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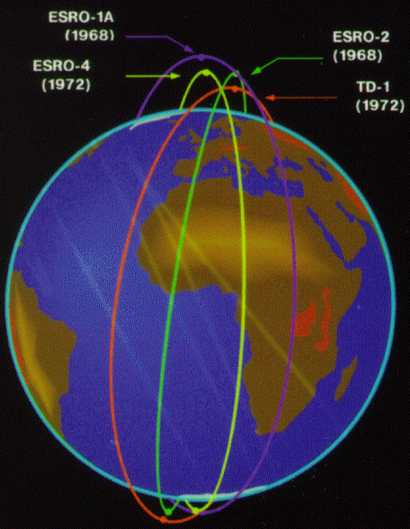
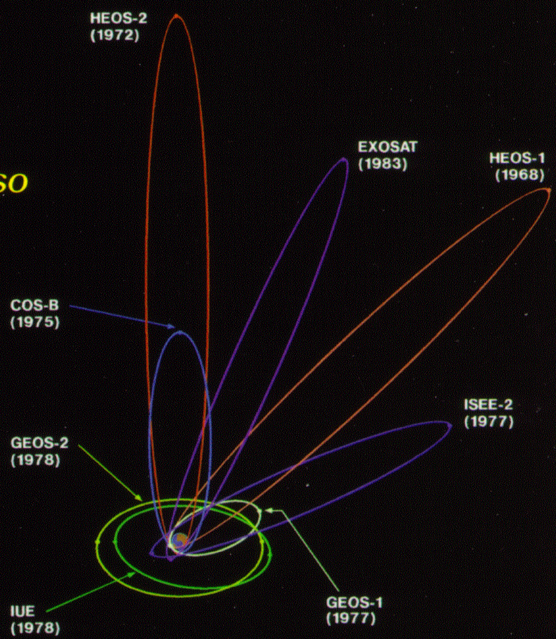
Big Technology, Little Science

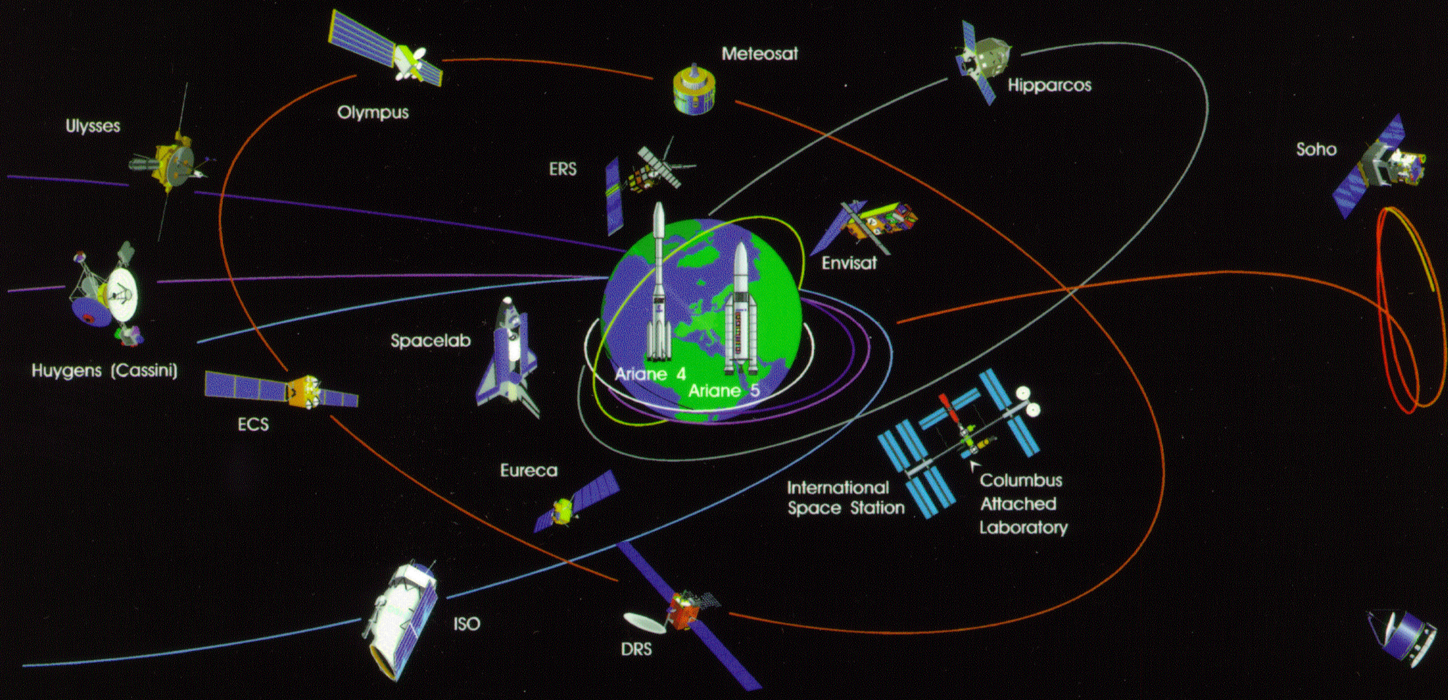
The European Use of Spacelab



by

Arturo Russo





European Space Agency
Agence spatiale européenne

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the European use of Spacelab

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The ESA History Study Reports are preliminary reports of studies carried out within the framework of an ESA Contract. As such, they will form the basis of a comprehensive study of European space activities covering the period 1958-1987. The authors would welcome comments and criticism, which should be sent to them at the appropriate address below.

The opinions and comments expressed and the conclusions reached are those of the authors and do not necessarily reflect the views or policy of the Agency.

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Big technology, little science: the European use of Spacelab *

Arturo Russo

Introduction

On 5 January 1972, the American President Richard Nixon announced his decision to "proceed at once with the development of an entirely new type of space transportation system designed to help transform the space frontier of the 1970s into familiar territory, easily accessible for human endeavor in the 1980s and '90s." This new system, Nixon explained, "will center on a reusable vehicle that could shuttle repeatedly from earth to orbit and back."[1] The commitment of the United States to the development of the Space Shuttle heralded a revolution in space activities. Since the early Sputniks and Explorers up to the Apollo missions to the Moon, the launch of every spacecraft into space required a vehicle whose cost and technical sophistication was generally much higher than that of the spacecraft itself, and which would ultimately be lost in the launch. It was like operating a railroad and throwing away the locomotive after every trip, some NASA officials used to say. A reusable vehicle would make the trip much more cost effective, they claimed, bringing the cost of space launches down by a factor of ten.[2]

In the new era of space exploration, the Shuttle would replace expendable boosters for launching satellites into low earth orbits and, in conjunction with upper stages, for sending spacecraft towards geosynchronous orbit or deep space. Other uses of the Shuttle were possible, however, taking advantage of its unique capabilities. In particular, the large cargo bay of the Orbiter could be used to support standard services and laboratory facilities for performing experiments in space. In this perspective, NASA studied the so-called Sortie Lab, a pressurised module fitting in the Shuttle cargo bay for the conduct of experimental activity in several scientific and technological fields. This was eventually called Spacelab, a manned space laboratory which could be used in different configurations on Shuttle sortie missions.

In 1973, an agreement was reached between NASA and the European Space Research Organisation (ESRO) by which the latter would be responsible for the design, development and manufacture in Europe of Spacelab and its associated equipment. More specifically, the ESRO/NASA Memorandum of Understanding (signed on 14 August 1973) and the Joint Programme Plan (signed on 26 September 1974) stated that ESRO would deliver to NASA one Spacelab flight unit, one engineering model and two sets of ground support equipment. The European space organisation would also provide sustaining engineering support through the first two Spacelab flights. In May 1975 the Spacelab programme was taken over by the newly created European Space Agency (ESA), the organisation which replaced ESRO in the

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* The work reported here has been performed in the framework of the project for the history of the European Space Agency (ESA). Unless otherwise specified, all primary unpublished sources cited are from the ESA collection in the Historical Archives of the European Communities, European University Institute, Florence. I wish to thank archivist G. Bonini for his helpful collaboration. A preliminary version of this paper was presented at the Congress of the Society for the History of Technology in Charlottesville, Virginia, in October 1995.

1 "The White House, Statement by the President", 5 January 1972, in Launius (1994), p. 232. On this decision, see Logsdon (1986) and McCurdy (1990), pp. 22-33.

2 Launius (1994), p. 107; McCurdy (1993), p. 87.

management of the joint European space effort.[3] The first Spacelab mission, originally planned for early 1980, was launched on 28 November 1983; three other missions followed in 1985, two supported by NASA and one by Germany. After the Shuttle Challenger accident of 28 January 1986, Spacelab flights were resumed in December 1990.

Spacelab was one of the most important and most expensive space programmes in Europe. For the first time since its beginnings in the early 1960s, the European space effort confronted the challenge of manned space flight, in the framework of the largest space collaboration ever undertaken by Europe and the United States. This co-operative venture posed unprecedented management problems, and many important technical and industrial difficulties had to be solved in Europe. The total cost of the Spacelab programme was of the order of $ 800 million, about 40 % higher than the original estimate. All ESA Member States except Ireland and Sweden participated, and the relative financial contributions were arranged according to their political and industrial interest in the programme. Germany paid the largest share, about 55 %, the other main contributions coming from Italy (15.6 %), France (10.3 %) and the United Kingdom (6.5 %). The industrial team was led by the German company ERNO, supported by ten co-contractors. More than forty companies in ESA Member States were involved in the development of the Spacelab system.[4]

Although important from the technical and industrial point of view, Spacelab could not be considered as an end in itself. It was a large facility for carrying out experimental activities in a large gamut of scientific and applications fields. The ultimate aim of the programme was to develop a system characterised by low-cost operations, versatility, good laboratory facilities and rapid user access, that could be used by as wide a community as possible. When Spacelab was conceived however, no such user community existed yet. As often happens in big science and technology fields, a large technological facility was developed and offered as a solution in search of a scientific problem. The supporters of the new facility had to convince the potential users of the benefit that they could derive from its use and to lead them to plan their future objectives accordingly.[5]

The aim of this paper is to review the history of the Spacelab programme from the point of view of a specific user community, namely the European space science community. The interest of such a viewpoint is twofold. Firstly, Europe was the birthplace of Spacelab and therefore a special responsibility vis-à-vis its utilisation was incumbent on European space scientists and policy makers. Secondly, the ESRO/ESA scientific programme suffered from severe budgetary constraints which had been imposed in the pre-Spacelab period and not revised after the decision to undertake this project. Scientists were therefore called upon to accommodate the new mission opportunities within the established budget in a very competitive framework. The analysis is divided into four main parts. In the first we will briefly describe the main features of the Spacelab system and the early reactions of scientists to the appeal of a scientific laboratory in space. In the next part, we will analyse the role of potential Spacelab missions in the planning of ESA's scientific programme for the 1980s. The third part, the most important one, is devoted to the European instrumentation on the first Spacelab mission, jointly realised by ESA and NASA in the framework of the Spacelab development programme. Finally, we will briefly discuss ESA plans for Spacelab utilisation after the first mission.

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3 Krige & Russo (1994), Sebesta (1995).

4 Shapland & Rycroft (1984). ESA comprised eleven Member States in the Spacelab period: Belgium, Denmark, France, Germany, Ireland, Italy, the Netherlands, Spain, Sweden, Switzerland and the United Kingdom. Austria was eventually associated in the Spacelab programme. A detailed historical account of the Spacelab programme from the American side was provided by the former NASA director of the programme, D. Lord (1987). L. Sebesta is preparing a history of the Spacelab programme within the framework of the ESA History Project.

5 Another example is discussed in Russo (1996).

The appeal of a scientific laboratory in space

The Spacelab concept consisted of a modular structure composed of two basic elements: a cylindrical pressurised module and an unpressurised U-shaped structure (pallet) (Figures 1 and 2). The module provided a shirt-sleeve laboratory environment for the experimenters and their equipment. It was connected to the Orbiter cabin by a crew transfer tunnel. The pallet acted as a platform where telescopes, antennas and other instruments which needed direct exposure to space could be mounted. A sophisticated Instrument Pointing System (IPS) was also developed in Europe in the framework of the Spacelab programme, for use with pallet-mounted equipment which required a high degree of pointing accuracy. The pallet instruments could be operated remotely from the module, the Orbiter cabin or by command link from the ground. A flight time of 7 days was envisaged for a standard Spacelab mission and the facility was designed for at least 50 flights or a ten-year lifetime.

Several configurations were possible, according to the specific objectives of each mission. The pressurised module could be composed of one or two segments, while pallet segments could be mounted either individually or in series of up to five segments. Spacelab's modular concept offered considerable flexibility for adaptation to a wide range of missions. By changing the number of module and pallet segments, one could obtain variations on the three basic flight configurations: module-only, module-and-pallet, and pallet-only (Figure 3). The flight unit that ESA delivered to NASA consisted of a long (two-segment) module plus five pallet segments. The first Spacelab mission was realised with the module and one pallet segment. A pallet-only configuration with three pallet segments and the IPS facility was used in the Spacelab 2 (SL-2) mission, actually the third to be launched, on 29 July 1985. Spacelab 3 (SL-3), launched on 29 April 1985, used a module-only configuration with the addition of a simple support structure to hold two experiments needing exposure to space. A similar configuration was also adopted for the German D-1 mission, on 30 October 1985, the last Spacelab flight before the Challenger accident. By that time, the manifest of Spacelab missions included 11 flights, in various configurations, between March 1986 and July 1988.[6]

Spacelab was heralded by its proponents as a new and exciting way to do research beyond the atmosphere (Figure 4). New opportunities would be offered to traditional space science disciplines and new fields would be opened up. In the field of astronomy, for example, it became possible to explore the spectral regions of infrared through the use of large, cryogenically cooled telescopes. Microgravity experiments in life sciences and material sciences would provide important results in view of a foreseeable future in which human communities would live and work in large space stations. "Spacelab is the indispensable element to transform the Shuttle into a first generation space station", ESRO's Director General claimed in 1973, adding that according to the NASA mission plans about 40 % of Shuttle flights would be devoted to Spacelab missions.[7]

Five aspects were pointed out as the main advantages to the users over conventional spacecraft. Firstly, the large weight and volume available for experimentation, i.e. from about 4 tonnes of payload in the module-only configuration to 9 tonnes in the pallet-only configuration. Secondly, the possibility of reusing equipment on subsequent flights, which allowed the repetition and modification of experiments. Thirdly, the availability of a laboratory-like environment in which scientists and other specialists could supervise the experiments and, if necessary, adjust and repair the instruments. Fourthly, the short experiment gestation time deriving from the frequent Shuttle/Spacelab flights and the re-use of standard equipment and basic services (laboratory

6 *ESA Bulletin*, No. 46, May 1986, p. 103.
7 ESRO/C(73)49, 13/7/73, pp. 1-2.

facilities, instrument racks, work benches, power supply, thermal control, data management, etc.). Finally, the low cost of Spacelab experiments compared to "traditional" spacecraft as a consequence of two main factors: (a) the relatively low cost of Shuttle launches associated with the large mass capability, which made the cost per kilogram of experiment mass small; (b) the less demanding standards on reliability of instrumentation because of the laboratory-type equipment and the presence of the experimenter for check-out and minor repair.

The reactions of scientists

While the Spacelab concept was being studied by NASA and ESRO, both space agencies took a number of initiatives to inform the scientific community about the capabilities of the Shuttle/Spacelab system, to assess the impact of the new facility on the different scientific and application fields, and to define the requirements of the potential users. In the summer of 1972 NASA organised a Space Shuttle Sortie Workshop, followed by the establishment of fifteen working groups to address questions relative to as many scientific, technological and application fields. ESRO, for its part, set up ten "Spacelab Payload Groups" to assist the Executive in defining the interfaces between Spacelab and the experiments and evaluating the Spacelab design *vis-à-vis* the users' requirements in the various scientific and technical disciplines.[8]

The reaction of scientists to the Spacelab advocates' arguments was far from being enthusiastic, however. According to the former NASA Director of the Spacelab programme:

> *Many of the potential experimenters were more than content with their unmanned satellites and sounding rockets and had no strong desire to become involved in the new manned systems. They could see nothing but loss of control of their experimental destinies and increased costs to make their instruments man-rated.*[9]

The lukewarm attitude of scientists towards the Shuttle/Spacelab system was evident on two important occasions at which the utilisation of the new facility was discussed by the community at large. The first was a symposium organised by ESRO in Frascati, Italy, in January 1973, attended by some 250 scientists and technologists. Then, in July that year, a two-week Summer Study was organised by the U. S. National Academy of Science at Woods Hole, Massachusetts.

