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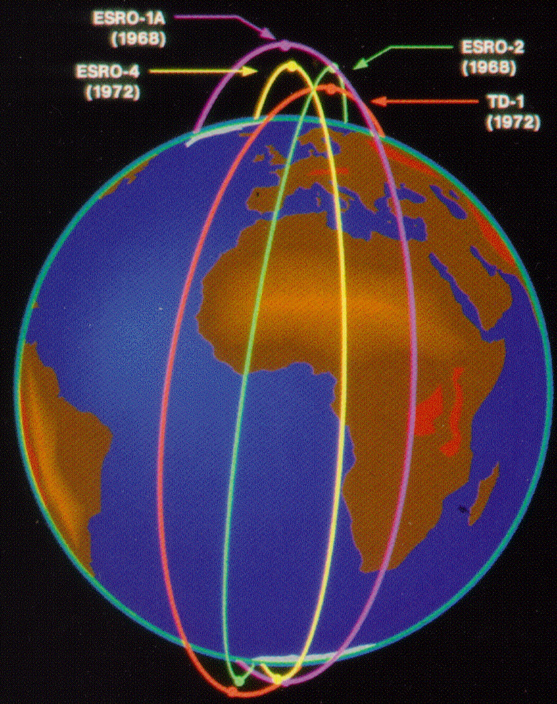
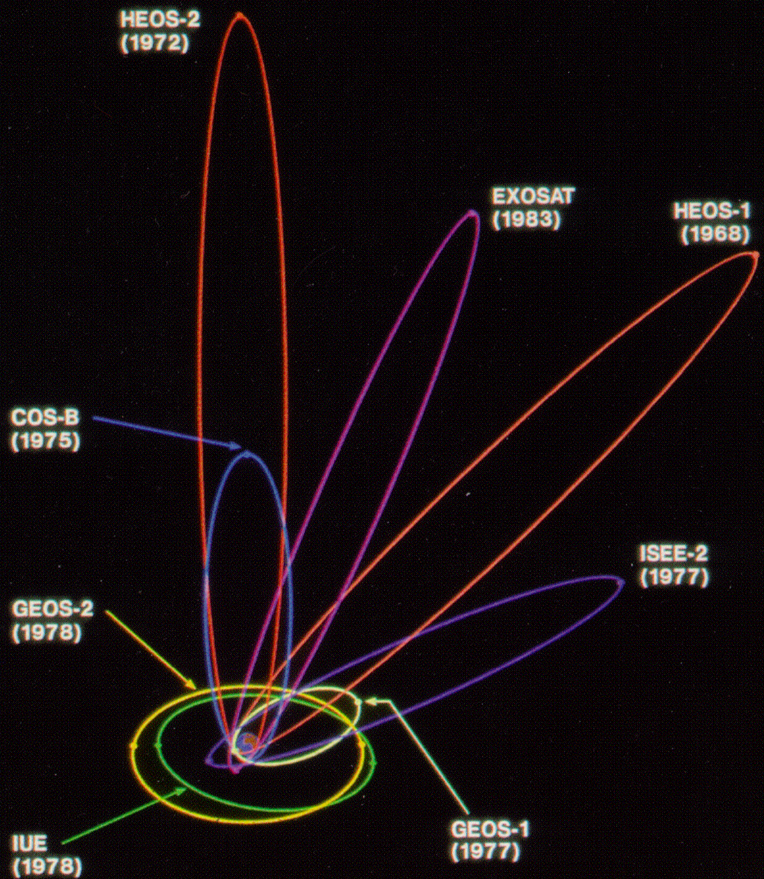
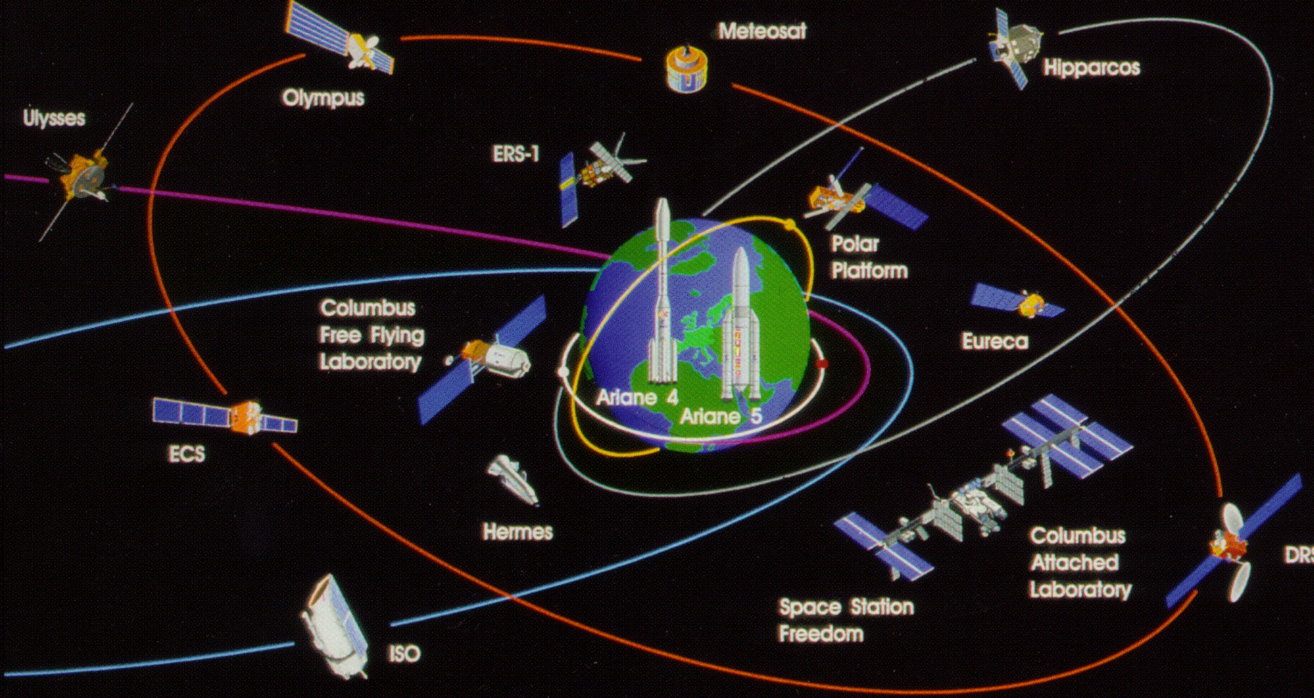




Choosing ESRO's First Scientific Satellites

by Arturo Russo



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CHOOSING ESRO'S FIRST SCIENTIFIC SATELLITES

Arturo Russo

In a previous report in this series we have discussed the definition and early development of ESRO's scientific satellite programme, from the days of the European Preparatory Commission for Space Research (COPERS) to the end of the Organization's first 3-year period.[1] Started with a rather ambitious and unfocused programme, covering almost all fields of space science by the envisaged launchings of 17 satellites in 8 years, ESRO was soon obliged to cope with the hard reality of technical difficulties, financial restrictions, and scientific competition within the scientific community. This caused a painful process of retrenchment and redefinition of the programme which drastically reduced the number of satellites and made the illusion vanish that ESRO might be able to cover all or most research fields. The most dramatic result of this process was the abandonment of the project for a Large Astronomical Satellite (LAS), a space telescope for UV stellar spectroscopy whose realization was beyond the capabilities of individual European countries and therefore had been one of the main reasons for ESRO's coming into existence.[2]

With reference to the general framework discussed in the first report, we will analyse here the choice of the scientific payloads of ESRO's first generation of satellites. These were the two small, unstabilized satellites ESRO I and ESRO II, launched in 1968 and renamed after launch *Aurorae* and *Iris* respectively; the two small highly eccentric orbit satellites HEOS-A and HEOS-A2, launched in 1968 and 1972 and then renamed HEOS-1 and HEOS-2; the medium size, stabilized satellite TD-1, launched in 1972; and the small satellite ESRO IV, also launched in 1972, which replaced the second satellite of the TD series (TD-2).

These satellites were multi-experiment satellites: the spacecraft carried a payload comprising several instruments provided by different research groups,

1 Russo (1992b).

2 For the story of LAS see Krige (1992a).

according to the agreed scientific mission of the satellite and to its technical specifications. The Launching Programme Advisory Committee (LPAC), including four or five scientists, was the independent scientific body called to make recommendations on ESRO's satellite programme, with regards both to the scientific missions of the Organization's satellites and to their actual payload composition. The input to the LPAC was the proposals coming from European research groups and recommended by six *ad hoc* working groups of experts in the various fields of space science; the chairmen of these groups generally attended the LPAC meetings (tables 1 and 2). The LPAC's recommendations were to be endorsed by the ESRO's Scientific and Technical Committee (STC), and finally approved by the Council of the Organization, both made of member state delegates.

At every level, the choice of a satellite or of a specific experiment in a payload involved several intertwined scientific and political aspects. A quick list, in a rather arbitrary order, should include: the proper assessment of the scientific importance of the various research fields in a long term perspective; the financial constraints which limited the range of good projects that could actually be implemented; the scientific and technical assessment of the various experiment proposals, both by themselves and with regards to their compatibility with other experiments in the same satellite payload; the unavoidable competition within the multi–national and multi–disciplinary space science community; the need to comply with the principle of *juste retour* in the geographical distribution of industrial contracts; the consideration of the scientific programmes of national space agencies in Europe and of the American NASA; the different views of ESRO's member states about the place of space research in the general framework of national space policies; and also the feelings, ambitions, expectations, idiosyncrasies and mutual relationships of the rather restricted number of scientists involved in ESRO's advisory bodies.

In this paper we will concentrate on those aspects that involved more directly the scientific community and that emerged as major issues in the discussions in the LPAC. The main theme will be, as to be expected, the growing competition between the various fields of space science within the progressive retrenching of the Organization's financial resources available for the satellite programme. After a first section devoted to a general overview of the status of the programme by the end of 1966, the paper is divided into two main parts. The first deals with the choice of the first small satellites' payloads (ESRO I and II, and HEOS–A) and with the difficult definition of the TD satellite programme. This part covers a time span going from early 1963, still in the COPERS period, when the scientific missions of ESRO I and II were defined, to the spring of 1966, when the payload composition of TD–2 was finally approved by the STC and Council. In the second part, the narrative starts from the spring of 1967, when the decision to recommend a second HEOS–type satellite was taken, and then analyses the complex situation determined by the crisis of the TD programme in 1968, and the debates which eventually led to the abandonment of TD–2 and the start of the far less ambitious ESRO IV project.

THE STATUS OF THE SCIENTIFIC SATELLITE PROGRAMME IN 1966

By mid–1966, more than two years after the official inception of ESRO and more than four years after the creation of COPERS, only six satellite projects had been approved by the ESRO Council, of the fifteen included in the revised 8–year programme of the Organization. These were grouped in four separate families with different technical and orbital characteristics (table 3).[3] The first family included only the two small unstabilized satellites ESRO I and ESRO II: these spacecraft had been designed for launching by *Scout* rockets into low orbit and were devoted to the study of the polar ionosphere, and to solar astronomy and cosmic ray studies respectively. The second family consisted of small, highly eccentric orbit satellites with apogees of about 200,000 km, designed for launching by means of a *Thor Delta* rocket. Three to four satellites of this type were included in ESRO's programme and the first member of the family, the 105–kg spin stabilized spacecraft HEOS–A, was devoted to the study of plasma, magnetic fields and cosmic rays inside and outside the magnetosphere.

The third family consisted of heavier, stabilized satellites whose weights, dimensions and characteristics had been designed with a view to their launching by means of a *Thor Delta* rocket into near earth orbits. The satellites in this family were planned to be built according to a standard design ("streetcar" concept) and,

[3] ESRO, *General Report*, 1964–65; Russo (1992b).

in fact, it was hoped that the TD–type spacecraft might be a sort of workhorse for the development of the main part of ESRO's satellite programme. Only the first two satellites had been approved, out of the four to six included in the programme, and they were being studied jointly. The first, named TD–1, was devoted to non–solar astronomy; the second, TD–2, carried experiments aimed at investigating the electromagnetic and particle radiations from the sun and their influence on the ionosphere during the period of maximum solar activity in 1968–69.

