pending NASA's final decision, and therefore the first project had to be either HELOS or the Daughter satellite of the IMP-M/D project. If the former was adopted, its cost development would prevent the start of a second project before 1976 and, as a consequence, ESRO participation in the IMP-M/D project would become incompatible with NASA's timetable. If, on the contrary, the Daughter satellite was adopted, it would be possible to undertake the second project (HELOS or the Venus Orbiter) one year later.

In this situation, the LPAC decided to recommend the programme which appeared less risky from the point of view of its actual feasibility and the more consistent with its three-year-old policy statement. It in fact finally agreed to recommend that ESRO should adopt the IMP-Daughter spacecraft and HELOS, the former starting in 1974 and scheduled for launch in 1977, the latter starting in 1975 and scheduled for launch in 1979. The LPAC's recommendation, endorsed by ESRO's Director General, was approved by the SPB and finally, in April, the Council approved the adoption of the two projects in the ESRO programme.[80] They were eventually renamed ISEE-2 and *Exosat*.[81]

Two considerations are called for regarding this conclusion. The first concerns the LPAC's decision to recommend the contextual adoption of two projects, although only one could actually start in the near future. Considering what we have said about the timing and the status of ESRO/NASA collaboration, this decision was not innocent as regards the choice of which projects had to be selected. If, in fact, only one project had been adopted, this could have been either

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[80] SPB, 3rd meeting (27/3/73), ESRO/PB-S/MIN/3, 11/4/73; Council, 56th session (11-12/4/73), ESRO/C/MIN/56, 3/5/73. The financial implications of this decision are presented in ESRO/PB-S(73)7, 14/3/73. According to the revised Convention the SPB would have the power to take final decisions on the scientific programme. As the new Convention was not yet in force, however, the decision taken by the Board was eventually submitted to Council for confirmation: ESRO/C(73)18, 29/3/73. At the Council meeting, the funding by ESRO of the HELOS payload was a matter of some controversy; eventually, on this specific aspect, Belgium and Spain voted against and France abstained.

[81] The acronym ISEE stands for *International Sun-Earth Explorer*. ISEE-1 and ISEE-2 (the former IMP Mother and Daughter satellites) were launched in tandem in October 1977; ISEE-3 (the IMP "heliocentric" satellite) was launched in August 1978. The launch of *Exosat* had to be delayed until as late as June 1983. A description of the ISEE mission at the time of its launch is in Durney (1978) and Eaton (1978). For *Exosat*, see Altmann *et al.* (1982) and Taylor *et al.* (1982).

HELOS or the Daughter satellite, and in both case the Venus Orbiter would have been in a more favourable condition at the time of decision on the second project. We can venture to say that the wish of the majority of the European space science community to realize both its pet projects played an important role in a decision which took advantage of the weakness of the Venus Orbiter in early 1973 and bound the long-term ESRO programme. This circumstance emerged when the LPAC's recommendation was submitted to the SPB for approval. Here the French delegation, supported by the Belgian, expressed reservations on HELOS and strongly advocated the Venus Orbiter. They insisted that there was no need to take an immèdiate decision on HELOS and proposed instead that, after the adoption of the Daughter satellite, tender actions should be carried out among the scientific community, in order to assess the real degree of interest in HELOS and the Venus Orbiter in Europe before the choice of the second project. A vote was then taken on the French proposal to postpone a decision on HELOS and it was rejected by 5 votes against (Germany, Italy, Netherlands, Switzerland, United Kingdom) and four votes in favour (Belgium, France, Spain, Sweden), with the abstension of Denmark. In the final vote on the LPAC's recommendation, Sweden joined the majority. We can only offer a suggestion about the positions expressed by SPB delegations, as no clear reasons emerge from the minutes of the meeting: on the one hand, no important research group was active in France in X-ray astronomy while French planetologists did certainly have an interest in the Venus Orbiter; *Exosat*, on the other hand, enjoyed full support from the influential scientific circles interested in X-ray astronomy in the UK, Netherlands and Italy, besides being supported by ESRO scientific and technical staff.