The scientists who participated in the Frascati meeting discussed the possible benefit of Spacelab for their disciplines in five scientific sessions whose results were presented by their chairpersons, all recognised spokesmen of the European space science community.[10] They did not hide the diffuse scepticism of the community itself regarding Spacelab. Two main disadvantages were pointed out, in particular. The first was the short duration of Spacelab missions. For Cornelis de Jager, who spoke on behalf of the solar physics community, "[Spacelab] is not the most appropriate spacecraft for any instrument intended for continual solar monitoring during long periods." The rapporteur for the high energy astrophysics session,

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8 Lord (1987), pp. 7-8; ESRO/PB-S(73)14, 10/9/73. The topics dealt with by the ESRO Spacelab payload groups were: infrared astronomy, stellar astronomy, solar astronomy, high energy astronomy, atmospheric and ionospheric sciences, life sciences, material sciences, earth resources, communications, and space electrophoresis. The results of the first six groups, specifically devoted to scientific fields, were published in the report *Spacelab programme. Views of the ESRO Spacelab payload groups: utilization of the Spacelab for science*,OSP/45, 30/5/73, available in the ESA Headquarters library, Paris.

9 Lord (1987), p. 7. The negative attitude of American space scientists towards the continuation of important manned spaceflight activity after their "distasteful experience" with the Apollo programme is discussed by Newell (1980), pp. 389-392.

10 LPAC(73)4, 31/1/73. The five scientific sessions and their chairpersons were: solar astronomy (H. Elliot and C. de Jager), infrared and ultra-violet astronomy (H.C. van de Hulst and G. Courtès), high energy astrophysics (G. Occhialini and C. Dilworth), space and plasma physics (J. Geiss and G. Haerendel), life sciences (P. Lindop). The life sciences session was a novelty in the European space science framework.

Giuseppe Occhialini, echoed de Jager's statement: "Spacelab can be considered equivalent to a super rocket for X-rays or a super balloon for gamma and cosmic rays. [...] This type of mission cannot supersede, not even replace free flying missions in our field, not even small satellites." The only way to compensate for the short duration of Spacelab missions was to have frequent flights of the same instrument. This, however, called for a clarification of the financial aspects with NASA. The obvious question was bluntly asked by Henk van de Hulst, the spokesman of the astronomer community: "On what principle will the cost per launch be determined and what is the present estimate?". Nobody was in a position to answer this question yet.[11]

The second disadvantage of Spacelab was precisely what some considered its main attraction, i.e. the presence of the experimenter directly supervising the performance of its instruments. Two major drawbacks of manned scientific missions were pointed out: the contamination caused by gases from the life-support equipment and the attitude instability caused by the crew. Another cause of concern was, of course, the high cost and complexity of man-rated space transportation systems, which risked jeopardising the vaunted attraction of the reduced time and cost in comparison with conventional space experiments.

In conclusion, most European space scientists were quite sceptical, or even suspicious, regarding Spacelab's performance in their fields of interest. Occhialini probably expressed the feelings of many participants in his conclusion: "We would not have chosen this particular type of vehicle in our field, but being there, it can be used."[12] There could be a place for Spacelab in the ESRO scientific programme, they argued, provided that Spacelab missions did not supersede the ongoing automatic spacecraft programmes and that certain conditions were fulfilled. In particular, it was deemed necessary to assure a frequent repetition of flights and it was recommended to give preference to pallet-only missions so that it would not be necessary to pay the performance penalty associated with manned flights.

The American space science community did not hold the scientific potential of Spacelab in any higher esteem, as was evident at the N.A.S. Summer Study:

> *The Sortie Lab was not the most popular programme presented to this group of scientists. With the exception of the life scientists present, most of the attendees felt their resources could be better placed on automated systems in the conventional space science disciplines. Once faced with the fact that a Sortie Lab would probably be provided by a European co-operative effort, they grudgingly conceded that there were some ways in which it could be useful to all disciplines.*[13]

Most American space scientists could see little use for Spacelab at that time and "wondered if they were going to be pressured into using it simply to keep man-in-space in the picture".[14] They were not even convinced of the usefulness of the Shuttle itself as a vehicle to carry scientific payloads into space. Firstly, it did not appear to be appropriate for small near-earth satellites of the kinds that were being launched by Scout rockets, both because they would hardly be accommodated within the Shuttle cost structure and because they had often to go into unusual orbits. Secondly, there were payloads headed for geosynchronous or other high-altitude orbits, or for escape trajectories to interplanetary space; if the Shuttle were to be used for the initial boost, suitable upper stages had to be developed to carry these payloads beyond the Shuttle's low-altitude orbit.

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11 The three quotations are from LPAC(73)4, cit., Annex 2, pp. 4, 7 and 6, respectively.
12 LPAC(73)4, cit., Annex 2, p. 7.
13 Lord (1987), p. 11.
14 Newell (1980), p. 391.

In conclusion, scientists on both sides of the Atlantic considered the Shuttle/Spacelab system of very little scientific interest, at least those involved in "traditional" space science disciplines. Against the obvious advantages of return capability, large payload availability, and on-board adjustment of experiments, there were serious disadvantages such as the short duration of missions, the limitation of attainable orbits, contamination and man-induced attitude changes. Moreover, the cost of Spacelab missions was still an open question which dramatically depended on the eventual performance of the Shuttle. However, in spite of the poor scientific arguments which could be made in favour of the Shuttle/Spacelab programme, the scientists could not ignore it. They could not control the technical development of launch vehicles, which actually depended on wider political and economic factors. The Shuttle appeared as the space transportation system of the following decades and they had to adjust their future plans accordingly.

For the European space science community, in particular, the political importance of Spacelab was outstanding. It was a key element of the "package deal" which, in 1973, solved a long-standing crisis in the European collaborative effort in space and paved the way for the creation of the European Space Agency. It also represented the start of a new era in U.S.-European space co-operation, indeed the ticket for Europe to participate in the American Space Shuttle programme. Space policy, not space science, was the main rationale for the development of Spacelab in Europe and European scientists had to cope with this fact.[15]

Planning ESA's scientific programmes in the 1980s and the role of Spacelab

By the time the Spacelab development programme was started, the European space science community was involved in the decision-making process to select ESRO/ESA's scientific missions to be flown in the early 1980s, the final decision being scheduled for the autumn 1976.[16] The role of the Shuttle/Spacelab system in space research was central in these discussions, which brought into focus the delicate transition period which the European space effort was going through. Three main aspects deserve being mentioned. Firstly, the ESRO/ESA scientific programme suffered from a severe financial constraint. The so-called "first package deal" between ESRO Member States had fixed at 27 MAU (in 1971 prices) the annual level of resources for this programme, the only one which was mandatory for all Member States according to a GNP contribution scale.[17] This ceiling was confirmed, apart from adjustments for inflation, in the second package deal (1973) and after the creation of ESA (1975), despite the dramatic increase in the total financial resources made available by Member States for the joint space effort (from 75 MAU in 1974 to 462.4 MAU in 1976). More precisely, after taking into account inflation and ESA's new budget structure, the annual level of the scientific programme was set at 58.7 MAU in 1975-prices from 1977 onwards.[18] The steady financial envelope gave great stability to the scientific programme, but the budget was now becoming critically low when compared to the increasing size of the scientific community calling on ESA and to the demands for more ambitious research projects in the new decade.

15 For the 1973 "package deal", see Krige and Russo (1994), pp. 103-114. The history of US-European cooperation in space is the subject of a forthcoming book by J. Logsdon and L. Sebesta.

16 Russo (1995).

17 With the first package deal (December 1971), ESRO Member States had agreed that the Organization, originally created for space research, should also develop application satellite programmes on an optional basis. Krige & Russo (1995), pp. 105-108. It must be remembered that MAU stands for million Accounting Units, a conventional monetary unit used since the early 1960s in the framework of the joint European space effort. Since 1975 the AU has been defined in terms of a "standard basket" of the EEC currencies weighted according to the average over five years of the gross national product and the intra-European trade of each state. In 1976, the value of the AU in terms of the main currencies was 1.30 US$; 3.05 DM; 5.22 FF; 0.57 GB£; 815 LIT. See Frank (1976). Todays's AU is equivalent to one ECU.

18 ESA/SPC(76)18, 25/5/76.

In this framework, and this is the second aspect, the advent of the Shuttle/Spacelab system posed a major problem. The new facility, in fact, not only offered new opportunities in the traditional space science disciplines, but also opened up research fields not covered by former ESRO/ESA activities, in particular zero-gravity research in bio-medical and material sciences. When the first package deal had established the financial envelope for the scientific budget, Spacelab was not yet in sight; when the latter was approved, in the framework of the second package deal, no special provision was foreseen for developing experimental payloads for Spacelab missions. Consequently, Spacelab scientific experiments should either be developed by groups of Member States as optional programmes or funded out of the scientific programme. In the former case, the mandatory and co-operative character of the scientific programme would be undermined; in the latter, new disciplines and scientific groups would compete for funding with the traditional ones. The space science community advocated the need to endorse the mandatory character of the scientific programme and then insisted that its budget should be increased in order to support new research fields as well as old ones, Spacelab missions as well as unmanned spacecraft. Member state governments, on the contrary, were adamantly against any increase of the mandatory budget, and their space policy makers held different views about the future of ESRO/ESA's scientific policy. Some argued that the Organisation should undertake large projects based on the use of the new space technologies and funded on an optional basis by interested Member States; others felt that the mandatory character of the scientific programme should not be jeopardised and that the new opportunities offered by the Shuttle/Spacelab system should compete with established research fields and space science technologies.[19]

This brings us to the third aspect, i.e. the place of science in the new institutional framework. The two package deals and the transformation of ESRO into ESA had certainly left the scientific programme, because of its mandatory character, at the core of the joint European space effort, but also in a very weak position from the political point of view. In the early 1960s, space research had been the main rationale for west European countries undertaking a co-operative effort in space, and the space science community played a major role in defining ESRO's institutional framework and scientific policy. The situation was quite different in the 1970s. Practical objectives such as commercial telecommunications, air traffic control and weather forecast had replaced scientific research as the principal aims of ESRO's and ESA's undertakings. Economic and commercial interests, technological innovation and industrial policy were the driving forces that shaped the European space effort, and science had to adjust its objectives and priorities accordingly. Even in science itself, national interests and programmes often entered the competitive game for selecting ESA scientific projects, jeopardising the scientists' claim to base their judgement on purely scientific arguments.

It is against this background that discussions on ESRO/ESA's future scientific programmes started in 1973 within the Launching Programme Advisory Committee (LPAC) and the two specialised working groups: the Astrophysics Working Group (AWG) and the Solar System Working Group (SSWG).[20] The most important conclusion was the abandonment of the policy statement that the LPAC had adopted in June 1970, by which priority had been given to magnetospheric studies and high energy astrophysics, while optical astronomy, solar physics and planetary missions had been excluded from ESRO's scientific programme, both for

19 Russo (1995), pp. 20-33.

20 Since the early days of ESRO, the LPAC was a body of five independent scientists whose task was to advise ESRO's Director General on all scientific matters. The chairmen of the two working groups usually participated in LPAC meetings. In 1974 a Life Sciences Working Group (LSWG) was also set up. With the advent of ESA, the LPAC was replaced by the six-member Science Advisory Committee (SAC), which also included a life science expert.

financial reasons and because of NASA's strong effort in these fields.[21] In the new situation created by the advent of the Shuttle/Spacelab system and the prospects of large-scale collaborative ventures with NASA, a new policy had to be established for scientific missions to be flown in the 1980s.

Many proposals were discussed in the second half of 1973 and early 1974, but no guidelines were defined at this stage, either regarding priorities between the various research fields or regarding preference for specific kinds of mission (e.g. automatic satellite or Spacelab missions, small or large spacecraft, purely European or co-operative projects). In the event, following the LPAC's recommendations, the ESRO Scientific Programme Board (SPB) decided in April 1974 that as many as thirteen missions should be studied at "mission definition" level, six of them foreseeing the utilisation of Spacelab.[22] All fields of space research were covered: infrared astronomy and planetary exploration, solar physics and astrometry, atmospheric studies and high energy astrophysics, ultra-violet astronomy and cosmic rays. This decision reflected the rather uncertain perspectives for space science in the following decade as well as the need to find a compromise between conflicting scientific and political options. On the one hand, the appeal of new space technologies such as reusable transportation systems, space laboratories, cryogenic telescopes for infrared astronomy, large optical telescopes, electric propulsion and so on, stimulated plans for ambitious large-scale projects. On the other hand, there were persisting uncertainties regarding such important matters as technical and financial feasibility, political approval, time schedules, ESA's new institutional framework, international legal arrangements and so on. Moreover, not all research fields required big science: medium-size satellites and proven technologies could be successfully used for atmospheric and magnetospheric studies or X- and gamma-ray astronomy. Many scientists would prefer to keep control over small, scientifically interesting projects rather than become entrapped in large, politically important ventures.

The results of the mission definition studies were discussed by the Working Groups and the LPAC in February 1975 and finally, following the latter's recommendations, the SPB selected five projects for feasibility (Phase A) studies, from which the final choice would eventually be made one year later. All of them required the Shuttle as the space transportation vehicle and three, in particular, foresaw the use of Spacelab. The two most important projects involved close co-operation with NASA, i.e. the Large Space Telescope (eventually renamed Hubble Space Telescope) and the Out-of-Ecliptic mission (OOE). In the former, ESA would provide one of the focal-plane instruments (the Faint Object Camera) and the solar array for the NASA-built telescope. The OOE mission consisted of the simultaneous launch of two spacecraft, one built in Europe and the other in the United States, into an escape orbit outside the ecliptic plane, for solar wind investigations and stereoscopic observation of the sun. Both Hubble and the OOE twin spacecraft were to be launched by the Shuttle.[23]

The three other projects were a Large Infrared Telescope (Lirts), an X-ray spectropolarimeter (Exspos), and a European contribution to the NASA programme for atmospheric, magnetospheric and plasma studies (AMPS). All of them involved extensive use of Spacelab; indeed they required many flights of the Shuttle-borne laboratory over several years in order to fulfil their scientific objectives. As to the Lirts (Figure 5), scientists stressed that a viable programme required one 7-day mission per year, four such missions being required to cover the

21 Russo (1993). On the basis of the LPAC's 1970 policy statement, the ISEE-2 and EXOSAT missions had been selected in spring 1973.

22 The SPB was the Council's delegate body for the scientific programme and comprised delegates from all Member States. After the creation of ESA, its functions were taken over by the Science Programme Committee (SPC).

23 A detailed historical account of the Hubble Space Telescope can be found in Smith (1989). For the origin of the OOE mission, see Hufbauer (1993).

whole celestial sphere. Should this condition not be fulfilled, they warned, a reconsideration of the project and of its desirability would be necessary. In the case of Exspos, it was also assumed that one flight per year represented a reasonable time scale, eight flights being required to cover all X-ray sources. Finally, the AMPS programme aimed at exploring the Earth's atmosphere and its plasma environment by the use of sophisticated instrumentation on Spacelab over a 5 to 10 year programme of flights. The European contribution would be a laser facility for active atmospheric sounding (Lidar) and a number of sub-satellites to be put into orbit from the Shuttle by special launching devices. In conclusion, whatever good scientific reasons existed for selecting these three projects for feasibility study, the choice was essentially based on highly optimistic expectations about the performance of the Shuttle/Spacelab system. Indeed, it was foreseen at that time that more than 20 NASA missions with European participation and 7 all-European missions would be performed in the period 1980 to 1985.[24]

In June 1976 the results of the feasibility studies were available and ESA's advisory committees and decision making bodies were finally called upon to select the projects to be adopted within the Agency's scientific programme. The uncertainty regarding Spacelab was now the main concern. Two questions were on the table. Firstly, the AMPS programme was under critical review within NASA and it looked as if European scientists would not gain admittance to it for some years (in fact, it was eventually abandoned). Consequently, AMPS could no longer be proposed as a realistic context for the lidar and the sub-satellites, which had now to be considered as independent projects within the framework of a possible fully-European programme of Spacelab missions. Secondly, some estimates of the operating costs of Spacelab projects were available (Table below) and the earlier optimism could no longer be justified. [25]

Summary table of financial aspects of major new projects (1977-1983)
(in MAU at mid-1976 price levels and 1977 exchange rates)

Project	Total cost	Remarks
Space Telescope	60.1	ESA contribution until 1983. Post-1983 costs estimated at ± 20 MAU.
OOE	71.0	ESA contribution until launch (1983).
LIRTS	40.3	Including launch and costs for a first 7-day mission. Following missions estimated at about 23 MAU.
EXSPOS	25.4	Including launch and costs for a first 7-day mission. Following missions estimated at about 11 MAU.