Finally, the last family included three large satellites for astronomical studies, the first of which was the Large Astronomical Satellite (LAS) to be devoted to high resolution stellar spectroscopy in the UV range. They were to be launched either by the rocket being developed by ESRO's sister organization, the European Space Research Organization (ELDO) or, failing that, by an *Atlas Agena* rocket.[4]

The scientific missions and the payload composition of these satellites had been agreed on in 1964–65 by the STC, on the basis of the recommendations of the LPAC, and had been approved by the Council. Of the 110 proposals for satellite experiments received by ESRO by the end of 1965 (table 4) and numbered from S–1 to S–110, 70 had been recommended by the *ad hoc* working groups and more than half had been allocated room in the payloads of the satellites under development.[5]

THE SMALL UNSTABILIZED SATELLITES ESRO I AND ESRO II

The scientific mission and the payload composition of ESRO's first two satellites had been recommended by the COPERS Launching Programme Sub–Committee (LPSC) in the spring of 1963 and then approved by its Scientific and Technical Working Group (GTST, from its French initials) (tables 5 and 6).[6] These satellites were also proposed to NASA as a co–operative effort, and

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[4] ELDO's early history is dealt with in De Maria & Krige (1992).

[5] The list of experiment proposals, with proper classification, is reported in the series of documents COPERS/LPSC/32, rev. 1–3, from 21/1/63 to 12/11/63, and ESRO/ST/87, plus rev. 1–2, from 25/11/64 to 7/3/67. See also ESRO's *General Report*, 1964–1965. The structure and functions of ESRO's advisory committees are discussed in Russo (1992b).

[6] LPSC, 5th meeting (6–7/3/63), COPERS/LPSC/70, 2/4/63; 6th meeting (29/4/63), COPERS/LPSC/84, 7/5/63. GTST, 9th meeting (30–31/5/63), COPERS/GTST/98, 20/6/63. Also COPERS/GTST/82, rev. 1, 14/6/63.

eventually NASA offered to provide free launchings of both satellites by *Scout* rockets.[7]

While keeping their original scientific missions, the payloads of the two satellites underwent a few important changes before final approval by the ESRO Council. In fact, by early 1964, experiment S–31, aimed at measuring micrometeorites, was withdrawn from ESRO II and the LPSC agreed that experiment S–42 should not be included in ESRO I, while in ESRO II the same experiment should possibly be extended to measure the helium 1584 Å line. It was also agreed to extend the aims of experiment S–71 in ESRO I and to include in ESRO II experiment S–72, proposed by J. Labeyrie and L. Koch of the *Centre d'Études Nucléaires* de Saclay and aimed at measuring solar protons.[8] Subsequently, preliminary design studies showed that the weight of the scientific payload was too high. This posed a question of priorities which, as was pointed out, "affect[ed] the whole philosophy of the satellites."[9] It was decided to ask the *ad hoc* working groups to discuss a "negative priority" list for the experiments already included in both satellites. This was not an easy operation, however. On the one hand, K. Rawer, from the Ionosphären Institut in Breisach, who had joined E. Vassy in the preparation of experiment S–70, strongly objected to the ION Group's recommendation to drop this experiment from ESRO I. On the other hand, R. Boyd preferred to withdraw his experiments S–42 and S–48 when he discovered that both were on the negative priority list for ESRO II. Eventually, the STC confirmed the exclusion of these three experiments in spite of the objections of the German Delegation in defence of Rawer's arguments (tables 7 and 8).[10]

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[7] In December 1963 and in January 1964, discussions took place in Washington and in Paris, respectively, between ESA and NASA about eventual co-operation in scientific satellite projects, in particular about the proposed payloads of ESRO I and II. The content and outcome of these discussions are presented in COPERS/GTST/139, 11/2/6.

[8] LPSC, 8th meeting (7–8/2/64), COPERS/LPSC/123, 3/3/64.

[9] Interim LPSC, 1st meeting (23/4/64), ESRO/ST/14, 4/6/64, p. 3. See also the meeting of the Interim Scientific and Technical Working Group (25–26/5/64), ESRO/ST/32, 11/6/64, p. 4.

[10] The decisions of the *ad hoc* working groups (with Rawer's objections) are in ESRO/ST/44, 20/7/64 and ESRO/ST/45, 29/7/64 for ESRO I and ESRO II respectively. Discussions and decisions were taken at the second meeting of the Interim LPSC (30/7/64), ESRO/ST/60, 31/8/64, p. 4–6, and at the first meeting of the STC (10–11/9/64), ESRO/ST/MIN/1, 14/10/64, p. 3–4. The new payloads recommended for ESRO I and ESRO II are presented in ESRO/C/73, 13/11/64 and were approved by the Council at its 5th session (25–26/11/64), ESRO/C/MIN/6, 11/1/65, p. 3.

Two considerations are suggested by inspection of tables 5 to 8. The first is the clear leadership of British groups, in particular those at University College (Boyd) and Imperial College (Elliot), in European space research. In fact, when approving the payload of ESRO I and ESRO II, the German delegation in the GTST "expressed concern that these two satellites seemed more national than international in character."[11] British space science had certainly a leadership role in Europe: it had started as early as in 1953 a rocket programme for ionospheric studies, with launchings going on since 1957, and was involved since 1959 in the *Ariel* satellite programme in collaboration with NASA. The British scientists, among whom Boyd and Elliot were authoritative spokesmen, had been enthusiastic about the perspective of European collaboration in space research and contributed significantly to the definition of the institutional framework and the scientific programme of the new Organization.[12]

The second consideration regards the scientific aims of the two satellites. These were small, unstabilized spacecraft, carrying very simple experiments designed to measure the radiation environment around the spacecraft, whether ionospheric particles, solar radiation or cosmic rays. This kind of experiment represented a direct extrapolation to satellite projects of the experience matured with sounding rocket experiments and met the scientific interests of a substantial part of the young but already well established European space science community. ESRO I, in particular, followed the well established tradition of rocket-borne experiments to investigate auroral phenomena and the polar ionosphere.

HEOS–A AND THE PROBLEM OF ESRO'S DEEP SPACE TELEMETRY NETWORK

Among the experiment proposals recommended by the *ad hoc* working groups in the spring of 1963, six required highly eccentric orbit satellites (HEOS). Three of these had been proposed by the PLA group, for studies of the interplanetary medium, and three by the COS group, for the study of the relation between the geomagnetic field fluctuations and the acceleration and dumping of Van Allen

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Experiment S–70 was rather heavy (4 kgs), with a high power consumption and mechanically complicated.

11 GTST, 9th meeting (30–31/5/63), COPERS/GTST/98, 20/6/63, p. 5.

12 Massey & Robins (1986), Krige (1992b), and Russo (1992b).

particles. The latter group had also recommended a space probe (SP) to measure cosmic rays, magnetic fields and interplanetary plasmas at considerable distance from the earth's magnetic fields. The LPSC invited the two groups to co-operate in order to find a good scientific mission for a spacecraft journey very far away from the earth and, at the same time, requested ESTEC to start studying possible orbits and associated tracking and telemetry problems.[13]

A meeting was arranged between the chairman of the PLA group and representatives of the COS group, followed by a meeting of the COS group which produced a proposal of an integrated payload with a set of experiments for simultaneous measurements of plasma, magnetic field and cosmic ray particles. The payload was eventually approved by the LPSC, with the further recommendation that a second HEOS or SP should be launched a year later and that for this, "consideration should be given in the first instance to the proposals from the PLA *ad hoc* working group."[14]

When the matter arrived at the STC, however, the French Delegation expressed their anxiety about the cost of the space probes due to the requirement of a deep space telemetry network. In fact, the network which ESRO was building for low orbit satellites (ESTRACK) was not suitable for spacecraft in highly eccentric or escape orbits. The problem regarded not only the first such spacecraft but the whole satellite programme of ESRO, in particular if the cometary mission under study should be chosen as the second large project after the LAS.[15]

A short technical digression may be useful at this point, with regards to four aspects of the difference between a network for low orbit satellites and a deep space network.[16] The first is the geographical requirement. For low orbits, the

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13 *Ad hoc* group G [COS group], 3rd meeting (19/3/63), COPERS/LPSC/78, 24/4/63, with appendices 1 and 2. LPSC, 6th meeting (29/4/63), COPERS/LPSC/84, 7/5/63; 8th meeting (7–8/2/64), COPERS/LPSC/123, 3/3/64. See also COPERS/LPSC/80, 26/4/63 and COPERS/GTST/82, rev. 1, 14/6/63. The terms highly eccentric orbit satellite and space probe were used rather interchangeably in this phase. As a matter of fact, the former is a satellite whose orbit is a highly eccentric ellipse with apogee of more than 50,000 km; a space probe is a spacecraft injected into an escape orbit.

14 COS group, 6th meeting (13/3/64), ESRO/ST/10, 21/4/64. Interim LPSC, 2nd meeting (20/7/64), ESRO/ST/60, 31/8/64, p. 7–8. All relevant documents are grouped in ESRO/ST/6, 15/4/64 and in ESRO/ST/33, 20/7/64.

15 STC, 1st meeting (10–11/9/64), ESRO/ST/MIN/1, 14/10/64.

16 ESRO/ST/6, 15/4/64, appendix 3. More technical aspects are presented in ESRO/ST/92, 12/1/65.

satellite motion is predominant as compared with the Earth's rotation and therefore, in order to observe all orbits at least once per revolution, about 8 to 10 stations are required along a great circle oriented broadly in the direction North–South. For a satellite on a highly eccentric orbit or for a space probe, the situation is entirely different because it is the Earth's motion which is predominant. In other words, when the spacecraft is far away from Earth, namely for most of its revolution time, it can be considered to stay motionless while the Earth rotates below it. In this case, a continuous observation can be achieved by a network consisting of three stations located almost at the same latitude (preferably lower than 30 deg) but evenly spaced from one another in longitude.

The second aspect regards the visibility time from a station. Low orbit satellites can be observed from one station for a short time, usually less than 20 minutes, and it is therefore necessary to record at low speed the instrument readings during most of the orbital period, and to play back the information rapidly when the satellite passes over a station. For satellites on highly eccentric orbits, the time during which it is visible from one station is of the order of hours (except if the station sees the satellite when it is near the perigee, in which case the observation time is of the order of 3 minutes). The information can be transmitted to Earth all along the orbit, either in real time, with a three–station network, or by playing back stored data if only two stations are available.

The third aspect regards the telemetry frequency. The ESRO network being built for low altitude satellites operated on 136/137 MHz, a frequency which is not very attractive for long distance space communication, due to galactic noise. Both for this reason and to increase the bit rate, it is preferable to use a higher frequency (400 or 1700 MHz) and then larger antenna dishes, with corresponding cost increase.

Finally, the fourth aspect regards the tracking of satellites. For tracking purposes it is not necessary to make position measurements evenly distributed over the orbit but it is imperative to make at least a minimum number of relatively accurate measurements during each orbit. Here again, ESRO's low orbit network drastically limited the possibility of making reliable measurements and it appeared inevitable to consider the realization of a system better suited for long distance tracking. This also had important implications in so far as time–scale and budget were concerned.