The second consideration is of a more general character and it regards the development of the ESRO scientific planning since 1969. In the context of the difficult times European cooperation in space was suffering in those years, the LPAC and the Directorate of Programmes and Planning made every effort to define a long-term scientific policy based on clear priority choices, accurate mission definition and feasibility studies, and intelligent cooperation with the sister agency beyond the Atlantic. The choice of IMP-M/D and HELOS after COS-B and GEOS was in fact the logical outcome of this effort. With the painful decision to close the rocket programme and the recognition that ESRO could not sustain a viable small satellite programme nor undertake alone large and

technically sophisticated projects, the forthcoming European Space Agency had to find its own ground for scientific activity by the selection of a limited number of original projects in well-selected research fields, and by the fostering of intelligent participation in cooperative projects with NASA. The decision to realize ISEE-2 and *Exosat* actually set the stage for ESA's next successful scientific missions *Giotto*, *Hypparcos*, and *Ulysses*.[82]

Conclusion

In July 1973, a few months after the adoption of ESRO's new scientific satellite projects, an important session of the European Space Conference marked the decisive turning point in the history of ESRO and, more generally, of Europe in space. A new "package deal" negotiated among ESRO member states gave the Organization the responsiblity for the new *Ariane* launcher programme, whose management was entrusted to the French *Centre National d'Etudes Spatiales*. This, in the words of the new Council chairman M. Lévy, "transform[ed] ESRO for the first time in effect into a space organization with a complete and balanced programme."[83] The same agreement, continued Lévy, foresaw for ESRO "the start of a great adventure", namely co-operation with NASA in the Space Shuttle programme by the construction of a space laboratory (Spacelab) to be integrated in the shuttle. Finally, a new applications programme, a satellite programme for the control of maritime navigation (MAROTS), was also decided on and entrusted to ESRO. From the institutional point of view, the implementation of the new

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[82] The *Giotto* mission to Halley's comet was approved in July 1980 and the spacecraft was launched five years later, in time for the fantastic encounter with Halley on the night of 13-14 March 1986. The *Hypparcos* project, a space telescope for accurate optical astrometry, was adopted by ESA in March 1980 and the spacecraft was launched in August 1989. As to *Ulysses*, this was originally conceived as ESA's contribution to a dual-spacecraft mission, one of which was to be constructed by NASA, to study the interplanetary medium, solar wind and cosmic rays out of the ecliptic plane (*Out-of-Ecliptic* mission and then *International Solar-Polar Mission*). ESA's contribution to this mission was approved in 1977 and then, after NASA cancelled the American spacecraft, the project was confirmed in 1984. The launch was originally scheduled in 1983 but it was then delayed to 1986 as a result of difficulties with the development of the Space Shuttle. The dramatic accident of the *Challenger*, in January 1986, caused a further long delay and the spacecraft had to be kept in storage until it was finally launched in October 1990.

[83] Lévy's foreword to ESRO's *General Report*, 1973, p. 7. About the 1973 package deal see McDougall (1985).

method *à la carte* of programme financing and the fact that each of the three new programmes was sponsored by one of the main member states – *Ariane* by France, Spacelab by Germany and MAROTS by the UK – gave strength and stability to ESRO's activity. Quoting again from Lévy's foreword to ESRO's *General Report*:

> It can therefore be said that the Organisation now has an almost completely charted programme until 1980, and that this programme is particularly rich and diversified. The ESRO budget, which was practically doubled after the first package deal in 1971, has again been doubled following the new package deal of July 1973.

As a matter of fact, with the liquidation of ELDO, also decided in 1973 after the cancellation of the Europa II and Europa III programmes, it was more than evident that the forthcoming European Space Agency would actually be based on ESRO's structure and on-going programme.