In the case of the Lirts, for example, the cost of a complete observation programme (four Spacelab missions) was estimated at about 109 MAU; as to Exspos, the cost of the required eight Spacelab missions was estimated at about 102 MAU. In addition, the Executive warned that a clear charging policy for the use of the Shuttle/Spacelab system had not yet been defined by NASA, and therefore the cost of re-flights was not under ESA's control and might be inaccurate by rather large amounts. These figures had to be compared with the estimated costs for ESA of

24 ESA, *Annual Report 1975*, p. 71. It is worth noting that this optimistic vision had driven ESRO's scientific advisory bodies to discard an infrared astronomy satellite (Cires) and a gamma-ray satellite (Logos) in favour of Lirts and Expos, in part because of their higher estimated cost compared with the competing Spacelab projects. By the end of 1975, the Executive recognized that this dependence on the Shuttle/Spacelab system was an undesirable situation and therefore, upon consultation with the scientific community, decided to study four Shuttle-independent contingency missions: Russo (1995), pp. 39-42 and 47.

25 ESA/SPC(76)33, 1/9/76.

the Space Telescope and the OOE projects, i.e. about 80 and 70 MAU, respectively. In this situation, it is hardly surprising that none of the Spacelab projects was eventually selected, in spite of the great interest many scientists had expressed for the infrared telescope. Following the recommendations of the Science Advisory Committee (SAC), in October 1976 the Science Programme Committee (SPC) definitively approved the European participation in the Space Telescope project and the European spacecraft in the OOE mission, later renamed the International Solar Polar Mission (ISPM). Spacelab thus left the main stream of ESA's scientific programme.[26] More precisely, one Spacelab project did remain under study as a candidate for the selection of new scientific missions scheduled for early 1980, namely a grazing-incidence X-ray solar telescope (GRIST), originally intended as the European contribution to an envisaged ESA/NASA four-telescope Spacelab payload for solar physics studies. Owing to the uncertainty of the NASA planning for a dedicated solar physics mission, GRIST had been discarded as a candidate for the 1976 selection but kept under study as a pure ESA project for the next selection. It was eventually abandoned in early 1979 because of the estimated high operational costs, and therefore all candidate projects for the 1980 selection were satellite missions, in particular the astrometry satellite *Hipparcos* and the cometary probe *Giotto* which were finally selected.

The first Spacelab mission

In parallel with the developments described above, ESA's scientific advisory bodies were discussing the experimental objectives of the first Spacelab flight. The primary goal of this mission was the verification of the performance of the Shuttle-borne laboratory and its subsystems in the framework of the Spacelab development programme, but half of the Spacelab resources would still be available for independent experimental activity. According to the Memorandum of Understanding, this part of the mission was to be jointly planned by ESA and NASA, each agency taking about half of the available resources for European and U.S. experiments, respectively. It was also contemplated that a European payload specialist would be on board. In this section we will review the first initiatives undertaken by ESA in order to define the European participation in the first Spacelab mission and to establish a suitable legal and financial framework to support it. In the following one, we will discuss the final definition of the European experiments in the first Spacelab payload.

The definition of a European model payload

Guidelines for the First Spacelab Payload (FSLP) were worked out by an ESRO/NASA Joint Planning Group (JPG) in April 1974 and eventually endorsed by the ESRO Director General and the NASA Administrator at their first annual review of the Spacelab programme on 20 May. The main elements were: (a) that the payload should be "complementary and consistent with future Spacelab missions," i.e. it should use as much as possible elements and techniques that could be used in future missions; and (b) that "the experiments should take advantage of the unique capability of Spacelab", in particular capitalising on "the capability of man to perform in the Spacelab environment".[27] The JPG also defined the technical constraints for the first Spacelab mission, the principal being:
the flight configuration would consist of a long pressurised module plus one platform for scientific instruments ("pallet");

- a a seven-day mission would be accomplished with up to 100 man-hours available for experiment operations;

26 Russo (1995), pp. 64-68.
27 ESRO/PB-S(74)27, 5/6/74, quotation from annex, p. 3. See also ESRO/C(74)45, 23/7/74; ESRO/JPPC(74)37, 12/11/74; and Lord (1987), pp. 121-127.

b a total mass of 3000 to 4000 kg and a power of 1.5 to 2.5 kW would be available for experiments, equally divided between European and American experiments;

c the instrument pointing system would not be available.

Following this agreement, the ESRO Executive circulated a "Call for Ideas" for the FSLP among the potential Spacelab user community in Europe, from which 241 replies were received. Most of them came from Germany (103 proposals), other main contributions coming from Britain (55 proposals) and France (42 proposals). About half of the proposed experiments concerned scientific disciplines still absent from European space activities, such as material sciences (80), life sciences (32) and earth resources surveys (35). Less than one quarter fell within the traditional fields of space research: atmospheric, magnetospheric and plasma physics (23); high energy astrophysics and cosmic rays (20); astronomy (10); solar physics (3). The others proposals concerned telecommunications (19), technology (15) and "others" (4).[28]

The proposals were thoroughly analysed by ESRO engineers and assessed in the light of the technical constraints of the first Spacelab flight. Various mission options were considered, divided into two different flight profiles: one earth-oriented, mainly devoted to atmospheric physics and remote sensing of earth resources; the other space-oriented, with priority given to astronomy, astrophysics and cosmic-ray observations. Experiments in material and life sciences, which did not require a particular orientation, were foreseen in both cases. These mission options were first discussed within the ESRO scientific advisory system and then presented at the JPG meeting of 5-6 November 1974, together with the parallel proposals coming from NASA. As a result of these discussions, it was agreed that priority should be given to an earth-oriented mission for two main reasons. Firstly, major astronomy instrumentation was particularly sensitive to contamination and the long-module configuration was not suited to providing a clean environment on the pallet; secondly, a mission with scientific objectives in the field of astronomy and astrophysics would benefit from the fine-pointing capability available in later flights.[29] This conclusion was endorsed by ESRO's Scientific Programme Board (SPB) and Spacelab Programme Board (SLPB), and finally approved by the Council's Joint Programmes and Policy Committee (JPPC).[30]

Following these preliminary discussions and decisions, a list of experimental objectives for the first Spacelab mission was recommended by the JPG and eventually approved by the Heads of the two space agencies at their meeting of 4 June 1975 (Appendix 1).[31] Subsequently, the ESRO Executive defined a model payload for the European complement of the FSLP (Appendix 2).[32] The basic elements in the scientific fields were the laser instrument for atmospheric studies that was discussed above (Lidar) and a sled facility for studying the

28 ESRO/JPPC(74)28, 20/9/74 (also attached to ESRO/PB-S(74)33, 7/10/74). The low number of proposals in astronomy and solar physics was essentially due to the fact that a pointing capability would not be available on the first mission.

29 ESRO/JPPC(74)37, 12/11/74. NASA plans are described in ESRO/JPPC(74)41, 19/11/74. The scientific aspects of the Executive's options were discussed by the AWG, SSWG and LSWG and by the LPAC; the technology and application objectives were discussed by the newly established Technology Advisory Group, Remote Sensing ad hoc Group, and Material Sciences Consulting Group. All advisory groups' recommendations are reported in ESRO/JPPC(74)37, annex 2, appendices 1 to 7.

30 SPB, 10th meeting (20/11/74), ESRO/PB-S/MIN/10, 20/1/75; SLPB, 17th meeting (25/11/74), ESRO/PB-SL/MIN/17, 14/1/75; JPPC, 10th meeting (27-28/11/74), ESRO/JPPC/MIN/17, 15/1/75. The complex procedure for arriving at the definition of the European complement for the first Spacelab payload is described in ESRO/JPPC(74)30, 9/10/74.

31 ESRO/JPPC(75)9, 20/3/75; ESA/FSLP(75)1, 28/7/75. By this time the European Space Agency had replaced ESRO. Director General Roy Gibson represented ESA while NASA was represented by its Adminitrator James Fletcher. The JPG formally dissolved after this meeting.

32 ESRO/FSLP(75)3, 18/4/75. Unless otherwise specified, the acronym FSLP will be used henceforth to represent the European complement for the first Spacelab payload.

behaviour of the vestibular system of astronauts under weightless conditions (Figures 6 and 7). Material science experiments were also well represented, particularly in the fields of electrophoretic separation, crystal growth, metallurgy and fluid physics. Finally, a significant fraction of the payload resources was allocated to earth observations by means of a metric camera and a microwave sensor. The Lidar was by far the most important instrument, requiring about half of the 1500 kg payload available to European experiments and accounting for a quarter of its cost. This was justified by the decision that the mission should be mainly devoted to atmospheric studies, as well as by the interest in testing the lidar facility in view of its possible use in the long-term AMPS programme. The main concern about the FSLP, however, was less the choice of its objectives and instrumentation than the question of funding, to which we now turn our attention.

The problem of funding

The legal arrangement between ESRO/ESA and the Member States participating in the Spacelab programme covered the development of the laboratory and the services needed during its first two flights, but it did not cover the experimental payload for the first mission, let alone subsequent ones. In principle, the participating states in the FSLP could be different from those participating in the Spacelab development programme itself. Moreover, the re-usability of Spacelab implied that some instrumentation could be flown on subsequent missions, with different participating states, not to mention the possibility of private or commercially-funded experiments. All this posed legal and institutional problems concerning funding, ownership and user rights which, according to the ESRO Executive, could only be solved by establishing a special (optional) FSLP programme, i.e. a specific arrangement between a group of participating states and ESRO. The Organisation itself could possibly contribute to the financing of the programme out of its general (mandatory) budget.[33]

When the issue was discussed in the JPPC, in November 1974, the idea of developing the FSLP as a special project was opposed by most smaller states (Belgium, Denmark, The Netherlands and Switzerland) as well as by the French and Italian delegations. Three main arguments were put forward. Firstly, a further reduction in the importance of the mandatory programme would result in less cohesion among Member States; secondly, participation in a new optional programme required parliamentary approval in some Member States, which would entail greater risk for such a programme than for one which was part of the Organisation's ongoing activities; finally, although developed as an optional programme, Spacelab was conceived as a general facility for the European space effort and its use should become more or less mandatory for all Member States in the 1980s (this was also the case of Ariane, the French insisted). Contrary to this position, the special project concept was supported for different reasons by the other delegations. Sweden did not participate in the Spacelab programme and therefore it could not accept the inclusion of the FSLP in ESRO's mandatory activities. Spain, which did participate in the Spacelab programme, made it clear that it had neither the financial resources nor the scientific interest to contribute to its first mission. The UK warned that the special project principle was "the only way in which Member States would retain the safeguards regarding the maximum payment they make to ESRO in one year." Finally, Germany was the strongest advocate of the special project and stated that its national authorities were in principle willing to finance up to 54 % of the FSLP cost, i.e. the same percentage as in the Spacelab programme itself. This offer, the German delegation stressed, "was not a bid for power, but was intended to ensure that the first Spacelab would not fly empty."[34]

33 ESRO/JPPC(74)40, 12/11/74; also attached to ESRO/PB-SL(74)14, 14/11/74.

34 JPPC, 10th meeting (27-28/11/74), ESRO/JPPC/MIN/10, 15/1/75, pp. 4-6. For the German position, see also ESRO/PB-SL(74)14, add. 1, 22/11/74.

Following this discussion, the Executive worked out, in spring 1975, a funding scheme for the FSLP based on the assumption that the various elements of the model payload described in Appendix 2 could be divided into two categories:

1 General experimental facilities and instrumentation of common interest, i.e.:
- the laser sounder (Lidar);
- the sled for vestibular studies;
- the metric camera;
- the microwave scatterometer;
- the material science equipment;

2 Specific instrumentation of interest only to the group proposing its inclusion and providing the experiment hardware, i.e.:
- passive atmospheric sounding instruments;
- astronomy experiments;
- human performance research support unit;
- cells and tissue research support unit;
- material science experiments;
- technology experiments.

The estimated total cost of the FSLP project was then broken down as in the following table:

General instrumentation		11.5 MAU
- pure science	*5.0 MAU*	
- earth observation	*2.2 MAU*	
- material science	*4.3 MAU*	
Specific instrumentation		4.3 MAU
- pure science	*2.5 MAU*	
- material science	*1.5 MAU*	
- technology	*0.3 MAU*	
Management and integration		5.8 MAU
Total		21.6 MAU

On this basis, the Executive proposed that the cost of the specific instrumentation should be covered by national funding, the ownership and utilisation rights of each item remaining with the funding institution. As regards the general instrumentation, it suggested that the scientific part (i.e. the Lidar and Sled) be supported by the Organisation's scientific programme while the various items of the non-scientific part should be developed either within the framework of a special project or by individual Member States, and delivered to ESRO/ESA under suitable conditions regarding their utilisation. The scientific programme would also cover a part of the management and integration cost proportional to the weight of the scientific part of the payload, thus bringing the share of the FSLP cost to be borne by the scientific budget to 7.4 MAU.[35]

The Executive's proposal was not endorsed, however, as France and Germany still had diverging opinions regarding the inclusion of part of the FSLP in the mandatory budget. The former, supported by Switzerland and Belgium, insisted that non-scientific elements should also be included in the mandatory budget. The latter, on the contrary, argued that only the astronomy experiments should be supported by the scientific programme; that the Lidar, the

35 ESRO/FSLP(75)3, 18/4/75. Following further consultations with national delegations, this document was rewritten as ESA/FSLP(75)3, 9/9/75.

Sled and the earth-observation instruments should be carried out as special projects; and that the material sciences instrumentation (which had an obvious application interest) should remain under national funding.[36] Pending a clarification of the political aspects of the FSLP funding, the Executive turned to the space science community in order to ascertain their reaction to the idea of funding the laser facility and the Sled for vestibular studies out of the scientific programme financial envelope. Not surprisingly the reaction was negative.

The scientists' concern

The desire of the Executive to have the principle of funding the two most important FSLP instruments out of the scientific budget approved as soon as possible derived from two main reasons. Firstly, it was necessary to give a firmer basis to the ESRO/NASA discussions about the European participation in the first Spacelab mission; secondly, the source of funding for the scientific facilities in the FSLP was an important aspect to be clarified in order to prepare the 1976 scientific programme budget. There were good arguments, in the Executive's opinion, for funding the Lidar and Sled out of the scientific budget. The former was already under study as a possible European contribution to the future AMPS missions, and therefore its inclusion in the FSLP was coherent with the Organisation's long-term scientific planning. The Lidar experiments "must essentially be considered as a purely scientific programme", the Executive argued. Moreover, "the Lidar is the only major scientific facility that could be developed on time by ESRO/ESA for the first Spacelab payload. Besides the Sled for vestibular studies, ESRO/ESA has no alternative plans for the scientific contribution to that payload."[37] As to the Sled, the newly created Life Sciences Working Group had strongly recommended this device, stressing the importance of vestibular studies for the comprehension of human performance in a zero-gravity environment. It was expected that a large number of life scientists on both sides of the Atlantic would benefit from such a device, designed to be flown on several Spacelab flights.