Facing these problems, and the French objections, the STC decided not to take a decision on the recommended payload before having investigated better the implications of the project as regards the setting-up of a deep space facility. In particular, it was also recognized that considerable differences in costs and technical requirements occurred between a network suitable for highly eccentric orbit satellites only and a network for deep space probes. The LPAC did not push the matter further for the moment but it agreed that a highly eccentric orbit with apogee of 200,000 km ought to be sufficient for the first highly eccentric orbit satellite (HEOS–A), as this would take the spacecraft outside the magnetosphere.[17] A study was then realized in ESTEC about a network suitable for such an orbit where two alternatives were presented:

1) A three–station network based on stations almost identical with ESTRACK type stations and located in, say, Australia, southern Europe and Mexico (or southern USA).
2) A two–station network using higher frequency and larger antenna dishes (about 25 m diameter).[18]

The first option would be satisfactory for HEOS–A and could also be used for near earth satellites in conjunction with the other stations in the ESTRACK network. The bit rate obtainable at 200,000 km was estimated 10 per sec. However, in order to convert it to a deep space network, it would require replacement of the antennae and change of the frequency of operation. The two–station network would allow a bit rate about three times higher and could be converted to deep space use by the relatively simple modification of changing the frequency of operation. On the other hand, the absence of a third station would produce a gap of about 6 hours in operation every 24 hours. The cost of the two networks was estimated as roughly the same, in the bracket of 40 to 50 million French francs (MFF). It was also estimated that both the addition of a third station to the two–station network and the conversion of the three–station network to large dishes would require about 20 MFF.

On this basis the matter was discussed again by the STC, where the scientific value of the payload recommended by the LPAC was strongly advocated by the

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[17] LPAC, 4th meeting (1/2/65), ESRO/ST/106, 17/2/65.

[18] ESRO/ST/111, 4/3/65. Other and more technical aspects are presented in ESRO/ST/92, 12/1/65.

Italian, Swedish and German delegations. It was finally agreed, with the abstentions of France and Belgium, to recommend to the Council the inclusion of this payload in the ESRO programme.[19] The Council did approve the payload but, following the arguments of the French delegation, it did not endorse any extension of the tracking and telemetry network in addition to the new ESTRACK station already planned in the Falkland Islands, and requested a further study before coming to a decision.[20] The study was eventually performed and it showed that, besides the available ESTRACK and CNES stations, one additional station was required in order to meet the minimum scientific requirements for HEOS–A. This additional coverage could be provided by a station planned by ELDO for its programme in Australia, at a cost of less than 1 MFF for additional equipment.[21] The Council approved this solution and, after a further recommendation of the COS group to include experiment S–79 to measure cosmic ray electrons, it approved the final payload of HEOS–A in the form given in table 9.[22]

THE TD PROGRAMME AND THE DEFINITION OF THE TD–1 PAYLOAD

Since the very beginning many experiment proposals had been recommended by the *ad hoc* groups for inclusion in the payload of a stabilized satellite and a design study for such a satellite was being performed by the Royal Aircraft Establishment.[23] The use of a stabilized platform made this spacecraft suitable for astronomical observations and in fact, in April 1964, the LPSC recommended to carry out two feasibility studies, one combining solar and stellar astronomy

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[19] STC, 4th meeting (10–11/3/65), ESRO/ST/MIN/4, 3/5/65, p. 7.

[20] Council, 6th session (24–25/3/65), ESRO/C/MIN/6, 14/6/65, p. 8. The French position is in ESRO/C/114, 24/3/65. The status and planning of ESTRACK by early 1965 is presented in ESRO/ST/94, 8/1/65.

[21] ESRO/C/119, 18/5/65.

[22] Council, 7th session (27–28/7/65), ESRO/C/MIN/7, 23/9/65; 9th session (24–26/11/65), ESRO/C/MIN/9, 31/1/66, p. 5. See ESRO/C/149, 12/11/65. An electron detector in the payload of HEOS–A had been recommended by the COS group at the beginning but no proposal was available at that time. The choice of S–79 was made by the COS group at its 10th meeting (14/4/65), COS/10, 17/5/65.

[23] ESRO/ST/5, 17/4/64.

experiments the other with only non-solar astronomy experiments.[24] Subsequently, at the very beginning of ESRO's official life, it was decided to devote the first stabilized satellite to stellar astronomy and the second to solar astronomy.[25] Only the payload of the former was approved (table 10a), however, while the other remained hung over because of the uncertainty about the revision of ESRO's 8-year programme.

When the advantage was recognized of using the *Thor Delta* (TD) rocket as a medium launching vehicle, the LPAC recommended a programme of six TD-type standard spacecraft, the first two of which (TD-1 and TD-2) were to be the already agreed satellites for stellar and solar astronomy, respectively. A third TD satellite was to be devoted to ionospheric studies and it was assumed that the solar satellite TD-2 and the ionospheric satellite TD-3 would be launched in time for the solar maximum in 1968-69, in order to study the correlation between solar activity and ionospheric phenomena.[26] Before any discussion about the payload composition of these two satellites could take place, however, financial difficulties and the opposition of a few member state delegations to the "streetcar" concept led to the abandonment of TD-3 and therefore it was decided to ask the *ad hoc* scientific groups to submit fresh proposals for TD-2, now to be considered as "a solar, ionospheric and geophysical satellite."[27] This was but a compromise, based on the idea that it could be possible to combine in a single spacecraft scientific objectives which pertained to very different scientific fields, namely the study of the sun as a star (solar physics), the study of the ionosphere (ionospheric physics), and the study of the solar-terrestrial relations (geophysics and solar wind studies). Hardly surprisingly, it revealed itself a bad compromise which led to harsh competition and eventually to the abandonment of TD-2.

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[24] Interim LPSC, 1st meeting (23/4/64), ESRO/ST/14, 4/6/64. A third payload, also including experiments devoted to solar and stellar astronomy but with more emphasis on the former was proposed by the SUN group. The different options are discussed in ESRO/ST/39, 17/7/64.

[25] Interim LPSC, 2nd meeting (30/7/64), ESRO/ST/60, 31/8/64; STC, 1st meeting (10-11/9/64), ESRO/ST/MIN/1, 14/10/64.

[26] LPAC, 2nd meeting (24/11/64), ESRO/ST/89. The LPAC also recommended that TD-4 should be devoted to atmospheric studies but this was not endorsed by the STC. For the discussions about the TD programme see Russo (1992b).

[27] LPAC, 5th meeting (19/3/65), ESRO/ST/116, 2/4/65, p. 6.

The problem of the payload composition of the two TD satellites was discussed by the LPAC in July 1965, after new information on the performance of the augmented *Thor Delta* launcher had shown that larger satellites of this series were possible and new payload space was thus available. Here the competition between scientists interested in the various field of space research showed itself a difficult issue to cope with.[28] On the one hand, B. Hultqvist, on behalf of the ION group, strongly argued in favour of experiment S-17, proposed by W. Dieminger, from the Max-Planck-Institut für Aeronomie in Lindau/Harz, and aimed at studying the topside of the ionosphere by a special sounder (the so-called "topside sounder"). This experiment had been originally suggested as the main experiment in the "ionospheric satellite" TD-3; now the ION group gave it the highest priority and insisted that it should be included in TD-2. On the other hand, C. de Jager, on behalf of the SUN group, argued that the two satellites should include a solar spectrograph covering the range from Lyman-alpha (1216 Å) up to 300 MeV and realized by the combination of 8 experiments.

A long discussion followed, in particular about the scientific merits of the topside sounder in comparison with other kinds of measurement, and in consideration of the fact that a vigorous programme of topside sounder satellites was already being pursued in Canada (*Alouette* satellite programme). It was also realized that the inclusion of the topside sounder would considerably affect the design of the satellite making it significantly different from TD-1, and thus jeopardizing the implementation of the streetcar concept. In the event, the LPAC confirmed that TD-1 and TD-2 should be based on the same design, with the possibility of stabilization of the order of 1 minute of arc, and therefore the topside sounder in its present design could not be included in the TD-2 payload. The LPAC recommended the addition of three more experiments to TD-1 (table 10b) and composed a tentative payload for TD-2, with the proviso that a study should be made on the possible modification of the topside experiment in such a way that

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[28] LPAC, 7th meeting (9/7/65), ESRO/ST/134, 5/8/65. On the augmented *Thor Delta* launcher see SCI/WP/32, 3/5/65 and SCI/WP/36, 6/7/65. The weight of the scientific package could be increased from 54 to 80 Kg. The recommendations of the three interested scientific *ad hoc* groups SUN, ION and COS are presented in SUN/12, 30/6/65; ION/18, 8/7/65 and COS/12, 8/7/65, respectively.

it could also be included. This was again a compromise, of course, and the conflict was to explode soon.

THE CONFLICT ON THE TD–2 PAYLOAD (THE TOPSIDE SOUNDER STORY) [29]

The discussion on the TD–2 satellite was resumed, in an atmosphere of growing tension, at the following meeting of the LPAC. In fact, further studies had demonstrated that, if one wanted a common design for the two satellites, the inclusion of the topside sounder experiment, even after reduction of weight, power and size, was scientifically and technologically incompatible with the probe experiments already approved for inclusion in the payload.[30] A choice had to be made therefore, and this could not be painless, considering that the LPAC had to confront "the opinions of the ION group and of other scientists and of letters which the chairman had received on this subject." After long discussions the LPAC concluded that:

> At this stage the LPAC should concern itself solely with giving its unbiased scientific judgement to the STC, taking into account, of course, the technical and financial resources available. [...] Considering all these factors, the LPAC felt that a higher scientific priority should be given to the probe experiments compared to the topside sounder.[31]

The main reason for the LPAC's decision was certainly the willingness to keep the design of TD–2 as much as possible similar to that of TD–1, both for financial reasons and because they wished to base the core of ESRO's satellite programme on a highly stabilized spacecraft, suitable for astrophysical investigation. The inclusion of the topside sounder would have required major changes in the design, in particular in the stabilization system, and would have significantly shifted the satellite's scientific mission towards the field of ionospheric research. The latter

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[29] A list of documents relevant for the history of the topside sounder proposal is in GEN/WP/74, 23/9/66.

[30] SCI/WP/40, 6/9/65.

[31] LPAC, 8th meeting (10/9/65), ESRO/ST/136, 5/10/65, p. 3–4. See also ESRO/ST/145, 24/9/65 and ESRO/C/131, 13/7/65.

was certainly respectable and it had been the first to take full advantage of the advent of space technologies; it was also true, however, that a lot of good work had been done already in this field and the future of space science was not there but rather in more complex satellite technologies, aimed at investigating distant celestial objects or the earth's space environment far beyond the atmosphere.

The reaction of the ION group could not have been harsher. The group in fact approved two resolutions in which the whole scientific policy of the LPAC was challenged and an alternative proposal for the TD–2 payload was recommended.[32] In the first resolution a strong case was made against the alleged unfair distribution of the experiments allocated in the five approved satellites (excluding the LAS) between the astronomical disciplines (covered by the SUN and STAR groups) and the disciplines covered by the other groups. In this context, the penalization of experiments of interest for the ION group was particularly underlined: they represented 35 % of proposals but only 23 % of allocated experiments. The document then claimed in crescendo:

> The *ad hoc* Working Group for the Ionosphere and Auroral Phenomena represents a larger number of groups actively interested in European space research than any of the other *ad hoc* working groups. The international reputation of the European work in these fields is very high. The total number of scientists engaged in ionospheric and auroral studies represents an important fraction of all scientists involved in ESRO activity.[33]

Blaming the LPAC for not having adequately taken into consideration the opinions and the expectations of the majority of scientists working in the ionospheric and auroral field, the ION group went as far as to recommend that the LPAC should include a full member with special interest in the ionosphere in

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32 ION group, 13th meeting (14/9/65), ION/24, 5/10/65. The resolutions approved are ION/22, 22/9/65 (on the LPAC policy) and ION/23, 22/9/65 (on the TD–2 payload). The latter was also sent to the STC with the code number ESRO/ST/141, 28/9/65. The strong dissatisfaction of the ION group towards the LPAC's scientific policy had already been expressed by Hultqvist a few months before when discussing the revision of ESRO's 8-year programme: STC, 4th meeting (10–11/3/65), ESRO/ST/MIN/4, 3/5/65. See Russo (1992b).