Space science was no longer the only component of this programme, nor the most important. It was however the one which was already providing useful results and the one upon which the very existence of a joint European effort in space could be based. By mid 1973 four ESRO satellites were orbiting around the earth (HEOS-1 and 2, ESRO IV and TD-1), one was scheduled for launch in 1975 (COS-B) and two were under development for launching in 1977 (GEOS and ISEE-2). Moreover, ESRO was actively involved in the co-operative IUE project which promised an important scientific return to European scientists. At the same time, which was most important, the Organization had finally succeeded in defining a scientific policy which gave coherence to the selection procedure of future programmes. And the procedure in fact went into motion again in the second half of 1973, along the lines already defined. In September the Director General asked the LPAC to discuss ESRO scientific policy for the period following ISEE-2 and *Exosat* in the early 1980s. The Astrophysics and the Solar System working groups were called to produce reports on this matter, according to their respective areas of interests, and new "Guidelines for ESRO scientific mission studies" were issued by the LPAC in January 1974. Within these

guidelines, eleven missions were recommended for immediate studies in view of the selection of the new project(s) foreseen in 1976.[84]

The most significant aspect of the maturation process which we have analysed in the previous pages can be recognized in the growing awareness among ESRO's scientific policymakers of the limits imposed on the Organization by its specific charter: that of a multinational organization whose aims and programmes had to be continuously negotiated by its member states on the basis of different, and sometimes conflicting, political and economic interests. In this negotiation, science, i.e. scientists' thirst for new knowledge about celestial phenomena, was not an indèpendent variable, but rather a component of a complex network dominated by more mundane affairs. ESRO's overall policy certainly kept science in its very foundation but its actual definition and development largely derived from forces other than scientific dreams. The *Blue Book* foresaw the launching of a large scientific satellite each year, plus a good number of smaller satellites; now European space scientists had accepted that ESRO could launch no more than one scientific medium-sized satellite every two or three years and they had learned how to make the best choice out of their best ideas. The eventual development of ESRO's scientific programme in the following years maybe disappointed the hopes and expectations of a few European scientific groups but one can safely say that it was also a matter of pride for the European space community as a whole.

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[84] The LPAC's report is coded LPAC(74)4, January 1974. The two working groups' reports are ASTRO(73)15, 18/1/74 and SOL(73)16, December 1973.

TABLE 1

The Caravane collaboration for the COS-B satellite

Laboratory	Group leader	Hardware
Centre d'Etudes Nucléaires de Saclay, France	J. Labeyrie	Anticoincidence counter
Max-Planck-Institut für Extraterrestrische Physik, Garching, Germany	R. Lüst	Spark chamber
Space Science Department, ESTEC, Noordwijk, Netherlands	E. Trendelenburg	Triggering telescope
Huygens Laboratory, University of Leiden, Netherlands	H. van de Hulst	Energy calorimeter
Istituto di Fisica, Università di Milano, Italy	G. Occhialini	Experiment electronics
Istituto di Fisica, Università di Palermo, Italy	L. Scarsi	Pulsar synchroniser

TABLE 2

The GEOS payload as recommended by the LPAC in June 1970

S-301	Study of thermal plasma	Centre National d'Études des Télécommunications Issy-les-Moulineaux, France
S-302b	Study of thermal plasma	Mullard Space Science Laboratory Dorking, U.K.
S-303	Composition, energy spectra and angular distributon of ions	Universität Bern, Switzerland Max-Planck-Institut, Garching, Germany
S-310	Pitch-angle distribution of electrons and protons (0.2 - 20 KeV)	Kiruna Geophysical Observatory, Sweden
S-321	Pitch-angle distribution of electrons (30 - 200 KeV) and protons (40 KeV - 1.4 MeV)	Max-Planck-Institut, Lindau, Germany
S-325	Electromagnetic wave fields in the magnetosphere (0.1 - 10,000 Hz)	Centre National d'Études des Télécommunications Issy-les-Moulineaux, France Danish Space Research Institute Lyngby, Denmark
S-328	DC, ELF and VLF electric fields in the magnetosphere	ESTEC, Noordwijk
S-329	DC electric field	Max-Planck-Institut, Garching, Germany
S-331	DC and ULF magnetic fields	Laboratorio di Ricerche Spaziali, CNR Frascati, Italy

Experiment S-331 was chosen against the similar experiment S-332 (Technischen Universität, Braunschweig, Germany) on the basis of consideration to fair geographical distribution.