The LPAC could hardly accept the Executive's arguments, however. Three main reasons were put forward for its opposition. Firstly, both instruments resulted from an outside initiative, contrary to the established ESRO tradition of experiment proposals emerging from widespread discussions within the European space science community; they were not supported by a consensus publicly expressed by the interested scientists nor had preliminary technical studies yet been completed. Secondly, contrary to the Executive's argument, the fact that the Lidar was under study in the framework of the future AMPS programme spoke against any urgency to approve its inclusion in the FSLP. As we have explained in the previous section, the European participation in this programme was just one out of five candidate projects for adoption in the future scientific programme, and a decision was only expected in autumn 1976, after the completion of the Phase-A studies. An earlier positive recommendation on the inclusion of the Lidar in the FSLP would give AMPS undue advantage in the eventual competition. Finally, the LPAC could not accept that such a significant fraction of the management and integration costs should be charged to the scientific budget as they represented costs necessarily incurred in gaining experience in the use of Spacelab. As a matter of fact, the Committee was very sensitive to the budget issue, both because the programme suffered from the strictly enforced ceiling established at the time of the first package deal, and because the severe financial situation in the ESRO-ESA transition period was having dramatic effects on the development of ongoing projects, the most painful being a delay in the Exosat satellite, which risked jeopardising the very validity of this mission. Why the funds which it was proposed should be allocated to the FSLP could not be used instead to prevent such a delay, was the obvious

36 The Executive's proposal was discussed at the second meeting (7/5/75) of a First Spacelab Payload Working Group set up by the JPPC, ESRO/FSLP/MIN/2, 13/6/75. The German position is presented in ESRO/FSLP(75)3, add. 1, 6/5/75.

37 ESRO/PB-S(75)11, 16/5/75, p. 2.

argument raised by one of the LPAC members, the Italian physicist G. Pizzella. No answer to this question was reported.[38]

Notwithstanding these reservations, the LPAC grudgingly expressed the opinion that the Lidar and the Sled might be valid experiments for inclusion in the FSLP, but it also stressed that this judgement was not based on any kind of competitive assessment and did not imply a positive recommendation on their funding out of the scientific budget. "The LPAC did not have the elements to decide whether they should have priority over other ways in which the scientific programme money be spent", the chairman H. van de Hulst reported to the SPB. Here the divergence in opinion between France and Germany emerged again, the former endorsing the Executive's proposal and the latter opposing it. As a consequence, the Board was unable to take a decision and the question was put off indefinitely, pending a clarification of its scientific and political aspects.[39]

A few remarks are called for regarding these first debates on the utilisation of Spacelab. Firstly, the lack of provision for the FSLP was becoming critically important in determining the course of events for European users of Spacelab. Like the European satellite launcher developed by ESRO's sister organisation ELDO, Spacelab was conceived as a political object on the negotiating table for European space policy and a technical challenge for European space industry.[40] It was assumed that it would become the main facility for all space activities in the Shuttle era, but a utilisation policy was never really discussed. When it was, the conclusions were not encouraging. On the one hand, scientists involved in traditional space science disciplines did not like it and did not miss the opportunity to stress that manned spaceflight should not jeopardise automatic spacecraft in space research. They were hardly ready to accept that part of the meagre resources of ESA's science programme should be diverted towards Spacelab experiments without very good scientific motivations. On the other hand, the new Spacelab disciplines (e.g. life and material sciences) lacked a strong constituency in the established space science community and could hardly win support for their projects. Finally, regarding applications, the use of Spacelab could only make sense against the perspective of large space stations, a very uncertain future in the mid-1970s, indeed. It being there, it can be used, many said, offering proposals for instrumentation and experiments as well; but when the problem of funding came to the fore, governments were very reluctant to invest resources in Spacelab utilisation in addition to their normal contribution to the ESA budget, with the obvious exception of Germany and, in part, France. These two countries, however, had different visions of Spacelab. For Germany, by far the largest contributor to the programme, Spacelab was intended as a facility dedicated mainly to application fields with potential commercial implications, such as manufacturing and processing materials in microgravity conditions. With this perspective, the German authorities wanted to retain as much control as possible in the users' hands from the very first mission. They announced that Germany was developing the material science equipment for the FSLP and stressed that "the executing country in this case is the holder of the utilisation right and the owner".[41] France, on the contrary, saw Spacelab and Ariane as the two legs of the European space effort in the 1980s and wanted to bind ESA Member States to mandatory utilisation of both, in scientific as well as application fields. We shall see in the following sections how this ambiguity regarding Spacelab in the context of European space activities, as well as the escalating costs of the programme, would eventually lead to the failure to establish a sizeable Spacelab utilisation effort.

38 LPAC, 59th meeting (23/5/75), LPAC(75)7, 8/7/75.

39 SPB, 13th meeting (23/5/75), ESRO/PB-S/MIN/13, 19/6/75, p. 11.

40 ELDO stands for European Launcher Development Organization. On its origin see Krige & Russo (1994), ch. 3. More details in Krige (1993) and De Maria (1993).

41 ESRO/FSLP(75)3, add. 1, 6/5/75, p. 2.

The definition of the first Spacelab payload

On 15 April 1975, at the last ministerial meeting of the European Space Conference, in Brussels, the Convention of the European Space Agency was finally approved. The new Agency came into *de facto* operation on 31 May, pending the ratification process in its eleven Member States (Belgium, Denmark, France, Germany, Ireland, Italy, Netherlands, Spain, Sweden, Switzerland and United Kingdom).[42] In the new framework, responsibility for the Spacelab programme remained with the Spacelab Programme Board (SLPB), comprising delegates from all participating states. The organisation of the FSLP project was entrusted by the ESA Council to a Working Group (FSLPWG) including delegates from all Member States, chaired by the Dutch delegate in the SLPB, J. Flinterman. In July 1976, it was renamed the Spacelab Payloads Advisory Group (SPAG), its tasks being enlarged to cover all Spacelab missions. Finally, in March 1979, the SPAG itself was disbanded and its functions were taken over by the SLPB. All aspects related to the scientific part of the payload and any expenditure that might come from the scientific programme budget, however, had to be discussed and endorsed by the Science Programme Committee (SPC), the delegate body that had replaced ESRO's Scientific Programme Board. The role of the old-standing LPAC was taken over by the new Science Advisory Committee (SAC), whose membership was increased to six in order to include an expert in life sciences.[43] The definition of the FSLP experiments, together with the selection of future scientific projects discussed above, were the first important decisions to be taken within the new Agency's decision-making structure.

A new proposal for the FSLP project

In view of the ESA/NASA decision on the final payload for the first Spacelab mission, scheduled for mid-1976, the Executive prepared, in February that year, a new proposal for the FSLP project.[44] Having discarded the idea of an optional programme for the development of the payload or part of it, the proposal confirmed that the specific experiments should be supported by national funding and suggested the following arrangement for the financing of the general instrumentation and the management and integration activities:

a the development of the Lidar telescope and the Sled should be funded out of the scientific budget, at an estimated cost of 5 MAU and 1 MAU, respectively;

b the material science equipment should be developed within the framework of the Spacelab programme, after suitable extension of its legal arrangement, at an estimated cost of 5 MAU;

c the remote sensing instrumentation for earth observation should be supported by the (mandatory) general budget, at an estimated cost of 2.4 MAU

d the management and integration activities should be performed by a small ESA group, called Spacelab Payload Integration & Co-ordination in Europe (SPICE), to be located at the German Aerospace Research Establishment (DFVLR) in Porz-Wahn; their cost, estimated at 6.28 MAU, should also be charged to the general budget.

The FSLP Working Group had no objection against the principle that the Lidar telescope and the Sled should be funded out of the scientific programme financial envelope, and invited the

42 Ireland, the only state which was not a member of ESRO, joined ESA at the end of 1975. The Convention officially came into force on 30 October 1980.

43 ESA/C(75)52, 7/11/75 and ESA/PB-SL(75)8, 26/11/75, both annex to ESA/FSLP(75)5, 2/12/75.

44 ESA/FSLP(76)1, rev. 1, 13/2/76.

SPC to approve it.[45] The rest of the Executive's proposal was only partially accepted, however, both because most Member States opposed the idea of funding the non-scientific elements of the FSLP on a GNP-based contribution scale, and because Germany wanted to keep control of FSLP hardware development. In the event, the Working Group recommended that, "in order to avoid duplication of investment", the possibility be envisaged of having the remote sensing and material sciences general facilities developed by interested Member States under national funding and made available for common use during the first and subsequent Spacelab missions (in fact both facilities were provided by Germany, as we shall discuss below). The question of the financing of SPICE remained pending as most delegations thought that the management, integration and operational activities should be funded by the users, but no clear criteria could be identified for how this expenditure could be shared out in such a way. On a provisional basis, it was agreed that SPICE operations should be supported by the Spacelab programme, with the proviso that the latter would be reimbursed after a solution was worked out. The main question, however, remained whether the principle of financing the Lidar and the Sled from the scientific programme budget would be endorsed by the SAC and finally approved by the SPC. It was to these bodies that the Executive now presented its new proposal.[46]

The unhappy end of the Lidar

The two instruments were on a slightly different footing. The Sled, in fact, was much less expensive than the Lidar and it been recommended both by the Life Science Working Group and by outside experts. A general consensus existed within the European bio-medical community about the validity of the vestibular experiments foreseen on the Sled and of other physiological studies which could be performed using this device. The situation was much more controversial for the Lidar, as important scientific and political questions were involved in the discussions. The inclusion of a laser facility in the FSLP had in fact been used as a working hypothesis since the very beginning of Spacelab planning and this instrument represented the largest and most sophisticated technical device onboard the first mission, the main scientific objective of which, it should be remembered, was the study of atmospheric phenomena. The Lidar, as we know, was also designed for use in the framework of the envisaged ESA/NASA co-operation in the AMPS programme; indeed it was a means for European scientists to gain access to such a programme. The AMPS programme, however, had not been included as a "new start" in the NASA budget for fiscal year 1977 and the prospects of U.S.-European co-operation in atmospheric and magnetospheric research with Spacelab instrumentation were now very uncertain. The implication was that the use of the Lidar after the first (co-operative) mission would only be possible for European scientists on a reimbursable basis. This circumstance posed a major problem. The Lidar was, in fact, a facility-class instrument whose scientific potential could only be fully realised by several Spacelab flights over many years. Its development for inclusion in the FSLP then implied: (a) that the European space science community would be willing to support a long-term programme in atmospheric physics based on laser sounding, to the detriment of other scientific projects and experimental techniques; (b) that national funding would be provided for the supplementary equipment (i.e. lasers and detectors) necessary to operate the Lidar telescope; (c) that the costs of refurbishing and reflying the Lidar instruments would be acceptable; and (d) that NASA would hopefully be interested in co-operating with ESA in the future, so that better conditions for the use of the Shuttle/Spacelab system could be obtained. Against this background, both the SAC and the SPC could hardly be reassured about the future of the Lidar after the first Spacelab mission, nor did they have elements for making a scientific case for its use in a single seven-day mission. But they could not easily discard it either, for the Lidar took such a large

45 FSLPWG, 1st meeting (18/2/76), ESA/FSLP/MIN/1, 8/3/76. The resolution approved at the meeting, from which the following quotation comes, is in Annex II.
46 ESA/SPC(76)3, 10/2/76.

fraction of the resources allocated to European instruments that its exclusion from the FSLP could prevent Europe from maintaining its 50 % of the payload capacity.

The SAC was requested to discuss the Lidar issue at its first meeting, in February 1976 and, like the LPAC nine months earlier, it was very hesitant to state an opinion before the scientific potential of the instrument had been discussed within the community at large, and quantitative information on its performance became available. After "an extensive discussion", the Committee agreed at this stage to endorse the principle of financing the Lidar out of the scientific budget, but reserved the right to return to this question after the Solar System Working Group had made a scientific assessment of this instrument and the results of Phase-A studies were available. The SAC also recommended that, in addition to the Lidar experiments, complementary atmospheric physics experiments should be performed on the first Spacelab mission using passive instruments.[47]

No less embarrassing was the discussion in the SPC two weeks later. Introducing the subject, the ESA Director of Planning and Future Programmes, A. Lebeau, "expressed regret that alternative solutions for the constitution of the first payload could no longer be proposed" and pointed out that, "in view of the uncertainties that subsisted in respect of the scientific merits and the cost of the Lidar", the decision the SPC was invited to take was "merely one of principle", a formal decision being requested only after the completion of Phase-A studies. Lacking alternatives, most delegations were prepared to endorse the Executive's proposal, but all expressed reservations about the unusual procedure, and concern about the impact of the Lidar financing on the future development of the scientific programme. The Dutch delegation, of which H. van de Hulst was an influential member, noted that there was "no evidence supporting the [Executive's] statement that the Lidar met with great scientific interest on the part of several delegations" and then brought up the sore point:

> *On the subject of scientific instrumentation for Spacelab generally, the delegation felt that more should be done to honour the earlier claim of rapid access with cheap experiments. It asked in what time a 'general facility' would become obsolete and how this time compared with a satellite life time.*[48]

In the event, the SPC agreed that financing of the FSLP Lidar out of the scientific budget was "not precluded", but it requested the Executive to issue a preliminary call for experiment proposals on the FSLP in order to have better information about the interest and intentions of the European space science community.[49]

In the following months, the Lidar could no longer escape from a thorough scientific assessment. The Solar System Working Group discussed the matter at length at its 27 April meeting, in which all SAC members participated (with the exception of the biology expert H.S. Wolff) together with three invited experts. In its final resolution, the SSWG recognised that "valuable new scientific results could be obtained through the use of the Lidar on the first Spacelab flight and that the long-term potential of the observations justified the interest in this facility". Two important qualifications were added, however. Firstly, that the inclusion of the Lidar in the FSLP should not prevent the inclusion of passive instruments for complementary atmospheric experiments. Secondly, that "future development and re-flight of the Lidar [should] be considered in the same way as other competitive projects".[50]

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47 SAC, 1st meeting (24/2/76), SAC(76)4, 7/4/76. The final resolution is reported in SAC(76)5, 3/3/76.
48 SPC, 3rd meeting (11/3/76), ESA/SPC/MIN/3, 13/4/76, p. 6 and add. 2, 18/6/76.
49 ESA/SPC/III/Res. 1, 9/4/76, attached to ESA/SPC/MIN/3, cit.
50 SSWG, 18th meeting (27-28/4/76), SOL(76)8, 2/7/76. The final resolution is reported in SOL(76)7, 29/4/76.

The SSWG recommendation was endorsed the following day by the SAC, but the discomfort of its members was again quite evident. The claim that valuable new scientific results could be obtained from the use of the Lidar on the first Spacelab mission was explicitly contested by some members and doubts were expressed regarding its scientific capability compared with other techniques. Moreover, it was pointed out that very little information existed about the costs to be borne by experimenters for building the lasers and detectors and for eventual re-flights of the instrument. The conclusion is a wonderful example of ambiguity, wishful thinking and powerlessness: contrary to the SSWG's opinion the SAC stated that the first flight of the Lidar would not yield a high scientific return but accepted that it be supported by the scientific budget in consideration of the possibility that the "ratio of scientific output to 'scientific' costs would increase in future flights". In fact, no one knew whether future flights would ever occur or who would pay for them.[51]

By early July, when the SSWG and the SAC were called to issue their final recommendation to the SPC, the situation had changed dramatically, as three new elements had come to the fore. Firstly, the development cost of the Lidar was now estimated at 8.4 MAU, i.e. much higher than previous estimates. Were it adopted in the scientific programme, then no additional activities could begin in 1977 and very few in 1978. Moreover, lacking definite information from NASA about the charging policy for the use of the Shuttle/Spacelab system, the cost of later flights was still unpredictable and only a tentative 1.4 to 2.7 MAU range was given by the Executive.[52] Secondly, the response to the preliminary call for experiment proposals for the FSLP showed that the Lidar hardly met with great scientific interest on the part of the European space science community. Only fifteen proposals out of 74 concerned the Lidar, some of them related not to atmospheric research but rather to geodetic and oceanographic measurements. Moreover, of all the experiments proposed in atmospheric physics, two thirds required passive techniques rather than active laser sounding.[53] Finally, the scientific case for the Lidar had been discussed *vis-à-vis* other research fields and experimental techniques at a scientific symposium, and it was clear that the majority of European space scientists did not like such a large fraction of the FSLP resources being taken by the Lidar.