33 ION/22, appendix, p. 1. In this appendix a table is presented with the distribution of experiment proposals and allocated experiments among the various *ad hoc* groups.

order "to remedy the present unsatisfactory situation [and] to ensure a more reasonable distribution of ESRO's limited resources."

With regards to the LPAC's decision on the TD-2 payload, the ION group's judgement was that " [it] is scientifically not sound and that it presents a deep deception of the justified expectations of European scientists engaged in geophysical research." They argued that the present design for TD-2, which required a very expensive stabilization, should be replaced by a new design for a geophysical satellite with no or inexpensive stabilization, carrying a payload based on the topside sounder (S-17) and a few other experiments.[34]

Lüst could not allow this criticism of legitimacy of his LPAC and prepared a statement which he submitted to the following Committee meeting.[35] In this statement the chairman reaffirmed that the LPAC composed payloads only on the basis of the agreed scientific mission of a given spacecraft, and taking into account the scientific merits of the experiment proposals and their technical and financial implications. As to the distribution of experiments among the various disciplines, Lüst insisted that "the LPAC achieved this distribution surprisingly well since the percentage of the allocated experiments seems to be balanced very well." In any case, he continued, "it must also be the task of the LPAC to stimulate research in those fields where the activity is not yet high enough." Finally, Lüst felt obliged to remark that two of the four members of the LPAC were involved in ionospheric research more or less directly and none of them was interested only in stellar astronomy.

After a long discussion, on which, unfortunately, we do not get any information from the minutes, the meeting agreed to Lüst's statement and only accepted the ION group's request that in future, if the LPAC did not follow the recommendations of an *ad hoc* group, detailed explanations should be reported to the group itself.

Then the turn of the STC came to deal with the matter and to make a recommendation to the Council. Here again scientific and technical aspects

[34] ION/22, p. 1; ION/23, p. 1.

[35] LPAC, 9th meeting (18/10/65), ESRO/ST/154, 9/11/65. Following quotations from p. 3. Only Lüst and Boyd of the LPAC attended the meeting. This was also attended by the President of the Council, A. Hocker, by all chairmen of the *ad hoc* groups except for de Jager, and by a numerous group from the Secretariat, including the Director General P. Auger and the Technical Director A.W. Lines.

intertwined with the still controversial question of the opportunity of making the spacecraft for TD–1 and TD–2 as far as possible identical. In the event the delegations were called to vote: Belgium, Denmark, France, Germany, Spain and Sweden voted for the inclusion of the topside sounder in the payload of TD–2; Italy, the Netherlands and the United Kingdom voted against; the Swiss delegation was absent. Therefore, upsetting the recommendation of the LPAC, the STC recommended that the probe experiments be replaced by the topside sounder.[36] The Council endorsed this decision and authorized the STC to make any changes that might prove necessary in order to fit the topside sounder in the payload.[37]

Some information on the composition of the STC at this meeting may be useful to understand the outcome of the discussion. Three influential scientists were delegates of the countries voting against the topside sounder, namely G. Occhialini (I), H. van de Hulst (NL) and R. Boyd (UK), the latter being also a member of the LPAC. Their vote was certainly determined by their scientific interests and by their preference for the streetcar concept for the TD series. The Netherlands delegation, for example, was explicit in the statement that "much of the information on the ionosphere is being constantly collected by other topside sounder experiments and therefore the topside sounder was less important than the other experiments." The United Kingdom delegation, on their side, said that "they had always believed that TD–1 and TD–2 should be as similar as possible." Finally, the ION group's suggestion to design a spacecraft with a much simpler stabilization system would exclude experiments aimed at direct solar observation and this, as ESRO's scientific director B. Bolin recalled, was hardly acceptable for a satellite aimed at studying solar–terrestrial phenomena related to the solar maximum.

The most influential countries voting in favour of the topside sounder were Sweden, France and Germany. Sweden was represented by B. Hultqvist, the chairman of the ION group and an obvious advocate of the topside sounder: he reaffirmed that "the topside sounder was the most powerful ionospheric equipment

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[36] STC, 6th meeting (5–6/10/65), ESRO/ST/MIN/6, 26/10/65. The discussion on the to side sounder is on p. 4–6. During the discussion, Lüst asked the vice-chairman B. Peters to take the chair in order to allow him greater freedom to express his views as chairman of the LPAC. The new payload composition is in ESRO/C/148, 12/11/65.

[37] Council, 9th session (24–26/11/65), ESRO/C/MIN/9, 31/1/66.

that existed," and that the ION group had proposed unanimously that it should be the key experiment in TD–2. France was notoriously against the streetcar concept and the French delegation in the STC did not include the LPAC member J. Blamont or other scientists but two top officials of the CNES (M. Bignier and A. Lebeau).[38] Germany was also critical of the streetcar concept and it was officially represented in the STC not by Lüst, the chairman of both the STC and the LPAC, but by Regula, a ministerial top official, and by W. Priester, a scientist involved in atmospheric research, with W. Dieminger, the proposer of the topside sounder, acting as an adviser. We have no hints about the reasons for the vote of the other delegations except, perhaps, the lukewarm attitude of Belgium towards the streetcar concept.[39]

After the STC meeting ESTEC's engineers put themselves to work with the S–17 experimenters in order to solve the technical difficulties connected with the inclusion of the topside sounder in the TD–2 payload. It was recognized that a modification of the antenna was possible so that it would not disturb the stabilization of the satellite but, on the other hand, a serious problem arose regarding the telemetry requirements. In fact, 60,000 bits per second were required to telemeter the complete output of the iongrams obtained and it was not possible to store such an amount of information on the tape recorder on board. Therefore, data could only be transmitted in real time during each pass of the satellite over a telemetry station and at least half of the time of contact with the station was required. This significantly limited the amount of information available from the topside sounder and, at the same time, it implied that half of the total telemetry capacity of the satellite had to be allocated to this experiment.[40]

According to W. Dieminger, the proposer of S–17, even in the worst condition the topside sounder experiment was still scientifically valuable but the LPAC wanted to reaffirm their reservations. They could not upset the policy established by the STC, of course, but the message they sent to the Committee was clear enough. In fact, the decision to confirm the topside sounder in the TD–2 payload

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[38] The opposition of the CENS's president J. Coulomb to the streetcar concept is presented in ESRO/C/114, 24/3/65.

[39] See the discussion on the streetcar concept at the 4th meeting of the STC (10–11/3/65), ESRO/ST/MIN/4, 3/5/65. The matter is discussed in more detail in Russo (1992b).

[40] SCI/WP/51, 9/12/65.

was agreed with the abstentions of two of the three members of the LPAC attending the meeting (Blamont and de Jager) and of four of the six chairmen of *ad hoc* groups (Frith, de Jager, Occhialini and Swings). The third LPAC member, chairman Lüst, who was also the chairman of the STC, could not but vote in favour while the fourth member, Boyd, an opponent of the topside sounder, was absent. The chairmen of *ad hoc* groups voting in favour were Hultqvist (of course) and L. Biermann, a German theoretical astrophysicist interested in solar wind phenomena.

The LPAC also agreed to present the STC with the following statement:

> The LPAC expresses concern about the technical difficulties which will probably be encountered in the development of TD–2. The experimenters involved should be kept informed on the status of the project and, particularly, on possible interference problems. The development costs of TD–2 should be thoroughly assessed.[41]

And in fact, a preliminary assessment of costs performed in ESTEC reopened the whole question. As the engineers vividly put it, it was not possible to deal cheaply way with the technical difficulty caused "by attempting to put an experiment into a satellite with which it is not compatible."[42] Taking together both TD satellites the figures were: 80 MF for two different scientific payloads integrated into a standard spacecraft, according to the streetcar concept; 100 to 125 MF for two different spacecraft but with common components; 160 to 275 for TD–1 and TD–2 as proposed. A wise alternative was then suggested, namely to build two similar TD satellites, as originally suggested by the LPAC, and to carry out the topside sounder experiment in a separate Scout–type satellite.

On the basis of the new information, the discussion on the topside sounder experiment was then resumed in the STC and a new vote was called. Now only the Swedish delegation (i.e. Hultqvist) was in favour: Belgium, Denmark, Germany, the Netherlands and the United Kingdom voted against; France, Italy and Spain abstained.[43] Then the question came to decide what should be done with the topside sounder. The Danish delegation stressed that it had voted for its

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41 LPAC, 10th meeting (13/12/65), ESRO/ST/168, 4/1/66, p. 6.

42 ESRO/ST/177, 27/1/66, p. 3.

43 STC, 8th meeting (14–15/2/66), ESRO/ST/MIN/8. The Swiss delegation was absent.

omission from TD–2 only on the understanding that it would be flown somehow or other. France and Italy called for further information. The German delegation pointed out that Dieminger's group had been working on this experiment for a long time. The British urged proper consideration of the scientific aspects, as "there would be many launchings of topside sounders on the other side of the Atlantic." In the event, it was agreed to request ESTEC to study the technical and financial implications of the Scout–satellite option, while the scientific merits of the project were to be discussed by the ION group and by the LPAC.[44]

Not surprisingly the ION group expressed a strong recommendation to launch S–17 by *Scout*.[45] They again recalled the outstanding contribution of European scientists to ionospheric physics and underlined that "the proposed experiment would involve an exceptional number of scientific groups." In fact five groups had indicated their wish to receive and process data from the topside sounder and Dieminger offered to waive the normal experimenters' priority for receiving his data and to enable other groups to participate fully in the analysis of the results. One can say that most of the scientific community interested in ionospheric studies was advocating that ESRO should launch the topside sounder experiment in one of its satellites. They did not succeed, however, as the LPAC, "taking into account the estimate of cost of 30 MFF, in view of the severe financial limitations of ESRO," decided not to recommend this expenditure "as being entirely justified on scientific grounds." The LPAC recognized, however, that:

> The sequence of events leading to this proposal, involving considerations other than scientific, may be taken into account when the Council makes its final decision.[46]

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[44] *Ibidem*, p. 5. The feasibility of a Scout–type satellite for launching the topside sounder is discussed in ION/30, 4/3/65. The STC also requested the Council for authorization to take a final decision on this matter but it did not obtain the necessary delegation of power: Council, 10th session (24–25/3/66), ESRO/C/MIN/10, 10/6/66, p. 3–4. See ESRO/C/174, 9/3/66.

[45] ION group, 15th meeting (15/3/66), ION/31, 17/3/66. The arguments in favour of the topside sounder are presented in detail in ION/32, 26/3/66, from which the follwing quotation is taken (p. 2).

[46] LPAC, 12th meeting (5/4/66), ESRO/ST/207, p. 4. The new chairman of the ION group, A.P. Willmore, abstained. The resolution of the LPAC is also reported in ESRO/ST/195, 13/4/66, with attached ION/32 and ESTEC's report SCI/WP/59, 25/3/66.

The chairman of the LPAC explained to the STC that this last sentence, which opened the door to a political decision in favour of the topside sounder, had been included in the approved statement because his committee felt that ESRO had certain responsibilities towards the experimenter, who had been working on this experiment for some time. Furthermore, Lüst recalled that "several delegations [in the STC] had agreed to the elimination of the topside sounder from the TD–2 payload on the understanding that some other solution would be found for this experiment." The STC finally agreed to endorse the LPAC's decision not to recommend to the Council the carrying of the topside sounder experiment on a separate *Scout* vehicle but, by a majority vote, decided to delete the last sentence.[47]

When the matter came again to the Council the German delegation stressed that "the future of Prof. Dieminger's group was at stake [as] it had been working on the topside sounder experiment for about a year on the understanding that it would be flown by ESRO." As a consequence, the Council approved the STC's recommendation which definitely ruled out the topside sounder experiment, but also asked the STC's chairman to assist Dieminger's group in his search for collaboration with NASA.[48]

The approved payloads of both TD–1 and TD–2 underwent small changes in the following months. In fact, in late 1966, experiments S–30 and S–96 were withdrawn from TD–1 and TD–2 respectively, and the *ad hoc* groups were called to submit recommendations for replacement. The LPAC eventually agreed to recommend experiment S–125/S–133 for TD–1 and experiments S–118 and S–126 for TD–2.[49] Finally, in early 1970, experiment S–1 was withdrawn from TD–1. The final configuration of the two payloads is reported in tables 11 and 12.