It was agreed that, in the event of weight problems arising during the project definition phase, experiment S-302b should be excluded.

Subsequently, experiments S-301, S-325 and S-328 were combined in one experiment, coded as S-300.

From LPAC/86, 17/6/70.

TABLE 3

Membership of the Launching Programme Advisory Committee (LPAC)

1969–70	1970–1971	1971–1972	1973
R. Lüst (chairman)	J. Geiss (chairman)	J. Geiss (chairman)	H.C. van de Hulst (chairman)
J. Geiss	H. Elliot	H. Elliot	H. Elliot
B. Hultqvist	B. Hultqvist	H.C. van de Hulst	G. Haerendel
G. Occhialini	G. Occhialini	B. Hultqvist	G. Pizzella
B. Strömgren	B. Strömgren	J.L. Steinberg	J.L. Steinberg

TABLE 4a

The Geophysics Panel

A.P. Willmore (chair)	University College, London
J. Blamont	Service d'Aéronomie, Verrières
A. Dollfus	Observatoire de Paris, Meudon
J.W. Dungey	Imperial College, London
C.-G. Fälthammar	Royal Institute of Technology, Stockholm
G. Haerendel	Max-Planck-Institut, Garching
J.A. Ratcliffe	Radio and Space Research Station, Slough
P. Rothwell	University of Southampton
U. von Zahn	Universität Bonn

TABLE 4b

The Astrophysics Panel

C. Dilworth (chair)	Università di Milano
G. Cocconi	CERN, Geneva
H. Elliot	Imperial College, London
A. Hewish	Cambridge University
L. Houziaux	Université de Liège
K.O. Kiepenheuer	Fraunhofer Institut, Fribourg
E. Schatzmann	Institut d'Astrophysique, Paris

From: LPAC/41, 8/9/69.

TABLE 5

Tentative satellite programme presented by J.A. Dinkespiler at the 31st LPAC meeting (27-28/2/70)

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
ESRO IV	3	3	3							
TD-1	10	10	10							
COS-B		3	9	9	9					
GEOS		1	6	8	8	7				
Small satell.	*		3	3	3					
Large satell.		*		10	10	10	10	10		
Small satell.			*		3	3	3			
Medium satell.				*		8	8	8	8	
HEO satell.				*		5	5	6		
Medium satell.					*		8	8	8	8
Small satell.						*		3	3	3

An asterisk indicates the time the project is approved.
Figures in the table are in MAU (Million Accounting Units).

From: LPAC/73, 3/4/70, p. 14

TABLE 6

Initial membership of LPAC's Working Groups (1972–1973)

Fundamental Physics Panel	Solar System Working Group	Astrophysics Working Group
H. Bondi (chairman)	G. Haerendel (chairman)	C. de Jager (chairman)
I. Roxburgh (deputy)	A. Dollfus (deputy)	L. Scarsi (deputy)
J. Blamont	M. Ackerman	M. Golay
G. Cocconi	H. Bolle	L. Houziaux
G. Colombo	C. Fälthammar	P. Léna
B. Laurent	K. Fregda	J. Lequeux
R. Lüst	E. Gérard	P. Mezger
G. Occhialini	J. King	B. Peters
E. Schatzman	G. Pfotzer	K. Pinkau
D. Sciama	M. Pick	K. Pounds
	G. Pizzella	M. Rees
	J. Quenby	
	F. Sanchez	
	L. Storey	

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European Space Agency
Agence spatiale européenne

Contact: ESA Publications Division
c/o ESTEC, PO Box 299, 2200 AG Noordwijk, The Netherlands
Tel (31) 71 565 3400 - Fax (31) 71 565 5433