On the basis of this new information, the political importance of the Lidar (i.e. the fact that it had been studied from the very beginning of the Spacelab programme and it was the main European instrument on the first Spacelab mission) could no longer counterbalance its poor scientific merit. The SSWG reversed its April decision, stating that "the scientific return [from the FSLP] would be greater from a passive sounding package than from the Lidar".[54] Within the SAC, only Giuseppe Colombo kept supporting the Lidar, and even though a formal recommendation was not voted the Chairman's final statement was unequivocal:

> *In previous meetings, the SAC had assessed the Lidar outside of a competitive framework. The Committee now had more information about the other opportunities that could be provided on Spacelab and [...] about the kind of science that could be done on the FSLP. From this [...] the Lidar seemed to have a more negative position than it had at the last meeting when the SAC had recommended the funding of the Lidar for the FSLP from the mandatory scientific programme budget.*[55]

51 SAC, 2nd meeting (28/4/76), SAC(76)8, 4/6/76, p. 6.
52 ESA/SPC(76)17, add. 1, 16/7/76.
53 ESA/SPC(76)16, 13/5/76.
54 SSWG, 19th meeting (1/7/76), SOL(76)14, 15/9/76, p. 3.
55 SAC, 3rd meeting (2/7/76), SAC(76)11, p. 6. About Colombo's dissenting opinion about the SAC policy, see Russo (1995), 60-64.

The final decision was up to the Science Programme Committee. Here, the Italian delegation was particularly resolute in defending the Lidar, "which represented Italy's only possibility of being present on the first Spacelab payload", and it warned that the Italian parliament might not ratify the ESA Convention if the country were to be excluded from a programme to which Italy was contributing 18 % of the budget (Italy's contribution to the Spacelab budget according to the 1973 "package deal"). The delegation insisted that, besides atmospheric research, "the Lidar would have great potential for many disciplines such as oceanography, geography and geodesy", and argued that "with a reasonable design it would be possible to include both the Lidar and the passive sounding-experiments".[56] These arguments did not convince the other delegations, however, and the Italians remained isolated with their ultimatum. Only the French delegation supported the inclusion of the Lidar in the FSLP, but in a much less sanguine way than the Italians, as it acknowledged that the scientific value of this facility could only be guaranteed over a ten-year period of flights. A similar position was held by Germany, which was less concerned about the inclusion of the Lidar in the FSLP than in keeping this facility under study in view of its eventual use in the long-term Spacelab flight programme. The British scientific community, on the contrary, was convinced that passive sounding experiments, possibly mounted on a stabilised platform, would provide more interesting results than active laser sounding for atmospheric studies.[57] Finally, the smaller Member States did not have strong feelings for or against the Lidar, but all expressed a concern that its funding out of the scientific budget could impair the other projects under study. In the event, by a controversial majority vote, the SPC decided against the inclusion of the Lidar in the FSLP, but agreed that a Phase-B study should be carried out in view of the possibility of it being flown on a subsequent flight.[58]

Following this decision, a Lidar Facility Team was set up by ESA to review the Phase-A study from two standpoints: (i) the re-assessment of the Lidar facility for atmospheric studies in the light of new technical developments, and (ii) the possible use of this facility in other disciplines, such as geodesy, geodynamics and oceanography.[59] On the basis of the Team's conclusions, a Phase-B study started with MATRA in June 1978 and was completed one year later. Two different missions were considered, with development costs estimated at approximately 18.4 MAU, not including the procurement of the laser devices.[60] The results of the study were given to the newly created Earth-Oriented Research Group to consider possible applications in the framework of the ESA Earth Observation Programme. In the event, the programme concentrated on the challenging ERS satellite project, and the Lidar disappeared.

The controversial approval of the Sled

The approval of the Sled for vestibular studies on the FSLP did not present as many problems as the Lidar. The cost was not very high and the facility enjoyed strong support from the interested scientific community. The main problem was the question of the eventual inclusion of life sciences in the ESA's scientific programme, which put further strain on the programme's

56 SPC, 5th meeting (30/7/76), ESA/SPC/MIN/5, 30/8/76, p. 8.

57 ESA/SPC(76)31, 22/7/76. A study on an integrated set of various passive instruments for atmospheric research in the FSLP was being performed under ESA contract by the Science Research Council at its Appleton Laboratory, Slough.

58 Belgium, Denmark, Spain, Sweden, Switzerland and the U.K. voted against the Lidar in the FSLP. Denmark, France, Germany, Italy, Sweden, Switzerland and the U.K. voted for a feasibility study. It should be mentioned that the SPC recommended a Phase-A study on a simple stabilized platform for passive sounding experiments, as advocated by the British delegation. When completed, the study showed that this coarse pointing system would be much more expensive (about 8 MAU) than expected, the time schedule for its development would be extremely tight, and not many of the proposed experiments would really need it (ESA/SPC(76), 6/12/76). On this basis, the SSWG and the SAC did not recommend its inclusion in the FSLP and the SPC eventually cancelled it.

59 ESA/SPC(78)3, 12/4/78.

60 SPC, 21st meeting, ESA/SPC/MIN/21, 25/10/79, p. 8.

budget. Pending a revision of the whole budgetary question, the SAC recommended that the Sled be flown on the FSLP in the framework of the scientific programme. The final SPC decision was more controversial, however, both because the estimated development cost of the Sled had increased to 1.8 MAU and for the stress the Lidar question had caused among SPC delegations. In fact, only five delegations voted in favour (France, Germany, Netherlands, Sweden and Switzerland), the others abstaining.[61]

After the Lidar had definitively been discarded, the 150-kg Sled (Figure 7) remained the only experimental facility on the FSLP supported by the scientific programme budget. The design and development programme was initiated with the German company ERNO in September 1977. At the end of the design phase, however, it became evident that the programme could not be realised within the original constraints of cost, mass and schedule. To the dismay of the Executive, in October 1978 ERNO submitted a revised proposal for the development of the Sled, from which emerged:

- a a cost increase of nearly 300 % compared to the baseline price (5.8 MAU at 1977 price level);
- b a design exceeding by about 35 kg the mass allocated to the Sled on the FSLP;
- c a delivery date showing an incompatibility of 6 months with the FSLP schedule;
- d reservations on compliance with the FSLP interface requirements which might result in a further cost increase.[62]

A rather nervous discussion in the SPC followed, in which "several delegations expressed disquiet at the general cost increases in the Spacelab experiments, which augured badly for future Spacelab utilisation".[63] ERNO was then instructed to stop work on the contract and a meeting was called between the Executive, the Sled Science Team and some members of the Life Sciences Working Group in order to investigate ways and means of salvaging the project. As a result, a significant relaxation of the initial specifications was agreed and a new Sled concept proposed which could be developed in-house, at a lower cost and within a tight schedule. The increase in the estimated cost-to-completion was relatively limited in absolute terms, additional resources being requested to the amount of 2.7 MAU.

The SAC endorsed the new plan, as it considered that cancellation of the Sled would endanger the future of European biomedical research in space, a field which would presumably benefit most from the use of Spacelab in the future. The Committee refrained from discussing the budgetary implications of the continuation of the Sled programme as this was a political matter for the SPC, but it stated clearly that "the scientists should not be penalised for cost increases for which they were not responsible and therefore new funds had to be provided by Member States in order to keep the Sled programme alive".[64] When the matter came to be discussed in the SPC, however, most delegations were firmly opposed to any increase in the Sled budget. The SPC then reserved the right to take a decision only after the Executive had investigated the possibility of cancelling the Sled and carrying out alternative biomedical experiments on the FSLP with the money still available in the Sled budget. Pending a final decision among the various options - agree to the Sled budget increase, use the available resources to carry out

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61 SPC, 5th meeting (30/7/76), ESA/SPC/MIN/5, 30/8/76. A favourable recommendation was expressed by the SAC at its first meeting (24/2/76), SAC(76)5, 3/3/76, and confirmed at the following two meetings. The new estimated cost of the sled is in ESA/SPC(76)17, add. 1, 16/7/76.

62 ESA/SPC(78)33, 8/11/78.

63 SPC, 17th meeting (14/11/78), ESA/SPC/MIN/17, 5/12/78, p. 7; ESA/SPC(79)3, 22/1/79. The French delegation noted that the French experiments on the FSLP were experiencing overruns of 200 and 300 %. See also Steinz (1980).

64 SAC, 16th meeting (22-23/1/79), SAC(79)4, 9/3/79, p. 9.

some biology experiments without the Sled, or eliminate the life sciences activities altogether and divert the remaining funds to other programmes - it was made clear "that the possibilities of obtaining the additional 2.7 MAU for Sled were extremely slight".[65]

In this situation, the European life science community took a strong line in order to salvage its first chance to enter space research. The Sled Science Team stated that "the cancellation of Sled would be viewed as a major disaster by the life science community, both in scientific and political terms". The LSWG, for its part, argued that "the abandonment of Sled [...] would be regarded as a breach of faith by ESA, which by offering experiment opportunities on Sled had caused teams in a number of member countries to expend considerable time, laboratory resources and money on the construction of experiments which are heavily dependent on Sled".[66] In a letter to the ESA Director General, the principal investigator of the Sled Vestibular Experiment, the German physiologist R. von Baumgarten, recalled that ESA had made firm statements to the European scientists and to NASA that the Sled would be built: "Relying on this, the European and American experimenters devoted several years of highly qualified manpower to the preparation of the Sled experiments and spent millions in the belief that ESA would make this facility available".[67] NASA also added its arguments in a letter from the director of its life science programmes, G.A. Soffen, to the chairman of the LSWG: "NASA and our scientific advisors consider vestibular experimentation as number one in priority for both scientific and operational reasons", Soffen wrote, "thus we feel strongly that ESA should continue to honour their commitment to develop the Sled facility for [the first Spacelab mission]". He went on to remind the European space policy makers of the commitments the USA and Canada had made to the Sled programme after the NASA Administrator and the ESA Director General had formally agreed that the first Spacelab mission would include in-flight vestibular experiments with a Sled facility provided by ESA: one million dollars already expended on experiment hardware development, including three ground-based Sled simulators; two years of dedicated work from qualified technical manpower; and a long-term research programme on the space-motion-sickness problem, for which the Sled experiments on the first Spacelab flight represented the first step.[68] Finally, the SAC advised that "failure to grant the 2.7 MAU would cause an amount of damage quite disproportionate to the sum involved", but warned that a decision to continue the Sled within the established financial envelope for the scientific programme "will reflect itself in a reduction of science plans in other areas".[69]

The pressure on the SPC to approve the new Sled plan was strong indeed, and the meeting at which the decision was to be taken was attended by the chairmen of the SAC and the LSWG, and by the NASA representative in Europe. Most delegations felt a moral obligation towards the scientists involved in the Sled experiments, but all were adamantly against any increase in the scientific programme budget. Approving the higher cost of Sled within the limits of the financial envelope of the scientific programme, however, implied coping with an important over-run in the 1980 budget (about 7 % of the total budget), with the risk of jeopardising other parts of the scientific programme. The plain truth was that the inclusion of life sciences in the scientific programme would either be at the expense of classical disciplines, which the established space science community could hardly accept, or implied an increase in the mandatory budget, which member state governments were not willing at all to comply with. In the event, the moral obligations prevailed and the addition of 2.7 MAU to the Sled budget was

65 SPC, 18th meeting (23-24/1/79), ESA/SPC/MIN/18, 22/2/79, p. 9.

66 The quotations are, respectively, from LIFE(79)5, 21/2/79 and LIFE(79)4, 21/2/79, both attached to ESA/SPC(79)8, 28/2/79.

67 ESA/SPC(79)8, add. 1, 19/3/79, annex 1.

68 ESA/SPC(79)8, add. 1, 19/3/79, annex 2.

69 SAC, 17th meeting (16/3/79), SAC(79)10, 3/5/79, annex 1. Also in ESA/SPC(79)8, add. 2.

finally approved, with Germany, Italy and the United Kingdom voting against.[70] However, this was not the end of the Sled story, as we shall see in a moment.

The final definition of the FSLP ... and the Sled slips out

Besides the Sled, the most important facility in the FSLP was a 500-kg double rack for material science instrumentation, including several types of heating furnaces, a fluid physics module and other equipment for about 40 space-processing experiments. Following its proposal for the FSLP project, the Executive argued that these instruments should be considered as "the first elements of a material science equipment pool, which could be extended for later missions", and suggested that the Agency be responsible for the management, development and integration of the material science package, or at least of its major part.[71] This approach, however, was not accepted by Germany, which was developing a strong effort in the material science field (an all-German Spacelab mission dedicated to material science experiments was already being prepared) and wanted to maintain direct control over this part of the payload.[72] Germany offered to develop, integrate and test the whole of the material science package, and to deliver it to ESA for inclusion in the FSLP, with the proviso that it remained the property of the Bundesministerium für Forschung und Technologie and the latter retained the right of disposal for the package itself for later missions. This solution was eventually approved by the FSLP Working Group, but the problem remained of defining suitable rules for the use of these and other instruments provided by national agencies from individual experimenters.[73]

This was the object of long and complex discussions, the main actors being the Executive and the German delegation in the SPAG.[74] The former wanted to establish a general legal framework governing access to and use of a European instrument pool for the first and subsequent Spacelab missions; in other words, it considered the FSLP as a basis for a medium-term policy for Spacelab utilisation under the aegis of ESA. Germany, on the contrary, insisted that the instruments intended for the first flight should remain the property of the countries that had supported their development, and that the arrangement for the FSLP should not set a precedent for any future policy for Spacelab use; in other words it considered that the Shuttle-borne laboratory would mainly be used by national agencies or industrial companies for commercially valuable experimental activity. In the event, the German view prevailed. Following a meeting between the Executive and the German delegation, the latter drafted its own text on the rules concerning the general instrumentation on the first Spacelab mission and insisted that this be taken as a basis for discussion instead of the text proposed by the Executive. It was eventually approved by the SPAG in January 1977.[75]

At the same meeting, the SPAG approved the final composition of the FSLP, which was eventually endorsed two weeks later by the ESA Council.[76] Besides the Sled for vestibular

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70 SPC, 19th meeting (22-23/3/79, ESA/SPC/MIN/19, 26/4/79.

71 ESA/FSLP(76)5, 16/3/76, p. 1; ESA/FSLP(76)7, 16/3/76.

72 FSLPWG, 2nd meeting (31/3/76), ESA/FSLP/MIN/2, 4/5/76.

73 ESA/FSLP(76)10, 11/6/76; FSLPWG, 3rd meeting (24/6/76), ESA/FSLP/MIN/3, 3/8/76. It was foreseen that Germany would integrate into the material science double rack two gradient furnaces procured from France and the fluid physics module procured from Italy.

74 The evolution of these discussions is reported in the series of documents ESA/SPAG(76)8, 24/8/76, with revisions 1 to 5. The rules under discussion regarded in general all Spacelab instrumentation, but in fact the main questions were related to the material science package.

75 SPAG, 3rd meeting (11/1/76), ESA/SPAG/MIN/3, 8/2/77. The German text is ESA/SPAG(76)8, rev. 4, 3/1/77; the Executive's is ESA/SPAG(76)8, rev. 3, 29/11/76. The final text, essentially identical to the German one, is ESA/SPAG(76)8, rev. 5, 14/2/77.

76 Council, 14th meeting (28/1/77), ESA/C/MIN/14, 17/2/77. The complete payload as approved at this stage is described in ESA/SPAG(76)22, 28/12/76, complemented by the guidelines given by the SPAG in ESA/SPAG(77)2, 12/1/77. Both of these documents were submitted to the Council under the cover ESA/C(77)8, 12/1/77.

studies and the material science double rack, it included a 155-kg metric camera and a 166-kg microwave sensor for earth observations, both provided by the German Aerospace Research Establishment (DFVLR), and about twenty nationally funded experiments in astronomy and solar physics, atmospheric and plasma physics, and life sciences. The most important instruments were a 137-kg grille spectrometer for atmospheric research, jointly provided by the Institut d'Aéronomie Spatiale de Belgique and the French Office National d'Etudes et de Recherches Aéronautiques (ONERA), and a 100-kg very-wide-field camera for astronomy observations provided by the Laboratoire d'Astronomie Spatiale in Marseilles, France. All of these facilities and experiments were complemented by approximately equivalent NASA equipment, whose main elements were two large instruments for active plasma-physics experiments (including a 400- kg electron gun provided by the University of Tokyo), a complex spectrometer for atmospheric studies and a *minilab* for life science experiments.[77]

The Sled had remained the only FSLP hardware supported by ESA. This facility, however, did not survive the dramatic crisis originated by the stricter weight constraints imposed by NASA at the beginning of 1980. On 14 January that year the ESA Director General received a formal request from the NASA Administrator to reduce the European portion of the FSLP to the original mass allocation of 1392 kg, along with a parallel effort by NASA. "Our current assessment of the Shuttle performance indicates that we must continue to assume that the original payload allocations will not be increased", the head of the American space agency wrote, "consequently, we must jointly agree to take the necessary steps to assure that the ESA and NASA complement of investigations do not exceed the original commitments when they are delivered for [final] integration".[78] He added that NASA would guarantee a free flight on subsequent missions with equivalent characteristics of the instruments that had to be removed from the FSLP because of the imposed weight constraints.