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[47] STC, 9th meeting (2–3/5/66), ESRO/ST/MIN/9, 7/6/66, p. 15. Italy, Netherlands, Spain, Sweden and the United Kingdom voted in favour of the deletion; France and Germany against; Belgium, Denmark and Switzerland abstained.

[48] Council, 11th session (22–24/6/66), ESRO/C/MIN/11, 15/7/66, p. 6.

[49] LPAC, 16th meeting (8–9/2/67), ESRO/ST/245, 8/3/67. The recommendation was accepted by the STC at its 14th meeting (21/2/67), ESRO/ST/MIN/14, 10/4/67. Both S–125 and S–133 aimed at measuring celestial gamma rays, the former being proposed by Lüst and the latter by Occhialini and Labeyrie. The two groups decided to collaborate and the experiment was eventually known as S–133. See also ESRO/ST/213, 9/9/66 and SCI/WP/75, 30/1/67.

One consideration is suggested by inspection of these tables, regarding the resulting hybrid composition of the two TD payloads. TD–1 had originally been devoted to non–solar astronomy; subsequently, when the new capability of the *Thor Delta* launcher allowed an increase of the payload weight, two experiments on solar physics had been added and one for cosmic ray studies. TD–2 was to be devoted to solar astronomy but, when financial and institutional difficulties led to the abandonment of TD–3, its mission was redefined in order to include other research fields. This resulted in very complex payloads, including various uncorrelated experiments in both branches of astrophysics (solar and stellar), in atmospheric and ionospheric physics, and in cosmic ray physics. Again this puts into evidence the fluid condition of the European space science community in 1965, still unable (and also unwilling, we should say) to use ESRO's limited resources to implement a satellite programme based on a few well defined scientific missions, supported by technically sophisticated instrumentation. On the contrary, in a context characterized by great uncertainty regarding the technical and financial conditions of the satellite programme, any research group or sector of the scientific community could lobby to get its share of ESRO's spacecraft. The lack of an authoritative scientific staff in ESRO and the weakness of its management *vis–à–vis* member state delegations are the main reasons for this unhealthy situation. In 1966 this was still compensated by the ongoing LAS project but eventually, after the abandonment of ESRO's most ambitious project and the drastic retrenchment of the financial resources available to the Organization, the need of establishing scientific guidelines and priorities became inescapable.

THE SECOND HIGHLY ECCENTRIC ORBIT SATELLITE AND THE ESLAB PROBLEM

In 1967, in the framework of discussions about future satellite projects, the LPAC recommended that the design of HEOS–A should be used for a second highly eccentric orbit satellite (HEOS–A2). The scientific mission of the new satellite had to be defined by the chairman of the LPAC together with the chairmen of the scientific *ad hoc* groups ION, PLA and COS. The recommendation was endorsed by the STC who invited scientific groups in

Europe to submit experiment proposals that, in their words, "could include either new experiments, repeats of experiments of HEOS–A1, or modified versions of these."[50]

By March 1968, seventeen experiment proposals were received and examined by the three interested *ad hoc* groups. They agreed that HEOS–A2 should be injected into an orbit of high latitude apogee and its mission should include "a study of propagation of cosmic rays in the solar system in correlation with direct measurements of interplanetary fields and particles and of the properties of the boundary between the magnetosphere and interplanetary space." On this basis, the chairmen of the groups proposed a payload composition to the LPAC.[51]

The LPAC had no difficulty in approving the proposed payload but for one experiment for which two almost identical proposals existed: S–204, proposed by D.E. Page, from ESRO's scientific laboratory (ESLAB), and S–217, proposed by J. Labeyrie, from the *Centre d'Études Nucléaires* in Saclay.[52] Both experiments aimed at measuring intermediate energy particles and, according to the COS group, "although S–204 was technically the better experiment, S–217 should have priority because of the wider energy ranges covered."[53] When reporting to the LPAC, however, the chairwoman of the COS group, C. Dilworth, said that both experiments had been modified since and now they resembled each other more than before so that, in her opinion, the matter should be referred back to the COS group for further discussion.

As a matter of fact, the choice between these two experiments involved considerations other than purely of scientific value. The real issue was that S–204 was the first experiment proposal coming from within ESRO which was a serious candidate for inclusion in an actual satellite payload, and it was in direct competition with a similar experiment proposed by a French group which usually enjoyed a large share in ESRO spacecraft. The establishment of a research laboratory within ESRO had been one of the main controversial issues in the

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50 LPAC, 17th meeting (11/4/67), ESRO/ST/253, 30/4/67; 18th meeting (28/9/67), ESRO/ST/271, 9/10/67. STC, 16th meeting (9–10/10/67), ESRO/ST/MIN/16, 29/11/67, p. 5. See also SCI/WP/94, 22/9/67.

51 ESRO/ST/290, 27/6/68, p. 1.

52 LPAC, 22nd meeting (3/5/68), LPAC/6, 17/6/68.

53 COS Group, 18th meeting (25–26/3/68), COS/37, 8/7/68, p. 3.

COPERS period, when the institutional framework of the Organization was discussed, and ESLAB was the outcome of a compromise which implied that ESRO's scientists were not to compete with research groups in member states.[54] This non-scientific consideration, more than the wider energy range covered, had possibly influenced the COS group's original choice of Labeyrie's experiment, "although S-204 was technically the better experiment." What had happened since exposed the real question, however, as the ESLAB group had shown that they could extend their energy range by a simple modification of their experiment and the Saclay group had taken over a part of the design of their competitor in order to improve the performance of their own.[55]

After a long discussion, which touched several issues well beyond the problem of just choosing one experiment for a small satellite, the LPAC agreed to seek a way out from the slippery ground in which aspects "apart from scientific value" had to be taken into consideration. Both proposals were referred back to the COS group for further consideration "on scientific and technical grounds", on the basis of the judgement of an external referee. Only if the group arrived at the opinion that no differences existed on these grounds between the two proposals, should the question be discussed again by the LPAC. The German cosmic ray physicist G. Pfotzer, assisted by COS group's members G. Pizzella and P. Rothwell, was invited to report on S-204 and S-217 and eventually, following their recommendation, the COS group reversed their former judgement and approved S-204.[56] The payload composition of HEOS-A2 was thus submitted to the approval of the STC and Council as in table 13.

No problems arose in the former, which did not even convene to discuss on the HEOS-A2 payload and the delegations voted *ad referendum*.[57] But it was quite different in the Council, where the controversy exploded openly when the French delegation "strongly protested against the manner in which the payload

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[54] Russo (1992b).

[55] C. Dilworth, private communication to the author. Among extra-scientific considerations one could add the fact that Page and the ESLAB group were somewhat outsiders in the European space science club while Labeyrie was a long-time friend and collaborator of C. Dilworth and G. Occhialini.

[56] COS Group, 19th meeting (5/6/68), COS/39, 18/10/68. The report of the referees is appended as annex I.

[57] ESRO/ST/290, 27/6/68. ESRO/ST/290, add. 1, 14/8/68.

composition had been decided." There was no question, they argued, about ESLAB's right to submit proposals for experiments, but "they must be of an original nature and not compete with the proposals submitted by national scientific groups." And they went as far as to add a statement that sounded like a menace:

> The decision taken had created a feeling of uneasiness within the French group whose proposal has been set aside. [...] The situation that had thus arisen was extremely unfortunate. [...] If the only French group of scientists concerned with the work of ESRO were led to have a negative attitude, it would be difficult for the French Delegation to defend the Organisation.[58]

A rather nervous discussion followed, in which the chairman of the LPAC, rather desperately, stressed that "the experiments were considered solely on the basis of their scientific value and the LPAC did not take account of political aspects." This was particularly true for the case under discussion, he added with plain naïvety as the point raised by the French was in fact a matter of policy. The Director General, on his own part, recalled that the ESLAB programme, which included the experiment under discussion, had been approved more than a year and a half before and argued that he could not agree that experiments proposed by ESLAB should not be allowed to compete on an equal footing with national groups:

> ESLAB had an extremely important task to carry out and it would be impossible to retain highly qualified scientists in ESLAB if they had the impression that there was no hope of seeing a practical application of their work.[59]

In the event, science prevailed over politics, and the payload of HEOS–A2 was approved as proposed by the LPAC, with the abstensions of the Belgian and French delegations and a generic recommendation to the STC for an improvement in the selection procedure of experiments.

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[58] Council, 25th session (8–9/10/68), ESRO/C/MIN/25, 6/11/68, p. 13 and 14. The French delegation also blamed the Director General because, when requesting the vote of the STC *ad referendum*, he had not officially informed them of the change in the payload composition: ESRO/C/370, 8/10/68.

[59] *Ibidem*, p. 13.

By early 1968 it appeared evident that the financial costs of the joint project TD–1/TD–2 had been greatly underestimated by the industrial consortium with which a preliminary contract had been signed one year earlier. In fact, a detailed revision resulted in a very large escalation of cost, from the original estimate of 109 MF to twice this figure. By the time the TD programme was finished, the ESRO directorate warned, the actual sum spent might well be in the region of 320 MFF, including capital facilities and launchings.[60] The ESRO Council was thus confronted with a difficult choice. On the one hand, it could decide to cancel the TD programme, the only large project left for the Organization in its 8–year period. This however implied devastating effects, such as the waste of the money, capital investment and human resources already invested; a great blow to the prestige of European industry; a traumatic effect on the experimenters and the definitive loss of confidence of the scientific community in ESRO. Going on with the TD programme, on the other hand, would severely squeeze and limit the funds available for the future scientific programme and would render more difficult the task of balancing the geographical distribution of contracts.

The bad news about the TD programme dropped like a bomb–shell in the dramatic financial and institutional crisis ESRO was living in early 1968. The Organization, in fact, was feeling the consequence of the member states' failure to reach agreement on the ceiling for the second three–year period (1967–1969), and therefore any budget decision required unanimous approval in the Council. All problems and difficulties accumulating in the seven years since the start of the European joint undertaking in space activities were showing up in all crudeness and, in the words of the Director General H. Bondi, "the future of ESRO looked bleak indeed".[61]

A dramatic discussion on the TD project took place at the Council session of 28–29 March 1968 but it came to nothing. The Council, in fact, did express an indication in favour of the continuation of the programme and authorized the extension of the preliminary contract for 4 months but, on the other hand, it could

[60] ESRO/C/342, 14/3/68, with add. 1 (21/3/68) and add. 2 (27/3/68).

[61] Bondi, 1984, p. 22. The institutional and financial aspects of ESRO's crisis in 1967–1968 will be dealt with in detail in another report in this series.

not find unanimous agreement to approve the inclusion in the 1968 budget of the contract authority required by the Director General to sign the final contract. The main opposition came from the Italian delegation, because of their deep dissatisfaction towards the geographical distribution of ESRO's industrial contracts.[62] An extraordinary Council session was then called one week later, on the occasion of the official inauguration of ESTEC, in the hope that a suitable solution could be found. This was not to be, however. The Italian delegation, in fact, subjected its approval to the continuation of the programme to the condition that Italy's participation in the programme be limited to 11.72 % of the original cost estimate (109 MFF for the construction of the satellites and 40 MFF for launchings). This, of course, was hardly acceptable by other member states and ESRO's Legal Adviser warned that there was no possiblity in the Convention of meeting the Italian delegation's request. As a consequence, Italy's one vote against the inclusion in the 1968 budget of the contract authority necessary for the placing of the TD contract resulted in a veto that blocked the project against the wishes of all other delegations. The Organisation, stressed the Director General, found itself "virtually without a programme" while the German and French delegations, on their part, cautioned that "the decision now made would have very serious consequences [...] as regards the Member States' future attitude towards ESRO."[63]

Following the Council decision, ESRO found itself in the necessity to cancel the TD programme outright. This meant the complete loss of 72 MFF already committed to the programme and the wastage of the facilities of ESTEC and ESTRACK installed to cater for the two satellites and destined to remain idle, pending a new programme. Moreover, from the scientific point of view, European scientists had lost the possibility of studying the solar maximum from space. In

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62 Council, 22nd session (28–29/3/68), ESRO/C/MIN/22, 22/4/68, p. 15. The resolution was approved by 6 votes in favour; Italy voted against, Switzerland and Denmark abstained, Belgium did note take part in the vote. From ESRO's *General Report* for 1967 (p. 114) we learn that, by the end of that year, Italy's financial contributions to ESRO was 11.41 per cent of total member state contributions while the percentage value of contracts placed in the country was 7.50. The ratio of contract percentage to contribution percentage was 0.657. This figure was significantly higher than for Denmark (0.358) and Spain (0.249); significantly lower than for France (1.954), Belgium (1.602), Switzerland (1.325), Netherlands (1.154), and Sweden (1.130); and comparable with that of Germany (0.612) and the United Kingdom (0.713). The latter two countries, however, were by far the most important contributors to ESRO (23.32 and 24.19 %, respectively) and therefore the absolute value of contracts was high.

63 Council, 23th session (4/4/68), ESRO/C/MIN/23, 3/5/68, p. 7.

this situation, which left the Organization "at the mercy of a single delegation's veto," Bondi felt that a solution had to be worked out in order to enable ESRO "to meet its obligation to the scientists who had experiments on the TD satellites." He suggested cancelling only one of the TD satellites, while the other could be continued as a special project under article VIII of the Convention, which allowed ESRO to develop projects on behalf of a group of member states, after approval by a two-thirds majority in the Council. The cancelled satellite would be replaced by a new, small satellite carrying only the experiments remaining scientifically valid.[64]

The STC endorsed Bondi's proposal with the proviso that first priority on future flight opportunities should be given to experiments from the cancelled TD satellite, and the proposal was then approved by the Council.[65] It was now the LPAC's task to advise as to which of the TD satellites should be cancelled and then on which of its experiments should be retained in the new satellite. A first discussion on this question took place at the restricted LPAC's meeting held during the COSPAR Symposium in Tokyo, on 14 May 1968, but no firm recommendation was issued in that occasion.[66] Eventually, as it appeared that there was no clear priority on scientific grounds as to which of the TD satellite projects should continue, the STC agreed to authorize the Director General, in consultation with the Bureau, to take the decision, after carrying out a technical and financial assessment.[67] This showed that, in order to enable significant simplification of the project, the spacecraft design had to be modified in the sense

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64 Bondi's proposal is presented in ESRO/C/349, 17/5/68, from which the first of the previous quotation is taken. Its legal and financial aspects are discussed in ESRO/C/350 and ESRO/C/351 respectively, both dated 17/5/68. See also ESRO/C/356, 21/5/68. The second quotation is from Bondi's presentation at the 18th meeting of the STC (6/5/68), ESRO?ST/MIN/18, 26/6/68, p. 2.

65 STC, 19th meeting (29/5/68), ESRO/ST/MIN/19, 28/6/68. Council, 24th session (30/5/68), ESRO/C/MIN/24, 7/6/68. At this session the Council approved to cancel one TD satellite and to pursue the other either as an ESRO project or as a special project. In the event, as unanimity was not reached, the TD-1 project was approved as a special project financed by all member states bar Italy: Council, 25th session (8-8/10/68), ESRO/C/MIN/25, 6/11/68. The complex legal and financial aspects of the TD special project are presented in ESRO/C/360 with several addenda and revisions.

66 LPAC, 23th meeting (14/5/68), LPAC/7, 26/6/68. The meeting was attended by LPAC members Lüst, De Jager, Hultqvist and Occhialini (Blamont being unable to attend), by ESLAB's director E.A. Trendelenburg and by J. Ortner of ESRO's Directorate of Programmes and Planning.

67 STC, 19th meeting (29/5/68), ESRO/ST/MIN/19, 28/6/68.

that it could keep its stabilization only if shone upon by the sun but not during eclipses. This implied that the satellite should be injected into an helio-synchronous orbit. Proper consideration of the experiments included in the two payloads showed that the scientific mission of TD–1 could still be fulfilled satisfactorily after this modification while that of TD–2 would be seriously jeopardized. Therefore the former was kept in the programme as a special project while a "TD–2 rescue operation" was undertaken in order to save as many as possible of the TD–2 experiments.[68]

THE TD–2 RESCUE OPERATION AND THE CHOICE OF ESRO IV

The problem of rescuing the still scientifically valid experiments of TD–2 was not easy, as it required "a solution [...] that was fast, compatible with the industrial policy of the Organisation, and did not consume so much of the available funds that it would prevent new projects being started."[69] Of the 11 experiments included in the satellite payload (table 12), 4 required solar pointing (S–39, S–106, S–118, S–126) while the others could be flown in unstabilized satellites. From the viewpoint of research fields involved, three experiments regarded solar physics (S–39, S–106, S–126); three regarded atmospheric physics (S–80, S–97 and S–118); three regarded ionospheric and auroral phenomena (S–45, S–85, and S–94); and two regarded solar wind (S–99 and S–103). It is thus evident that any solution of the rescue operation involved a complex decision on how to take into account various scientific interests.

In September 1968, three options were presented to the LPAC and the STC by ESRO's Directorate for Programmes and Planning. The first was to rescue some of the experiments not requiring solar pointing by using an unstabilized spacecraft like ESRO I or ESRO II. In particular, the ESRO I satellite structure could be used to make a so–called ESRO III satellite carrying the ionospheric experiments S–45, S–85 and S–94; otherwise, by using the former ESRO II spacecraft with improved

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68 ESRO, *General Report*, 1968. The TD–1 special project is described in ESRO/C/362, 23/9/68, and add. 1, 27/9/68. A general account of the TD–2 rescue operation is in ESRO/ST/303, 19/2/69.

69 STC, 20th meeting, 7/10/68, ESRO/ST/MIN/20, 18/11/68, p. 7. Also LPAC, 24th meeting (first session, 23/9/68), LPAC/15, 13/11/68.

solar cells, a so-called ESRO IV satellite could be realized carrying the atmospheric experiment S-80 and the solar wind experiments S-99 and S-103 (the other non solar-pointing atmospheric experiment S-97 had been withdrawn). The cost estimate of the spacecraft was 25 MF and 20 MF respectively, with an additional 7.5 MF for the *Scout* launcher. ESRO III would be ready for flight in September 1971; ESRO IV by the end of 1971.

The second option was to use a NASA-OSO (Orbiting Solar Observatory) spacecraft for flying three of the four solar pointing TD-2 experiments, namely S-39, S-106 and S-118. In this case ESRO would purchase a flight unit of a standard OSO spacecraft from NASA at a cost of around 40 MF and would place these experiments in the pointing section of the satellite. The remaining payload capacity would be put at NASA's disposal for American experimenters in order to obtain in exchange the provision of a *Thor Delta* launcher without charge (the cost of such a launcher was about 20 MF). The launch of such a satellite was possible before the end of 1972, still in time to cover the solar maximum.

Finally, the third option foresaw the development in Europe of a new spacecraft with good solar stabilization capability. In fact, the ESRO's Secretariat had received "an unofficial proposal from a European firm to develop a stabilized satellite with a higher degree of stabilization than the OSO, at a lower cost, and with a faster delivery schedule and under more satisfactory contract conditions than had hitherto been thought possible." This solution, however, could not be realized before the end of 1974 and was more expensive than the others. It actually envisaged the development of a real new solar satellite project.[70]

The LPAC did not feel able to give preference to the different possibilities or to establish priorities between them. Looking at the matter from a purely scientific point of view, the Committee seemed less interested in rescuing the TD-2 experiments than in starting a vigorous programme in solar physics in collaboration with NASA.[71] The latter, in fact, had suggested a joint ESRO/NASA project for building two improved OSO spacecraft, carrying experiments provided in equal number by the two agencies, and the LPAC felt that ESRO should not miss this opportunity. The STC, on their side, avoided taking a decision at this

70 STC, 20th meeting (7/10/68), ESRO/ST/MIN/20, 18/11/68, p. 7.

71 LPAC, 24th meeting (first session, 23/9/68), LPAC/15, 13/11/68.

stage, limiting themselves to entrust the LPAC with the responsibility of "examining and recommending whether the experiments were of sufficient value to merit their being given priority over newer proposals."[72] Thus the issue went back to the LPAC.

As a matter of fact, the problem of the TD–2 replacement had important political and scientific implications that made any decision difficult and painful. First of all, from the scientific point of view, it was necessary to assess the scientific worthiness of the TD–2 experiments at the time when they could be flown *vis-à-vis* new experiment proposals. As the Danish delegation in the STC put it: "there was a risk of conflict between the moral obligation of the Organisation to fly the displaced TD–2 experiments and the interests of the future projects." Moreover, as it was evident that the rescue operation could not save all TD–2 experiments, a selection had to be made and this involved a major issue of scientific policy, namely the role of solar physics in ESRO's programme. Among the political aspects, there was the need to place a certain number of sub-contracts to firms other than those that had been responsible for the construction of ESRO I and II so as to comply with the requirements of fair geographical distribution of contracts. Another important political issue, connected with the OSO option, regarded the hostilty of several member states to any choice involving "buying American."

Three dramatic meetings of the LPAC were held between November 1968 and March 1969 to discuss the whole matter. At the first, all TD–2 experimenters presented their work in progress and called strongly on the moral obligation ESRO had towards them.[73] This was particularly stressed by those proposing solar pointing experiments. K. Pounds, on behalf of the Leicester University's group of experiment S–39, said that they had already spent 70 % of the total contract sum for their spectrograph and stated that, for his group, "it would be essential that ESRO did not delay further a decision on whether or not experiment S–39 would be flown before the end of 1972." The Münich group proposing S–118 claimed that this experiment represented a new technique for the study of the oxygen content of the upper atmosphere and "no other experiment of its kind had been

[72] STC, 20th meeting (7/10/68), ESRO/ST/MIN/20, 18/11/68, p. 7–8.

[73] LPAC, 25th meeting (19/11/68), LPAC/19, 8/1/69. Following quotations from p. 4–6. Technical information on the various TD–2 experiments were presented in LPAC/14, 11/11/68.

designed so far by any other group." They had already invested 800,000 DM in the development of the instrument and Lüst added that "[this] group would probably be disbanded were this experiment to be suppressed." De Jager, while advocating the scientific merit of experiment S–126 ("the best existing for scanning the solar disk in soft X–rays"), recognized that it could not be included in a standard OSO spacecraft and volunteered to withdraw the experiment if ESRO decided to rescue the solar pointing experiments by using such a satellite. He added, however, that:

> It was his sincere hope that, in the event of the experiment being withdrawn for the reasons stated, ESRO would take into consideration the efforts so far made in the realisation of the instrument and examine the possibility of flying an improved version some time in the future on a solar satellite with highly improved scanning capabilities."

As a matter of fact, for most European space scientists and for the LPAC, the rescue of the solar pointing experiments, and thus the involvement of ESRO in the rapidly evolving discipline of solar physics, was certainly more appealing than the ESRO III or ESRO IV solution. The time factor was essential in this case since significant results could be obtained by the proposed experiments only if the satellite were launched not later than 1972 and this excluded the possibility of building a new satellite in Europe. In the event, the LPAC recommended the second option, namely to buy an OSO spacecraft to fly the solar pointing experiments S–39, S–106 and S–118 in its pointing section, leaving the non pointing section to American experiments in exchange for free launching by *Thor Delta*.