The mass estimate for the European portion of the FSLP exceeded the prescribed allocation by 122 kg but, considering a requested mass margin to cover the later payload increase, the necessary mass saving amounted to about 220 kg.[79] The Executive then elaborated a set of criteria and procedures for "de-scoping" the FSLP by removing experiments and/or facilities from the payload. Four options were identified, each of which foresaw the removal of one or two heavy experiments:

a the metric camera plus the very wide field camera (VWFC);

b the Sled and its experiments;

c the microwave remote sensing experiment plus the VWFC;

d the grille spectrometer plus the VWFC.

In all cases, the de-scoped experiments would be flown on subsequent Spacelab missions planned by NASA, over a period of time ranging from 11 months for the grille spectrometer to 29 months for the Sled.

On the basis of its analysis of the scientific aspects of the various options, and taking into account the NASA position, the Executive recommended that option 4 be selected, namely the

77 Shapland & Rycroft (1984), pp. 181-187, and Lord (1986), pp. 347-349.
78 ESA/SAC(80)6, 31/1/80, annex.
79 ESA/SAC(80)6, 31/1/80.

transfer of the grille spectrometer and the VWFC to later flights.[80] The main reasons for this recommendation can be grouped into three main categories:

a Both the metric camera or the microwave experiment (options 1 and 3) were general facilities with a pioneering character in the new field of earth-oriented research; a wide interest in this kind of investigation had been demonstrated by the response to the call for experiment proposals, 103 of which had been accepted for the metric camera and 45 for the microwave experiment; finally, both instruments were being developed by DFVLR, by far the main player in all Spacelab matters.

b The Sled (option 2) could not be accommodated on the first NASA mission devoted to life sciences (SL-4) for technical reasons, and therefore it could only be flown on the subsequent life science mission (SL-10), with a launch delay of about 2.5 years; such a long postponement was unacceptable for the experimenters' team; NASA attached highest priority to the Sled, due both to the importance of vestibular studies for the man-in-space programme and because half of the Sled experiments were from U.S. and Canadian scientists, and it insisted that this facility should remain in the FSLP.

c NASA had offered the earliest possible flight opportunity (SL-3) for the grille spectrometer, less than one year after the first mission, with a technical arrangement which promised a probably larger scientific return; two flight opportunities were offered for the VWFC, on SL-4 or SL-5, which implied a relatively short launch delay (16 to 18 months) and an undiminished scientific return.

The Executive's position aimed at keeping all of the major experimental facilities in the FSLP, in particular the one supported by ESA. It was hardly a surprise, when the matter came to be discussed in the SPC, that the French and Belgian delegations (the latter being represented by the principal investigator of the grille spectrometer, M. Ackerman) "protested very strongly" against the Executive's proposal and invited the Committee to reject it. "By de-scoping [the grille spectrometer experiment] one of the main scientific objectives of FSLP would be deleted", the Belgian delegation argued, stating that if this instrument were to be accommodated on the SL-3 mission, "it would lose much of its value since it would be flown together with a similar United States experiment". The French warned that "if either the grille spectrometer or the very wide focal [sic] camera were to be de-scoped, France would probably have to abandon those experiments completely".[81]

Notwithstanding these positions, the SPC finally decided (with France and Belgium voting against, and Switzerland abstaining) to recommend that the Spacelab Programme Board accept to retain the Sled on the FSLP and to transfer the grille spectrometer and the VWFC to later flights. The Board did not concur, however. In a very strong written statement circulated at the meeting, the French delegation warned that the consequences of holding back the two major French and Belgian experiments "are not of a minor nature":

> *It would be an illusion to imagine that such a measure specifically affecting those investigators who have most directly invested in the scientific use of Spacelab and mutilating the results expected from half the human and financial investment by the French scientific community, should be without impact on the subsequent participation that may be expected from the same community. The catastrophic situation that would be brought about for France by the adoption of option 4*

80 ESA/PB-SL(80)4., 25/2/80. The Executive's proposal was endorsed by the majority of the SAC members, after consultations during a teleconference on 28/2/80: cf. ESA/SPC(80)8, 26/2/80 and ESA/PB-SL(80)4, add. 1, 3/3/80.

81 SPC, 23rd meeting (4-5/3/80), ESA/SPC/MIN/23, 3/4/80, pp. 10-11.

proposed by the Executive could not be without consequence to its future use of Spacelab under the auspices of the European Space Agency.[82]

After a nervous discussion and two divisive votes, the Board finally decided to remove the Sled from the FSLP, four delegations voting in favour (Belgium, Denmark, France and Netherlands), two against (Germany and U.K.) and four abstaining (Austria, Italy, Spain and Switzerland).[83] ESA's scientific programme was thus definitely excluded from the first Spacelab mission and no ESA experimental facility was onboard the laboratory on its maiden flight. In a sense, the Sled was sacrificed just because, being an ESA facility, Member States would not be as embarrassed by its removal from the payload as in the case of national facilities or experiments. It was an essentially political decision which caused much frustration among the many life scientists from ten scientific institutes and universities in France, Germany, Canada and the United States who were preparing the vestibular experiments to be performed with the Sled. Their hopes now rested on the possibility of having a new flight opportunity as early as possible.

A later mission for the Sled

Following the SLPB decision, NASA offered to include the Sled on its dedicated life science mission SL-4 (scheduled for May 1984) and to take over all responsibility for the experiments as well, including integration activities; Germany, for its part, insisted that the Sled be accommodated on the German D-1 mission (scheduled for August 1984), in order to maintain the European character of this facility. The NASA option was less expensive by far, the two options requiring additional expenditure of 1 MAU and 3.6 MAU for the American and German solutions, respectively, but, as the Executive put it, "accepting that all integration activities of European experiments and co-ordination with European experimenters be done in the USA would mean, in practice, abandoning all future Sled use for European purposes and make the European development of the Sled meaningless".[84] The scientists in the Sled Science Team and the Life Science Working Group, on the contrary, recommended that the American offer should be accepted, both for the shorter delay in the flight schedule and because SL-4 was a dedicated life science mission, while D-1 would mainly be devoted to material science experiments. Opinions were much divided among national delegations in the SLPB: Austria, Belgium, Italy and the U.K. favoured the SL-4 option; Denmark, Germany and Spain expressed their preference for the D-1 mission; France advocated SL-4, but felt that the German proposal should not ruled out and hoped that, "the Programme Board would, in a spirit of solidarity, decide that Sled should fly on D-1 if this were at all possible".[85]

In the event, it was agreed that a decision should be unanimously taken by the participants in the FSLP project in December 1980. The choice implied political as well as scientific and financial considerations. On the one hand, by offering to fly the Sled free of charge on the next available flight, NASA considered that it had fulfilled its obligations after the off-loading from the first mission, and it refrained from making any explicit statement about the possibility of a free flight for the Sled on a subsequent NASA mission in case ESA decided to fly this device on D-1. The German offer, on the other hand, was very generous as it foresaw that all flight and mission costs, including payload integration, transportation to the USA and back, launch and payload operations, would be borne by Germany in order to keep the ESA costs as low as

82 ESA/PB-SL(80)4, add. 3, 11/3/80, p. 3.

83 SLPB, 30th meeting, part I (12/3/80), ESA/PB-SL/MIN/30/I, 26/3/80.

84 ESA/PB-SL(80)28, 1/9/80, p. 2.

85 PBSL, 32nd meeting (17-18/9/80), ESA/PB-SL/MIN/32, 23/10/80, p. 10. The possibility was also contemplated of flying the Sled on both SL-4 and D-1, but it had to be discarded because only one flight unit was available and the scheduled time separation between the two mission was not sufficient for refurbishment.

possible. The German authorities underlined the "European" character of the D-1 mission, in fact the only foreseeable European mission after the failure to reach an agreement on a co-operative Spacelab utilisation programme (as discussed in the following section). The D-1 payload would include the material science equipment developed for the FSLP (with facilities provided by France and Italy), and scientists from other European countries were invited to participate in the experimental activities. Moreover, Germany had offered a flight opportunity on D-1 for the envisaged ESA-developed Biorack facility for life science experiments.[86]

At the December meeting of the SLPB, unanimous agreement could not be reached, despite the impassioned arguments put forward by the German delegation in favour of "the first truly European Spacelab flight". Austria, Belgium, Italy and U.K. persisted in supporting SL-4, which was also preferred by the Netherlands. Denmark, France, Germany, Spain and Switzerland, on the other hand, advocated D-1. As a consequence, the matter had to be deferred to the Council meeting scheduled for a few days later.[87] Here the stalemate was finally overcome in a spirit of European solidarity. The German and French pressure for an important European use of Spacelab prevailed over the economic and scientific arguments of the two other major Member States (Italy and the UK) and of the interested scientific community. In fact, after receiving formal assurance that 3.6 MAU was a realistic estimate for flying the Sled on D-1, all delegations declared their willingness to join in a unanimous vote in favour of this solution.[88] With hindsight, it was a good decision from the scientists' viewpoint also. In fact, NASA's first life science mission had to be postponed and, at the time of the launch of the first Spacelab mission, it was scheduled for January 1986, i.e. two months after D-1. Owing to the Challenger accident, it was eventually launched on 5 June 1991, almost six years after the Sled had successfully flown on the German Spacelab mission.[89]

The Spacelab Utilisation Programme and the funding of the FSLP

When the first Spacelab mission was finally launched, on 28 November 1983, it was already evident that no dedicated ESA missions would be flown in the foreseeable future. The German D-1 mission, scheduled for autumn 1985, was at that time the only firm flight opportunity for ESA-developed instruments, i.e. the Sled and the Biorack, a multi-user facility for studying the effects of microgravity and cosmic radiation on living organisms developed within the newly established ESA Microgravity Programme. For the longer term, a re-flight of the Biorack facility was foreseen on the joint ESA/NASA International Microgravity Laboratory (IML-1), in May 1987. As we shall see in this section, all initiatives by the ESA Executive to define long-term plans for Spacelab utilisation were frustrated by the concurrence of two main difficulties. Firstly, as was to be expected, there was the problem of funding. NASA's charging policy for the use of the Spacelab/Shuttle system did not in fact consider any preferential treatment for European missions and therefore, facing the escalating costs of the Spacelab programme, Member State governments became more and more reluctant to commit further resources for Spacelab utilisation. Secondly, there was the relationship between the envisaged ESA Spacelab utilisation programme and the very important German activity in this field. Germany, in fact, wished to benefit as much as possible from the project in which it had invested so much, and wanted to keep control over European Spacelab missions whether they carried the ESA flag or that of the German Federal Republic. It is against this background that we will briefly discuss the origin and early development of the Spacelab Utilisation Programme

86 ESA/PB-SL(80)43, 25/11/80, with add. 1, 8/12/80, and add. 2, 9/12/80.
87 SLPB, 33rd meeting (10/12/80), ESA/PB-SL/MIN/33, 20/1/81, p. 9.
88 Council, 45th meeting (14-15/12/80), ESA/C/MIN/45, 27/1/81, pp. 10-12.
89 Wedde-Mühlhausen *et al.* (1987).

(SLUP), an optional programme financed by most ESA Member States, in whose framework the FSLP itself was also accommodated.

The question of Spacelab utilisation had two different aspects. On the one hand, there was the still pending problem of the management and integration activities for the FSLP to be performed by SPICE; on the other, it was necessary to outline long-term plans for the European utilisation of Spacelab after the first mission, and to define the role of ESA accordingly. In the Executive's view, these two facets were strictly intertwined. In fact, the degree of financial support to SPICE, particularly regarding the investments in technical equipment and infrastructure, critically depended both on the level of FSLP integration to be performed in Europe and on the envisaged role of ESA/SPICE in the framework of future European Spacelab missions.

In early 1977, the Executive worked out a proposal for the FSLP in which three main options were suggested as regards the integration activities in Europe.[90] Option A foresaw a minimum level of European effort (pre-level IV integration): SPICE activities would be limited to support instrument development, then the instruments would be sent to NASA for all four levels of integration, with the exception of the material science double rack which would be pre-integrated in Europe in all three alternatives. In option B, most the European part of the payload would be physically pre-integrated and functionally tested at a central establishment in Europe (possibly SPICE) endowed with the necessary ground support equipment (level IV integration). The complete package could be dispatched either to NASA's Marshall Space Flight Center (option B1) for completing level IV integration or directly to the launch site at Kennedy Space Center (option B2). Finally, option C foresaw a maximum level of integration and testing in Europe, including pre-level III activities with a complete set of ground support equipment. The estimated costs for the various options (at 1976 price levels) were 10.83 MAU for option A; 13.42 and 13.14 MAU for options B1 and B2, respectively; and 17.63 MAU for option C. The differences stemmed mainly from the expenditure required by the investments for the ground support equipment.(0.19 and 7.21 MAU for the extreme options, respectively).

While the various alternatives were strictly applicable only to the FSLP, the Executive insisted that this had to be considered in the context of a long-term Spacelab utilisation programme involving several flights over a period of years:

> *In the search for a cost effective solution it is worth to note that, although the initial investment requirement of option C is the largest, this option also exhibits the lowest recurring costs. It follows that, over a period of years, the initial investment is recouped. In fact, studies indicate that the amortisation of the cost of the pre-level III [ground support equipment] would be complete within about 10 missions - or by 1983 if the current utilisation model applies.*[91]

Three possible contribution schemes for the financing of the FSLP were suggested: the first foresaw the same contribution scale as in the Spacelab development programme; the second foresaw that the activities related to the scientific part of the payload would be financed out of the ESA scientific budget and the rest divided among Member States in proportion to the weight of their instrumentation; the third foresaw that the FSLP would be developed in the

90 ESA/SPAG(77)6, 11/2/77. A preliminary version of this document is ESA/SPAG(76)23, 5/1/77. Four integration levels were foreseen in the Spacelab Programme Requirements defined in an ESA/NASA document of 24/9/75: level I and II were to take place at the launch site; level III integration could be performed in technical centres but required important Spacelab-dedicated technical facilities; level IV integration was possible at user home facilities with minimum Spacelab support equipment. See also Lord (1986), p. 514-516.

91 ESA/SPAG(77)6, cit., p. 4. At that time the first Spacelab mission was scheduled for 1980 and the latter statement gives an idea of how optimistic the expectations were about the Spacelab flight schedule.

framework of the long-term Spacelab utilisation programme that the Executive was working out in parallel with the FSLP cost study, according to the contribution scale eventually agreed on by the participating states.[92]

The principle that significant FSLP integration tasks (i.e. an option intermediate between B2 and C) should be performed in Europe was generally endorsed by the SPAG, but with two important qualifications. Firstly, that this should be achieved in the framework of the general budgetary constraints, which called for a reduction in the estimated costs, e.g. by performing the physical integration in industry. Secondly, that the decision on the FSLP should not be binding for future missions. The German delegation, in particular, argued that ESA should not become involved in large-scale investment when it was responsible for only a small part of the payload: "there should be no attempt to transform SPICE into a comprehensive space-flight centre" they said, insisting that most of integration work should be performed in a industrial establishment (possibly in Germany) rather than in an ESA centre. In the German view, a clear distinction had to be made between the first and subsequent missions. The former could be financed according to the Spacelab programme contribution scale, and Germany was prepared to contribute more than 50 % of the budget; the latter should be carried out in the form of optional individual missions in which Member States would participate according to their interests, and ESA's role should be limited to providing SPICE services financed on a GNP basis.[93]

In April 1977, the Executive finally submitted to the SPAG and the Council its ambitious proposal for a Spacelab Utilisation Programme (SLUP), also including the FSLP project.[94] The aim of the programme was to promote a rapid growth of Spacelab utilisation in Europe, both in the traditional space disciplines and in the new fields opened up by the advent of the space laboratory. In this framework, the Agency's role would be twofold. On the one hand, it would provide services to European users, such as assisting the experimenters in preparing and testing their instruments, planning Spacelab missions, co-ordinating with NASA activities, training mission specialists, procuring ground support equipment and Spacelab subsystems, collecting and distributing data, and so on. On the other, ESA would also design and implement a number of dedicated European missions to be developed in the form of optional programmes by interested Member States. In order to estimate the required effort, three utilisation models were considered, which foresaw European participation in as many as 13 to 23 Spacelab missions in the period 1980-1985, including a number of fully dedicated European missions ranging from 2 in the lowest option to 7 in the highest. The total cost of Spacelab utilisation in the period 1977-1985 was estimated at about 255, 330 and 485 MAU (at 1976 price level), for the three models, respectively; the fraction to be paid to NASA for access to the Space Transportation System (Shuttle) was estimated at 54 %, 59 % and 64 %, respectively.[95]

In order to define a charging policy determining the part of the Spacelab utilisation costs to be charged to the users and the part to be funded by ESA out of the SLUP budget, three phases were distinguished in the programme: an initial phase (1977 to about 1981), in which ESA

92 ESA/SPAG(77)7, 18/2/77. The general outlines of the Spacelab utilization programme were anticipated in a document prepared for the first meeting of the ESA Council at Ministerial Level, on 14-15 February 1977: ESA/SPAG(77)1, 11/1/77, with annex ESA/C-M(77)14. The meeting expressed a general consensus on the principle of establishing such a programme within the framework of ESA

93 SPAG, 4th meeting (24/2/77), ESA/SPAG/MIN/4, 24/3/77, p. 4. The resolution approved was reported in ESA/SPAG(77)12, 4/3/77. The German position was spelled out in a written document reported in ESA/SPAG(77)11, 25/2/77.

94 ESA/EXEC(77)4, April 1977, annex to ESA/SPAG(77)13, 3/5/77. A summary of this document, intended for presentation to the Council, is in ESA/C(77)32, 16/5/77.

95 These figures did not include the cost of experiments, which would be charged to the users. Approximate figures for these costs were given for the three models, i.e. about 117, 153 and 233 MAU.

would have to fund the basic investments in order to permit the integration and flight of the FSLP, and to set up the capability for implementing a complete payload in Europe; a consolidation phase (1982 to 1985, approximately), the objective of which would be to ensure that the funding was taken over progressively by the users, according to a specified set of principles; and a permanent regime phase (after about 1985) during which it was reasonable to foresee that the ESA subsidy would cover only the operation of SPICE and its equipment. The result of this exercise was the SLUP budget level for the years 1977 to 1985, in each the three utilisation models. The total budget for the entire period was estimated at about 202, 155 and 347 MAU, respectively. According to the Executive, the low utilisation model was not sufficient to satisfy the user community, and it therefore proposed that the medium model be taken as the reference for elaborating the programme.

The Council did not endorse this ambitious plan.[96] In fact, there were several reasons for ESA Member States' negative attitude towards the SLUP concept as proposed by the ESA Executive. Firstly, as a matter of principle, all delegations insisted that the question of the financing of the FSLP and related SPICE activities should be dealt with separately from any long-term utilisation programme. While a rapid decision was requested on the former, in order to give the FSLP project a proper institutional and financial framework, the European participation in subsequent Spacelab missions still suffered from too many uncertainties and difficulties, particularly regarding the utilisation costs of the Shuttle/Spacelab system. In this situation, the Council felt that all mission models presented in the Executive's proposal were far too ambitious and that, in any case, it was still premature to enter into any commitment. Secondly, and more generally, the ESA Member States were negotiating at that time a new package deal on a group of the Agency's activities, including the Ariane production and the telecommunication programmes, and some argued that the Spacelab utilisation programme should be discussed and agreed on within the package deal framework. Thirdly, and more specifically, some delegations, notably Germany, opposed the idea that ESA should assume a role of mandatory intermediary between NASA and European users. In their opinion, national space authorities, research laboratories and industries should maintain the right to approach NASA directly for having access to the Shuttle/Spacelab system and they insisted that the Agency should not have a monopoly of the facilities required for high level testing and integration of Spacelab instruments in Europe. Finally, there was the problem of FSLP funding. While Germany had stated its willingness to pay 53 % of the costs of the FSLP programme, as it did for Spacelab, no agreement could be reached on the way in which the remaining 47 % should be divided among the other participants. For France, the costs should be apportioned in accordance with the Spacelab agreement, but this was strongly opposed by Belgium and Italy, which did not want to maintain their high rates of contribution to the Spacelab development programme for the FSLP activities.

After many negotiations, extending over several meetings of the SPAG, the Administrative and Finance Committee (AFC) and the Council, it was finally agreed that "the Agency be used as a framework for the execution of a new optional programme, called the Spacelab Utilisation Programme, intended to promote and facilitate utilisation of the Spacelab by European users". The programme objectives included two different tasks. Firstly, the setting-up of a Spacelab-access service, managed by SPICE, "comprising all the auxiliary means that are necessary for the execution of the different missions and that the user cannot provide himself". It was assumed that the costs of this service would be charged to the users. Secondly, the preparation and execution of ESA-funded missions, "in which the participating states may take part if they wish". More specifically, this task comprised the FSLP mission and two "demonstration

96 Council, 17th meeting (25-26/5/77), ESA/C/MIN/17, 16/6/77. See also SPAG, 5th meeting (18/5/77), ESA/SPAG/MIN/5, 15/6/77, and 6th meeting (23/6/77), ESA/SPAG/MIN/6, 1/7/77.

missions" to be launched in the period 1981-1983.[97] All Member States participating in the Spacelab programme eventually accepted to participate in the new programme (including Austria, a non Member State participating in the Spacelab programme), but funds were only committed to the FSLP, at a level of 12 MAU (at 1976 price level), with Germany contributing 56.3 %, France 12.8 %, Italy 9.3 % and the United Kingdom 8.4 %. It was agreed that the objectives, cost and contribution scheme for the demonstration missions would be determined in the future by a unanimous agreement of the States wishing to participate in each of these missions. As regards subsequent missions, it was simply stated that their cost would be borne by the users concerned, with some support eventually provided by ESA.[98]

The abandonment of the demonstration mission concept

Once the long-standing question of the financing of the FSLP had been settled, the ESA Executive started the definition studies to prepare the two demonstration missions foreseen in the SLUP plan. These missions were to be devoted to microgravity research (material sciences and life sciences) and earth-oriented disciplines (atmospheric sciences, earth resources and geodesy), respectively; their twofold objective was to demonstrate the full versatility of Spacelab in many scientific and application fields, and the low-cost, easy-access concept of Spacelab payloads.[99]

Two problem areas emerged in this phase. Firstly, apart from Germany and to a certain extent France, the other Member States were very reluctant to invest resources in Spacelab utilisation. The cost escalation of the Spacelab programme and the persisting uncertainty regarding the NASA charging policy prevented European governments and industry from committing to an important utilisation programme in which most of the money would certainly go to NASA for Shuttle operations. Secondly, Germany informed its partners that it was preparing two national Spacelab missions whose objectives were essentially the same as those of the envisaged ESA missions and which were scheduled for launch in the same period.[100]After many discussions between the ESA Executive and the German authorities, a compromise was worked out. The four ESA and German missions would be jointly planned, and the earth-oriented German mission would be replaced by an astronomy mission. Germany confirmed its willingness to contribute important instrumentation and manpower to the ESA payloads, and stated that its national missions were open to complementary participation by other European groups.[101] The German authorities did not hide, however, their desire to secure a leading role in the performance of demonstration missions and stressed that they would hold fast to their schedule. The first German mission was firmly planned for June 1982, and they declared that, "although the other Member States were invited to join, there is no intention of slowing down the planning of the mission." Similarly, it was assumed that the ESA earth-oriented mission would take place in spring or autumn 1982 and "if the mission takes place later, the German interest in it would decrease".[102]

97 ESA/C/MIN/XX/Res. 1, 4/10/77, attached to the minutes of the 20th Council meeting (3-4/10/77), ESA/C/MIN/20, 17/10/77. This Council decision, which approved the SLUP principle, followed the recommendation adopted at the 7th SPAG meeting (11/7/77), ESA/SPAG/MIN/7, 27/7/77.

98 Council 22nd meeting (12-14/12/77), ESA/C/MIN/22, 4/1/78, and annex ESA/C/XXII/Dec. 2, 12/12/77. A preliminary budgetary proposal was presented by the Executive in ESA/SPAG(77)20, 27/6/77 and its evolution is reported in the series of documents ESA/C(77)81, 8/9/77, with subsequent additions and revisions. All Council resolutions related to the approval of the SLUP are attached to ESA/SPAG(77)35, 16/12/77.

99 ESA/SPAG(77)24, 27/6/77. The Executive had originally suggested (ESA/SPAG(77)21, 14/6/77) three demonstration missions, devoted to microgravity, earth-oriented and space-oriented disciplines, respectively.

100 ESA/SPAG(77)28, 6/12/77; SPAG, 8th meeting (20/12/77), ESA/SPAG/MIN/8, 25/1/78.

101 ESA/SPAG(78)4, 16/2/78; ESA/SPAG(78)8, 17/2/78.

102 SPAG, 10th meeting (29/6/78), ESA/SPAG/MIN/10, 31/7/78, p. 4.

The hard reality soon became evident. Following a preliminary call for experimental proposals, more than 200 proposals were received by June 1978, but no Member State delegation, with the obvious exception of Germany, was in a position to give any firm indication about the financing of the national experiments.[103] In the next year, the dramatic financial situation of the whole Spacelab programme prevented the ESA Council from adopting any important decision on the demonstration missions. Firstly, new technical problems with the Shuttle development programme resulted in further slippages of the scheduled date of the first Spacelab flight, from July to December 1980, then to June 1981 and finally to April 1982. Secondly, it became clear that the development cost could not be kept within 120 % of the original estimate and therefore new arrangements had to be negotiated by the participants in the programme to exceed this ceiling; Finally, the projected costs of the FSLP itself had almost doubled when compared to the initial estimate. By October 1978, with a launch still scheduled for June 1981, the cost-to-completion was estimated at 26.3 MAU (at 1978 price levels, corresponding to 22.3 MAU at 1976 price levels), with no reserve or contingency for unforeseen factors such as a new launch slippage. This increase was considered "unacceptable" by the Executive, which urged the SPAG to suggest "a change in philosophy [...] taking into account the effects such a change would have upon the industrial policy".[104] In the event, following a complex cost-reduction exercise and some heated discussions among SPAG delegations, it was decided to drastically simplify the integration activities in Europe, with all physical integration carried out at ERNO's establishments. The new cost estimate was 21.7 MAU (at 1978 price levels, corresponding to 15.8 MAU at 1976 price levels).[105]

To make a long story short, in September 1979 the Council decided to stop planning the dedicated ESA demonstration missions and to search for participation in NASA missions with a full pallet or an experiment rack. It became evident that any European programme for the utilisation of Spacelab after the FSLP would not include dedicated ESA missions until after the mid-1980s. As we have anticipated, it was eventually agreed in 1981 to participate in the German D-1 mission by providing the Sled and the Biorack facilities, and one of the payload specialists. The ESA Council also agreed to undertake an optional Microgravity Programme with the objective of developing advanced Spacelab facilities and ensuring the necessary flight opportunities in future NASA and German missions. The first phase of the programme was approved in February 1982 with ten participating states; the programme elements were the Biorack, an Improved Fluid Physics Module (IFPM), and a series of rocket experiments. After the Challenger accident on 28 January 1986, all Shuttle activities were stopped and Phase 2 of the Microgravity Programme was delayed accordingly. In the event, the Biorack facility was included in the first flight of the International Microgravity Laboratory (IML-1), in January 1992. Other ESA-developed facilities were flown on the German D-2 mission, in April 1993, and on the IML-2 mission, in July 1994. The former carried a sophisticated facility for experiments in human physiology (Anthrorack) and an Advanced Fluid Physics facility. The latter carried four multi-user facilities: the Biorack, a Bubble Drop and Particle Unit (BDPU) and a Critical-Point Facility (CPF) for the study of transparent fluids, and an Advanced Protein Crystallisation Facility (APCF) for studying the growth of single protein crystals. In more recent times, we can recall that the APCF was carried on the USML-2 Spacelab flight in October 1995, while five ESA multi-user facilities were included in the Life and Microgravity

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103 ESA/SPAG(78)12, 19/6/78; ESA/SPAG/MIN/10, cit.

104 ESA/SPAG(78)22, 18/10/78, p. 7.

105 ESA/SPAG(78)28, 30/11/78; ESA/SPAG(79)1, 12/2/79. SPAG, 11th meeting (26/10/78), ESA/SPAG/MIN/11, 22/11/78; 12th meeting (7/12/78), ESA/SPAG/MIN/12, 11/1/79, and 13th meeting (21/2/79), ESA/SPAG/MIN/13, 23/3/79. The main controversial issue was whether integration should be performed in German industry or in the U.S. or at a non-industrial European centre (ESTEC or CNES). Owing to further launch slippage of the first Spacelab mission, a new cost figure had to be approved in 1980 at 28.9 MAU with a contingency of 1.5 MAU (both at 1978 prices): *ESA Annual Report 1980*, p. 54.

Spacelab (LMS) mission in June 1996: BDPU, APCF, the Advanced Gradient Heating Facility (AGHF), the Torque Velocity Dynamometer (TVD), and the Microgravity Measurement Assembly (MMA).

Epilogue

A few months after the successful accomplishment of the first Spacelab mission, a member of the ESA staff who had been associated with the Spacelab programme since its very beginning could not conceal his disenchantment:

> *The aim was to make space readily accessible to all experimenters [...] Many of our early dreams have been dispelled by such things as high launch costs, the high standards of safety needed by a manned system, and the large amount of documentation that must be handled by scientists and engineers alike. A significant high-cost factor arises from the sheer size of Spacelab. It takes over 4 tonnes of experiment equipment to use its capability fully. Although the cost per kilogram of experiment put into orbit is low, the total mission cost is quite high.*[106]

Such disillusionment was probably widespread in many quarters, with the former NASA director of the Spacelab programme resenting "the comments from dissidents in the public and scientific press" and blaming the scientists, "who were still insisting that man was unnecessary for space research [...] and received far more recognition from the news media than they deserved".[107]

For the European scientific community, the last word on Spacelab was spelled out in a report on the development of space science in the 1980s, prepared by the SAC during 1978 in consultation with the community at large and published in December that year.[108] "Spacelab [...] represents a good vehicle for such disciplines as the microgravity sciences and astronomy", the SAC wrote when the first mission was being delayed from mid-1981 to spring 1982, ESA's planned demonstration missions were about to be definitely jeopardised, and the Spacelab development programme was entering its most dramatic financial crisis. "But even for these [disciplines]", the SAC went on, "high cost is a major obstacle to its use, and this has been the determining factor in the rejection of excellent candidate projects". For the SAC as well as for most space scientists, the launch cost per kilogramme of experiment mass was not a good indicator for assessing the worth of Spacelab in space research. Firstly, the cost of small experiments turned out to be as high as on unmanned satellites, particularly because of the stringent safety requirements; secondly, the short duration of flights made Spacelab uncompetitive with conventional spacecraft on a cost/observation-day basis.[109] "What was supposed to be a platform to carry, in particular, rocket-type experiments into space for seven days has turned out to be a platform to carry the most expensive type of satellite experiments for this same period of time", the SAC members insisted, echoing the criticism that had been voiced from various parts of the scientific community. Furthermore, the Spacelab payload-integration scheme had not met the original promise of short lead times, again because of the manned-safety requirements, and the re-flight time would not be as short as initially advertised. In conclusion, only a drastic reduction in the 'effective' cost to science of Spacelab launches

106 D.J. Shapland's preface (June 1984) to Shapland & Rycroft (1984), p. 7.

107 Lord, *Spacelab* (1987), p. 389.

108 SAC, *Recommendations on the development of space science in the 1980s*, ESA SP-1015, December 1978; also referenced as SAC(78)17 and circulated under cover ESA/SPC(79)2, 3/1/79. The following quotations are from pp. 47-48 and 57-58.