At the LPAC's second meeting, in January 1969, the framework had radically changed.[74] In fact, ESRO's Director for Programmes and Plans, J.–A. Dinkespiler, informed that NASA was not interested in the proposed arrangement and consequently, if ESRO wanted to use an OSO spacecraft to rescue its solar pointing experiments, it would have to pay for both the satellite and the launcher. In this case, however, it would be possible to accommodate in the spacecraft also the non–pointing experiments, thus rescuing most of the TD–2 experiments. But this solution implied paying some 65 to 105 MF to NASA and it seemed hardly

[74] LPAC, 26th meeting (8/1/69), LPAC/25, 13/2/69. Following quotations from p. 4–6 and 8.

feasible to persuade ESRO's member states to spend their money across the Atlantic. Only very strong scientific arguments could justify the effort, as Bondi chose to stress:

> The Director General would only consider the OSO solution as a possibility if the LPAC were to state categorically that this was the *only* possible solution. If any other possibility existed and it was a question of preference on the part of the LPAC, he could not, for political reasons, undertake to recommend this solution to the STC and Council.

Another possibility did exist, as a study made by ESRO showed that it was possible to design and build in Europe a small solar-pointing, Scout-type satellite to fly the three experiments already approved for the OSO solution (EUROSOL project).[75] The main drawback laid in the time scale as it would not be possible to launch this satellite before the second half of 1973. In conclusion, Dinkespiler listed the costs (including launchers) and schedules of the various solutions for the TD-2 rescue operation as they presented themselves at that stage:

European pointing satellite	100	MFF	second half of 1973
OSO-a (without prototype)	65	MFF	Spring 1972
OSO-b (with prototype)	105	MFF	end 1972
ESRO III or IV	35 - 40	MFF	end 1971

Facing this situation, the LPAC could only choose the line of least resistance, if only from the political and not from the scientific and financial viewpoint:

> The LPAC felt it desirable to have a European solar satellite developed and flown by 1973 on condition that all three experimenters concerned would agree to this solution, particularly with regard to the time scale. [...] In the event of any one answer being negative, ESRO would be left with the choice of pursuing the OSO solution or abandoning the rescue operation for the pointing experiments.

In other words, the members of the LPAC and the chairmen of the *ad hoc* groups, who acted on behalf of the European space science community, did not

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[75] This project is described in annex I to ESRO/ST/303, 19/2/69.

feel strong enough to advocate the purchase of an American spacecraft on the basis of purely scientific arguments, namely the possibility of rescuing most of the TD–2 experiments at good price and the need to hold the launch date of the solar experiments before the end of 1972. They rather hoped that the experimenters could accept the postponement of one year so as to save a minimum solar physics programme in ESRO.

At this stage, following a question from the chairman of the COS group, C. Dilworth, the Director for Satellite and Sounding Rocket Programmes in ESTEC, P. Blassel, specified that the schedule presented was correct only if ESRO accorded the highest priority to the solar satellite, i.e. in preference to HEOS–A2. In fact, as the TD–1 project was already occupying almost the entire technical staff, and because of the difficulty of recruiting competent staff at short notice, only one new project could be started and a priority had to be established. This information radically changed the situation. For the LPAC, in fact, any delay in the development and launch of HEOS–A2 was not acceptable, as this "would amount to ESRO's disappointing the experimenters involved in this satellite." Therefore, assuming the HEOS–A2 project to take first priority and to start in Spring 1969, the realistic time scale had to be changed as follows:

European pointing satellite	Spring 1974
OSO–a (without prototype)	Autumn 1972
OSO–b (with prototype)	mid–1973
ESRO III or IV	mid–1972

The new time scale affected the position of the LPAC and led its members to assume a more resolute line *vis–à–vis* the STC and the Council:

> The LPAC as well as the solar experimenters themselves regard 1972 as the latest possible launch date for the rescue of the TD–2 solar pointing expriments. This condition cannot be achieved using a European solar satellite due to the time factor imposed. Therefore, the LPAC recommends the rescue of the experiments on board an OSO satellite without prototype, being the only possible solution within the required time scale. If Council were not to support this

recommendation, the rescue operation for the solar poiniting experiments could not be realised.

As we see, facing the prospects of a delay of almost 2 years compared to the most acceptable launch date, the LPAC felt they had good enough scientific arguments to overcome political opposition. They knew this would not be easy, however, and called the community to a lobbying initiative:

> The scientists themselves should brief their delegations so that they had a full understanding of the implications for the European scientific community should they reject the OSO proposal for political reasons.

They did not succeed, however. On the eve of the STC meeting called to issue its final recommendation to the Council, the LPAC met again and it was clear at that moment that there was no hope of getting the OSO solution approved. On the one hand, this solution was certainly attractive from the financial point of view and by far the most interesting one from the scientific point of view. On the other hand it was of no technical interest to Europe and thus contrary to ESRO's industrial policy. Unless this policy was modified for this purpose, the rescue of the TD–2 pointing experiments had to be abandoned. In conclusion, while the OSO solution was still listed among possible options, the LPAC agreed to recommend the launching of ESRO IV, for which the possibility of allocating in its payload, after slight modification, five non–pointing experiments had been shown (table 14).[76]

It is quite probable that, by that time, European solar physicists had decided to abandon the controversial OSO solution for launching obsolete experiments and to set a more promising attack front, namely lobbying to get ESRO to start an advanced solar satellite project. In fact, at the STC meeting on the following day, the main spokesman of this community in Europe, the LPAC member C. De Jager, who spoke on behalf of the Dutch delegation, declared that:

> Although they had no objections in principle against buying an OSO in the United States, they did not think this was the desirable solution for the solar physicists: their requirements went beyond launching simply one or two solar experiments on an OSO and would be far

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[76] LPAC, 27th meeting (5/3/69), LPAC/27, 26/3/69. See ESRO/ST/302, 19/2/69, with add. 1, 5/3/69, and ESRO/ST/303, 19/2/69. For the ESRO IV payload see LPAC/21, 23/12/68.

better satisfied with a more advanced solar project later in the programme.[77]

In the event, the STC endorsed (with the abstention of France and Belgium) the LPAC's recommendation to develop the ESRO IV project and adopted a recommendation, put forward by Lüst, by which ESRO was urged to initiate, as soon as possible:

> A feasibility study for a sophisticated solar satellite, which should be included among the proposals for a major project from which a choice would be made in 1970/1971.[78]

Conclusion

The solar physics community did not have its feasibility study, nor did it have a chance to advocate its satellite against other project proposals. In fact, in 1969, after the decision to build the two new satellites COS-B and GEOS, the LPAC was called to discuss ESRO's long-term scientific policy, in order to enable the Organization to make "a careful selection of new feasibility studies to be initiated on future projects."[79] Two panels were created for this purpose, the *Astrophysics Panel* and the *Geophysics Panel*, whose reports were discussed by the *ad hoc* groups and eventually submitted to the LPAC. The outcome was a policy definition which definitely excluded stellar astronomy and high resolution solar astronomy from ESRO's future satellite programme, and confined these fields to rocket experiments. According to the LPAC's scientific policy on ESRO satellite programme for the late 1970s, primary consideration had to be given to a very limited number of research fields, including fundamental physics (like the investigation of the general theory of gravitation), high energy astrophysics (X–

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[77] STC, 21st meeting (6/3/69), ESRO/ST/MIN/21, 24/3/69, p. 4.

[78] *Ibidem*. It appears from the minutes that only Sweden considered that "the policy of not buying American" should be slackened in this case and the OSO solution should be adopted. ESRO IV was approved by the Council, together with HEOS-A2, at its 27th session (25–26/3/69), ESRO/C/MIN/27, 4/4/69. See also ESRO/C/397, 14/3/69.

[79] ESRO/ST/330, 10/10/69, p. 1. For the choice of COS-B and GEOS see Russo (1992a). The discussion on the new ESRO's policy definition will be dealt with in detail in a following report in this series and we anticipate its conclusions here.

ray and low-energy gamma-ray astronomy), cosmic ray studies, and plasma physics investigations in the magnetosphere. As a consequence, the structure of ESRO's scientific advisory groups was reorganized in 1971, the existing six *ad hoc* groups being replaced by an Astrophysics Working Group, a Solar Phsyics Working Group, and a Fundamental Physics Panel.

By 1969 the first phase of ESRO's life came to an end. The Organization's first generation of satellites were in orbit (ESRO I and II, HEOS-1) or under development and scheduled for launch in 1972 (HEOS-2, TD-1 and ESRO IV): this was the actual outcome of the ambitious programme which the ESRO pioneers had written for COPERS in 1961, the so-called *Blue Book*.[80] With the approval of two new satellite projects (COS-B and GEOS) and the policy definition of early 1970 a new phase was opened: it was definitely recognized that ESRO could not support all fields of space science in a viable way but it had to select a few, well-phased major projects according to agreed scientific guidelines. Choices had to be made in order to establish priorities and concentrate efforts in those fields where: (a) interesting new scientific results were to be expected; (b) technical complexity and financial needs fell within the limits of ESRO's capabilities; and (c) a safe niche for original results existed between the programmes of the two space superpowers.

At this turning point there were winners and losers, of course. Among the former we can easily identify the cosmic ray physicists, who firmly occupied both the ground of magnetospheric investigation and that of high energy astrophysics: both COS-B and GEOS were recommended and strongly advocated by the COS group, and the X-ray mission of the following EXOSAT satellite was also an achievement of the same sector of the space science community. The most illustrious losers were, needless to say, the astronomers. Those interested in stellar astronomy first lost the Large Astronomical Satellite (LAS) and then did not succeed in getting the less ambitious UVAS (Ultra Violet Astronomy Satellite) project approved against COS-B and GEOS. Solar astronomers, on their side, lost TD-2 and did not even have a second chance.

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[80] *Report of the Scientific and Technical Working Group to the European Commission for Space Research*, 2nd edition, December 1961. See Russo (1992b).

At the beginning of the new decade ESRO was reaching maturity. Something of the muddled enthusiasm of its early period had faded away and a new awareness of the role and limits of the Organization had emerged from the hard times of the crisis. Important changes in the organizational structure gave more flexibility and autonomy to the Organization and ESRO's member states reaffirmed their confidence in it by agreeing on its extension beyond the 8-year period covered by the original Convention. The scientific programme could be planned on a more secure basis and, moreover, member states entrusted to ESRO the task of studying and eventually implementing a new programme on application satellites. In the difficult and controversial situation of European cooperation in space, ESRO represented the most solid element.

TABLE 1

Membership of the Launching Programme Advisory Committe (LPAC)

1964–67	1968–69	1969–70
R. Lüst (chairman)	R. Lüst (chairman)	R. Lüst (chairman)
J. Blamont	J. Blamont	J. Geiss
R. Boyd	B. Hultqvist	B. Hultqvist
C. de Jager	C. de Jager	G. Occhialini
	G. Occhialini	B. Strömgren

TABLE 2

Chairmen of *ad hoc* Working Groups

		1964–65	1966	1967–68
ATM	Atmospheric structure	R. Frith	R. Frith	F. Möller
ION	Ionospheric and auroral phenomena	B. Hultqvist	A. Willmore	A. Willmore
SUN	Solar astronomy	C. de Jager	R. Michard	R. Michard
PLA	Moon, planets, comets and inter-planetary medium	L. Bierman	L. Bierman	J. Geiss
STAR	Stellar astronomy	P. Swings	P. Swings	L. Gratton
COS	Cosmic rays and Trapped radiation	G. Occhialini	B. Peters	C. Dilworth

TABLE 3

Satellite projects in ESRO's scientific programme by the end of 1965

Spacecraft families	Names of satellites	Total weight (kg)	Scientific payload (kg)	Initial apogee (km)	Initial perigee (km)	Orbital inclinat.	Launch date
Small satellites	1. ESRO I	81	19	1500	275	90°	1967
	2. ESRO II	80	20	1100	350	98°	1967
Highly eccentric orbit satellites	1. HEOS-A	105	25	240,000	200	33°	1968
	2.						1970
	(3)						(1971)
	4.						1971
Medium-size stabilized satellites	1. TD-1	400	80	500	500	98°	1969
	2. TD-2	400	63	1200	350	90°	1969
	(3)						(1970)
	4.						1970/71
	(5)						(1971/72)
	6.						1971/72
Large astronomical satellites	1. LAS	800	225	650	650	0 or 90°	1970
	2.						1971
	3.						1972

From ESRO, *General Report*, 1964-65, fig. 2.9 and 2.10.

Only the names of the projects actually approved are indicated. Notice that two TD satellites and one HEOS satellite are in brackets because their actual realization seemed already jeopardized by lack of financial resources.

TABLE 4

Satellite experiment proposals by the end of 1965
broken down according to disciplinary fields

ATM	Atmospheric Structure and Meteorology	8
ION	Ionospheric and Auroral Phenomena	39
SUN	Solar Astronomy	16
STAR	Stellar Astronmy	7
PLA	Study of the Moon, Planets and Interplanetary Medium	14
COS	Cosmic Rays and Trapped Radiation	25
---	Space Biology	1
	TOTAL	110

From ESRO *General Report*, 1964–65, p. 26–27.

TABLE 5

The payload of ESRO I (polar ionosphere) approved in spring 1963

S-32	Auroral photometry	D.R. Bates Queen's University, Belfast
S-42	Helium lines HeII (304 Å) and HeI (584 Å)	R. Boyd University College, London
S-44	Ionospheric electron temperature and density	R. Boyd University College, London
S-45	Ionospheric composition and ion temperature	R. Boyd University College, London
S-70	Ionospheric sounding	E. Vassy Lab. Physique de l'Atmosphère, Paris
S-71	Flux and energy spectrum of electrons and protons	J. Rybner Technical University, Copenhagen J.A. Ratcliffe Radio and Space Research Station, Slough B. Hultqvist Kiruna Geophysical Observatory

From: COPERS/GTST/82, rev. 1, 14/6/63, p. 2.

TABLE 6

The payload of ESRO II approved in spring 1963

(solar astronomy and cosmic rays)

S–25	Trapped radiation	H. Elliot Imperial College, London
S–27	Solar and Van Allen belt protons	H. Elliot Imperial College, London
S–28	Protons and alpha particles in cosmic rays	H. Elliot Imperial College, London
S–29	High energy cosmic ray electrons	J.G. Wilson University of Leeds
S–31	Measurements of micrometeorites	D.R. Bates Queen's University, Belfast
S–36/37	Solar X rays	E.A. Stewardson University of Leicester R.L.F. Boyd University College, London
S–42	Helium lines HeII (304 Å) and HeI (584 Å)	R.L.F. Boyd University College, London
S–48	Measurement of Lyman alpha	R.L.F. Boyd University College, London

From: COPERT/GTST/82, rev. 1, 14/6/63.

TABLE 7

The final configuration of the payload of ESRO I (polar ionosphere)

S-32	Auroral photometry	D.R. Bates Queen's University, Belfast A. Omholt, A. Egeland Oslo University
S-44	Ionospheric electron temperature and density	R. Boyd, A.P. Willmore University College, London
S-45	Ionospheric composition and ion temperature	R. Boyd, A.P. Willmore University College, London
S-71A	Flux and energy spectrum of electrons, 40–400 KeV	R. Daziel and D.E. Page Radio and Space Research Station, Slough
S-71B	Electron and proton density	B. Hultqvist, W. Riedler Kiruna Geophysical Observatory
S-71C	Energy spectrum of auroral protons	M.F. Soras Bergen University O.E. Petersen Technical University, Copenhagen
S-71D	Angular distribution of particles	B. Landmark and G. Skovli Norwegian Space Committee O.E. Petersen Technical University, Copenhagen
S-71E	Energy spectrum of protons, 1–30 MeV 40–400 KeV	R. Daziel and D.E. Page Radio and Space Research Station, Slough

From: ESRO, *General Report*, 1964–1965.

TABLE 8

The final configuration of the payload of ESRO II

(solar astronomy and cosmic rays)

S–25	Trapped radiation	H. Elliot, J.J. Quenby Imperial College, London
S–27	Solar and Van Allen belt protons	H. Elliot, J.J. Quenby Imperial College, London
S–28	Protons and alpha particles in cosmic rays	H. Elliot, J.J. Quenby Imperial College, London
S–29	High energy cosmic ray electrons	P.L. Marsden University of Leeds
S–36	Solar X rays, 1–20 Å	E.A. Stewardson, K.A. Pounds University of Leicester R.L.F. Boyd University College, London
S–37	Solar X rays, 44–70 Å	C. De Jager, W. De Graaf Utrecht Observatory
S–72	Flux and energy spectrum of solar protons, 35–1000 MeV	J. Labeyrie, L. Koch Centre d'Études Nucléaires, Saclay

From: ESRO, *General Report*, 1964–1965.

TABLE 9

The payload of HEOS-A approved in autumn 1965

S-58/S-73	Flux, energy spectrum and angular distribution of interplanetary plasma	C. De Jager Utrecht Observatory R. Coutrez Université de Bruxelles A. Bonetti University of Bari G. Pizzella University of Rome
S-24A	Interplanetary magnetic field	H. Elliot, P.C. Edgecock Imperial College, London
S-24B	High energy cosmic ray protons	H. Elliot, A.R Engel Imperial College, London
S-24C	Solar protons, 1-20 MeV	H. Elliot, R.J. Hynds Imperial College, London
S-16	Ion cloud to study the interaction between interplanetary plasma and magnetic fields	R. Lüst Max Planck Inst. für Extra-terrestrische Forschung, Garching
S-72	Solar and cosmic ray protons	J. Labeyrie, L. Koch Centre d'Études Nucléaires, Saclay
S-79	Cosmic ray electrons, 50-600 MeV	C. Dilworth University of Milan J. Labeyrie Centre d'Études Nucléaires, Saclay

N.B.: The complex experiment S-24 was made up of the original proposals S-24 and S-27, both presented by Elliot.

N.B.: The collaboration S-58/S-73 was made up from experiment proposals originally presented by the Brussels group (S-58) and by the Rome/Bari group (S-73).

From: ESRO/ST/109, 3/3/65 and ESRO, *General Report* 1964-1965.

TABLE 10a

The payload of TD-1 approved in summer 1964

S-1/S-2/S-68	Scanning of the sky in the ultraviolet and infrared	P. Swings Université de Liège H.E. Butler Royal Observatory, Edinburgh
S-30	Celestial gamma rays	G.W. Hutchinson, D. Ramsden University of Southampton
S-59	Stellar spectrography in the UV	C. De Jager, A.B. Underhill Utrecht Observatory
S-77	Celestial X rays (3-30 KeV)	J. Labeyrie, L. Koch Centre d'Études Nucléaires, Saclay

N.B. Experiment S-1 (IR scanning) and S-2 (UV scanning) were originally presented by Swings; experiment S-68 (IR scanning) was originally presented by Swings and Butler.

TABLE 10b

Addition to the payload of TD-1 in 1965

S-67A	Primary cosmic ray particles	J. Labeyrie, L. Koch Centre d'Études Nucléaires, Saclay
S-88	Solar gamma rays, 50-300 MeV	J. Bland, G. Occhialini University of Milan
S-100	Solar X rays, 40-300 KeV	C. De Jager, J.N. Van Gils Utrecht Observatory

From: ESRO/ST/145, 24/9/65 and ESRO *General Report* 1964-1965.

TABLE 11

The final configuration of the TD-1 payload

S-2/S-68	Scanning of the sky in the ultraviolet and infrared (1000-3000 Å)	P. Swings University of Liège H.E. Butler Royal Observatory, Edinburgh
S-59	Stellar spectrography in the UV	C. De Jager, A.B. Underhill Utrecht Observatory
S-67A	Primary cosmic ray particles	J. Labeyrie, L. Koch Centre d'Études Nucléaires, Saclay
S-77	Celestial X rays (3-30 KeV)	J. Labeyrie, L. Koch Centre d'Études Nucléaires, Saclay
S-88	Solar gamma rays, 50-300 MeV	J. Bland, G. Occhialini University of Milan
S-100	Solar X rays, 40-300 KeV	C. De Jager, J.N. Van Gils Utrecht Observatory
S-133	Celestial gamma rays, 70-300 MeV	J. Labeyrie, Y. Koechlin Centre d'Études Nucléaires, Saclay G. Occhialini, L. Scarsi University of Milan R. Lüst Max-Planck-Institut, Garching

From: ESRO, *General Report*, 1967.

TABLE 12

The final configuration of the TD-2 payload

S-39	Solar X-ray spectrometry	E.A. Stewardson, K.A.Pounds University of Leicester
S-45 (*)	Ionospheric composition and ion temperature probe	R.L.F. Boyd, A.P. Willmore University College, London
S-80	Neutral particle composition of the upper atmosphere	W. Priester, U. Von Zahn University of Bonn
S-85	Low energy auroral electrons	R. Dalziel, T. Briant Radio and Space Research Station, Slough
S-94	Auroral particles	B. Hultqvist, W. Riedler Kiruna Geophysical Observatory
S-97	Light emission from oxygen and ionized nitrogen	J.E. Blamont Service d'Aéronomie, CNES, Verrières
S-99	Solar protons, 13-160 MeV	C. De Jager, H.F. Van Beck Utrecht Observatory
S-103	Solar protons, 0.6-28 MeV	R. Lüst, D. Hovestadt Max Plank Institut, Garching
S-106	Solar UV spectrography	R.L.F. Boyd, M. Timothy University College, London
S-118	Optical determination of thermospheric O_2 concentration	F. Moller University of München
S-126	Scanning of the solar corona in the range 15-35 Å	C. De Jager Utrecht Observatory

(*) Besides S-45, two more probe experiments had been originally included in the payload: S-11 (by K. Rawer, from the Ionosphären Institut, Breisach) and S-93 (by J. Sayers, from the University of Birmingham). Subsequently, for technical reason, only one could be kept and the ION group recommended S-45 at its 14th meeting (19/11/65), ION/27, 7/12/65.

From: ESRO, *General Report*, 1966.

TABLE 13

The final configuration of the HEOS-A2 payload

S-201	Magnetic field measurement	H. Elliot Imperial College, London
S-202	Plasma measurement	G. Pizzella University of Rome
S-203	ELF radiation in solar wind and magnetosphere	B. Peters Danish Space Research Institute Copenhagen
S-204	Intermediate energy particles	D.E. Page Space Science Department (ex ESLAB), ESTEC
S-209	High energy cosmic ray electrons	C. Dilworth University of Milan J. Labeyrie Centre d'Études Nucléaires, Saclay
S-210	Measurement of solar wind	Rosenbauer Max-Planck-Institut, Garching
S-215	Measurement of micrometeorites	J. Zähringer Max-Planck-Institut Heidelberg

From: ESRO *General Report*, 1968.

TABLE 14

The payload of ESRO-IV

S-45	Density, temperature and composition of positive ions	R.L.F. Boyd, A.P. Willmore University College, London
S-80	Mass spectrometer of neutral gases	W. Priester, U. Von Zahn University of Bonn
S-94	Auroral particles	B. Hultqvist, W. Riedler Kiruna Geophysical Observatory
S-99	Galactic and solar particles, 2.5-320 MeV	C. De Jager, H.F. Van Beck Utrecht Observatory
S-103	Galactic and solar particles, 2.5-360 MeV	R. Lüst, D. Hovestadt Max Plank Institut, Garching

From: ESRO, *General Report*, 1969.

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