109 The cost/kg of experiment mass was the main argument in the Executive's document SAC(79)12, 26/4/79, but it was strongly criticized by the SAC at its 18th meeting (9-10/5/79), SAC(79)16, 25/6/79, and 19th meeting (26/9/79), SAC(79)25, 8/11/79.

could stimulate a significant utilisation programme, "which will represent a dividend for the European initiatives and investments involved in the creation of Spacelab". The SAC's position, in any case, left no room for indulgence:

> *Regarding the future utilisation of Spacelab, the SAC is of the opinion that the scientific community should consider itself a* potential user *of this means of transportation, and not a* promoter *of it. In no way should the community and the Working Groups themselves undertake the task of programming the utilisation of Spacelab* [emphasis added].

High operation costs and lack of a sufficiently large, motivated and influential user community were the two main aspects of Spacelab's shortcomings. Two others can be pointed out in order to understand ESA's failure to establish a sizeable Spacelab utilisation effort. Firstly, the unequal partnership between NASA and ESA was felt in Europe to be unduly penalising for European interests in this joint venture. Such issues as the poor transfer of technology, the lack of significant contracts for Europe in the Spacelab operational phase, the pricing policy for user access to the Shuttle/Spacelab system, and the fact that only one other Spacelab was procured by NASA after the first unit, were the main areas of controversy. In this situation, and facing the cost escalation of the programme, European governments became more and more disenchanted with the future of Spacelab. European industry, for its part, could hardly be excited about a large utilisation programme for Spacelab when most of the money would go to NASA for Shuttle operations.

Secondly, ESA's multinational structure and the different interests of its Member States made it impossible to build a strong and unitary direction as regards Spacelab utilisation. It is striking to observe that the Spacelab Programme Board, the delegate body responsible since 1973 for directing the Spacelab development programme on behalf of the participating states, was not responsible for planning its first mission (let alone subsequent ones) until spring 1979. In the ESRO framework, this task was first assigned to the Scientific Programme Board (for scientific projects) and the Joint Programmes and Policy Committee (for the other projects). Subsequently, the First Spacelab Payload Working Group was set up, whose main task, however, was to find a solution to the hot question of FSLP funding. In late 1976, it was replaced by the Spacelab Payloads Advisory Group (SPAG), with wider terms of reference, but the scientific projects, including the new field of life sciences, remained under the competence of the Science Programme Committee. An advisory group made up of national delegates was also created to deal with the remote-sensing (RESPAG), and a Material Science Consultant Croup of independent experts was added to the SAC and the Astrophysics, Solar System and Life Science working groups. Each of these boards, committees and advisory groups intervened in the decision-making process, with the Council retaining responsibility for all final decisions.

The decision-making process was long and complex, and the ESA Executive lamented that "in the area of the Spacelab utilisation programme ESA suffered from the absence of a policy and a mission clearly defined by the Member States".[110] For Germany, Spacelab was essentially like a national programme, in view of the country's large effort. It could not do it alone, however, and its European partners did not like to leave too much control in German hands. "[Italy is] not prepared to subsidise the acquisition of experience by German industry", the Italian delegation declared when it was proposed to integrate the FSLP in ERNO in order to reduce costs. The German delegation retorted pointing out that Germany was paying 56 % of the cost of the FSLP, "to say nothing of the equipment and manpower which was made available free of charge to the programme." It blamed the larger Member States for not showing "a greater

110 SPAG, 2nd meeting (30/11/76), ESA/SPAG/MIN/2, 28/12/76, p. 13.

interest in using the Spacelab", and the Science Programme Committee for not showing "sufficient enthusiasm for the facilities offered by Spacelab".[111]

Indeed, one can hardly find any enthusiasm in the records of discussions on Spacelab utilisation. Whether because of doubts regarding its real scientific value or concern about its costs, the initial optimism about the potential of the Shuttle/Spacelab system vanished soon. The Spacelab programme was criticised in Europe as being a 1 billion dollar gift to the U.S. Space Shuttle programme: "Europe's most expensive gift to the people of the United States since the statue of Liberty", the head of the German delegation in the ESA Council remarked.[112] In fact, the Europeans agreed to build Spacelab with their own money and ship it to the United States and "all ESA received overtly in return was the free use of half of the payload bay on the first flight", as the first ESA Director General, Roy Gibson, put it with hindsight.[113] European governments were greatly disappointed by NASA's pricing policy, which did not consider any "preferred access" to the Shuttle/Spacelab system for European users, and they hardly appreciated the fact that the USA procured only one additional flight unit, barely complying with the requirements of the Memorandum of Understanding. We can perhaps fairly conclude by quoting the former NASA director of the Spacelab programme from the conclusion of his long historical account: "since the end of the [...] program, the attitude of European and U.S. representatives toward future co-operation has become increasingly suspicious or combative."[114]

111 SPAG, 13th meeting (21/2/79), ESA/SPAG/MIN/13, 23/3/79, pp. 5 and 9.
112 W. Finke, quoted in McCurdy (1990), p. 102.
113 Gibson (1992), p. 42.
114 Lord (1987), p. 400.

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Appendices and Figures

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Appendix 1: Experimental objectives for the first Spacelab mission *

Experimental objectives for the first Spacelab mission recommended on 16 January 1975 by the two co-chairmen of the ESRO/NASA Joint Planning Group, J. Collet and G.W. Sharp, to the ESA Director General and the NASA Administrator:

- To demonstrate the capability to investigate the fundamental science in vapour, liquid and solid-phase interaction under gravity-free conditions, observing among other things:
    - crystal growth, metallurgical phenomena and separation of biological material;
    - cloud microphysics;
    - drop dynamics.
- To investigate key natural cause and effect relationships that exist in the near-earth environment by performing active and interactive experiments on and in the earth's atmosphere and magnetosphere.
- To conduct investigations on the effects of the space environment (zero gravity and/or hard radiation-HZE) on body fluid redistribution, vestibular function, growth, development and organisation on living systems such as man, animals, plants, cells and tissues.
- To demonstrate the capability to monitor the atmosphere and its effect on environmental quality by surveying the atmosphere for trace constituents, identifying their sources, flow patterns and decay mechanisms.
- To demonstrate the capability to observe and monitor the earth's surface, in particular to obtain high-resolution, metric-quality images, and to develop space-borne all-weather remote-sensing methods.
- To observe extended sources of radiation in the visible, ultraviolet, and infrared spectra too faint for earth-based observations and possibly evaluate the effect of the Shuttle/Spacelab environment on such astronomical studies.
- To demonstrate and use the capability of Spacelab as a technology development and test facility to perform experiments in the space environment in areas such as tribology and heat transfer.
- In the field of communications, to conduct investigations that will provide a basis for the efficient utilisation of orbital spacing and frequency spectrum, including:
    - studies of effects and anomalies of propagation from earth and space, and
    - measurements of terrestrial RFI sources;
    - to demonstrate the performance and operational capabilities of advanced satellite communications and navigation subsystems.

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* ESRO/JPPC(75)9, 20/3/75.

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Appendix 2: List of elements in the European model payload for the first Spacelab mission *

	Estimated cost (MAU)
Atmospheric research and astronomy	
Laser sounder (Lidar)	4.0
Passive atmospheric sounder	0.8
Astronomy add-on experiment	1.2
Life sciences	
Sled for vestibular studies	1.0
Human performance research support unit	
Radiobiology unit	0.5
Plant holding and support unit	
Cells and tissue research support unit	
Material sciences	
Isothermal furnace 1250°	0.5
Vacuum furnace 1250°	0.25
Gradient furnace 1200°	0.35
Gradient furnace 2000° (O_2 atmosphere)	0.30
Acoustic positioning and stirring equipment	0.30
Electromagnetic positioning facility	0.30
Electromagnetic positioning facility	0.30
Free-flow electrophoresis facility	1.3
Fundamental floating zone experiment	0.4
Material science integrated test facility	0.3
Various material science experiments	1.5
Earth observation	
Microwave scatterometer	1.8
Metric camera	0.4
Technology	
Advanced heat-pipe system	0.3

* ESRO/FSLP(75)3, 18/4/75.

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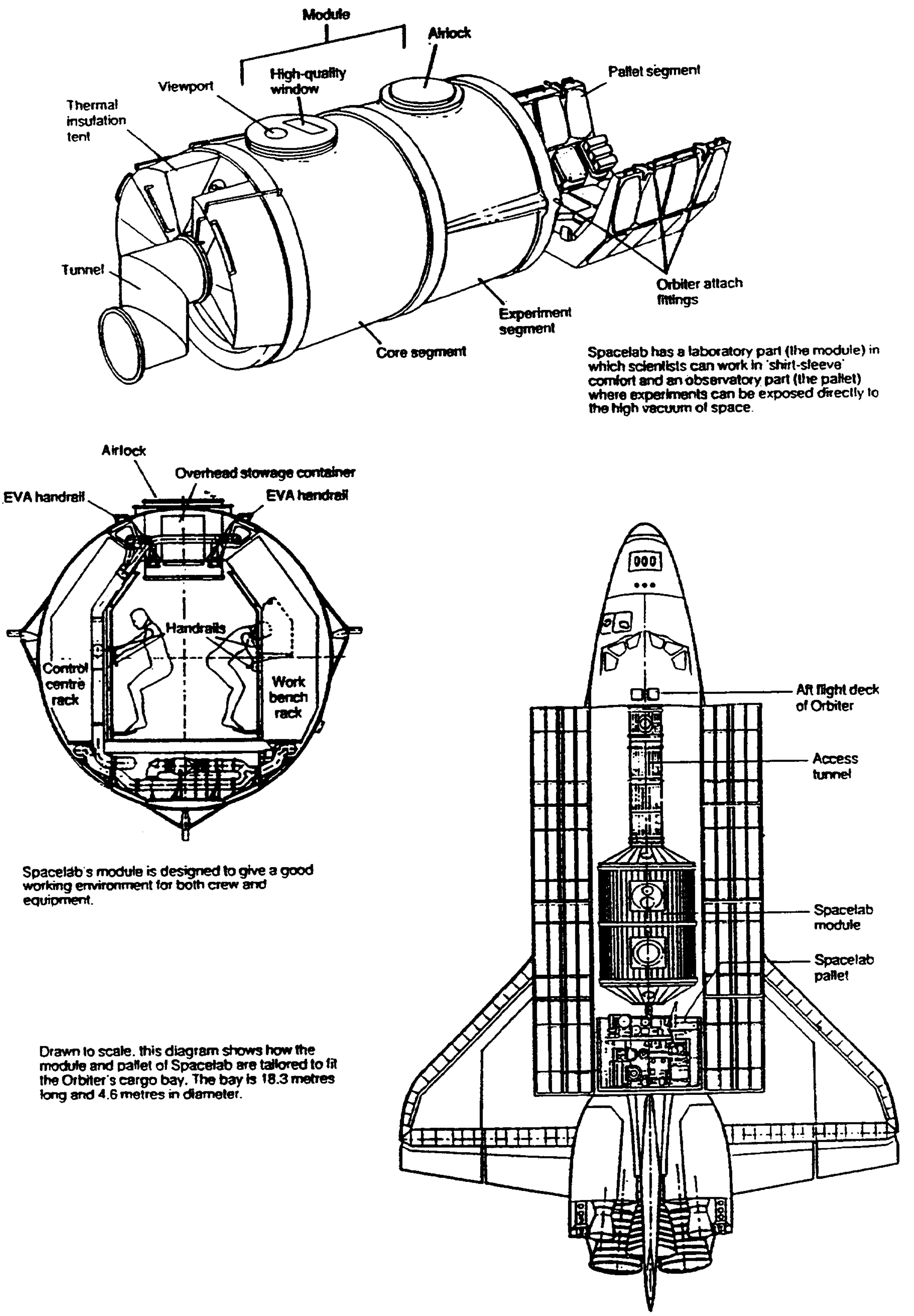

Figure 1

The Spacelab concept [Shapland & Rycroft (1984)]

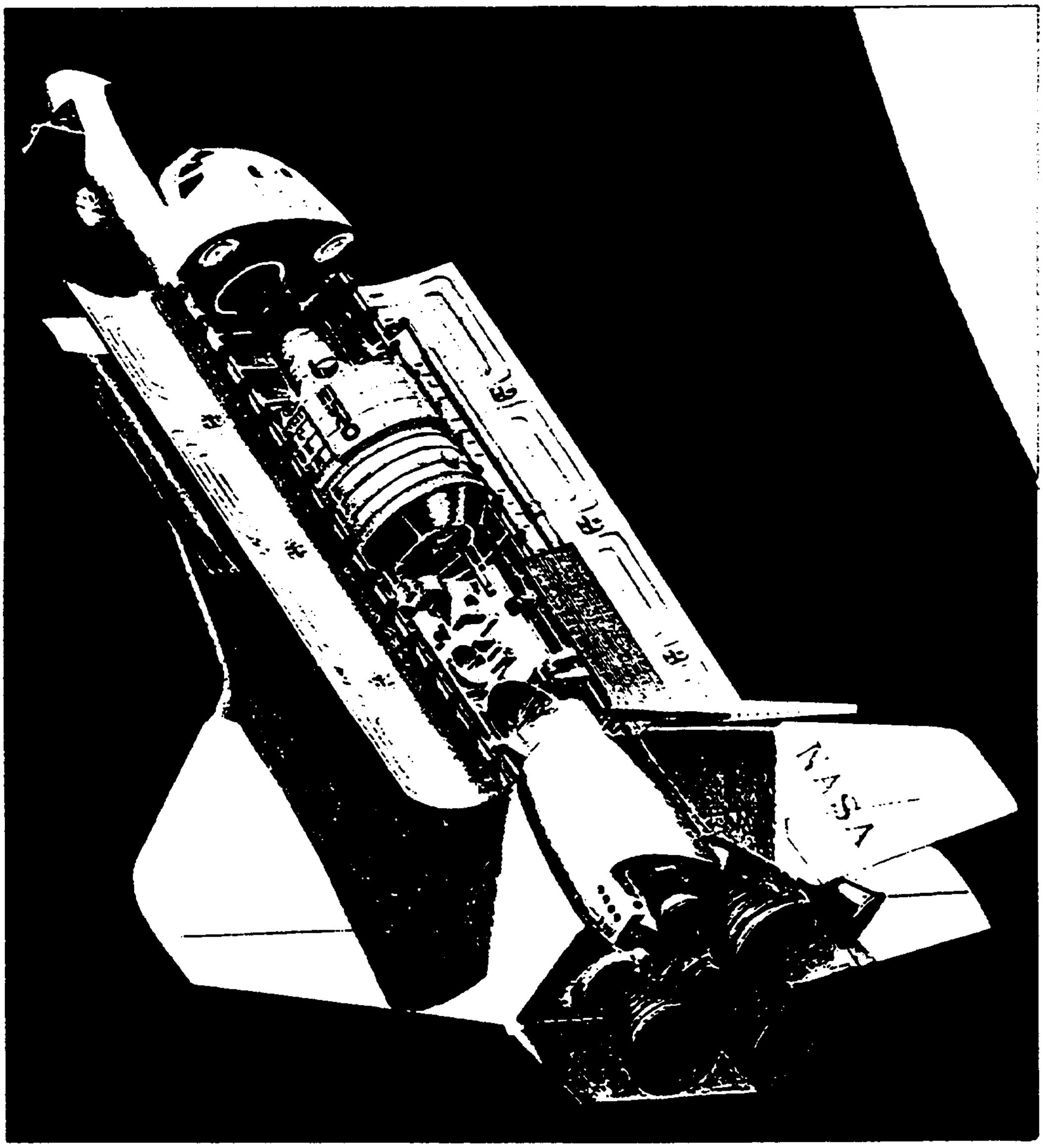

Figure 2

Artist's impression of Spacelab in the Shuttle cargo bay [Lord (1987), p. 485]

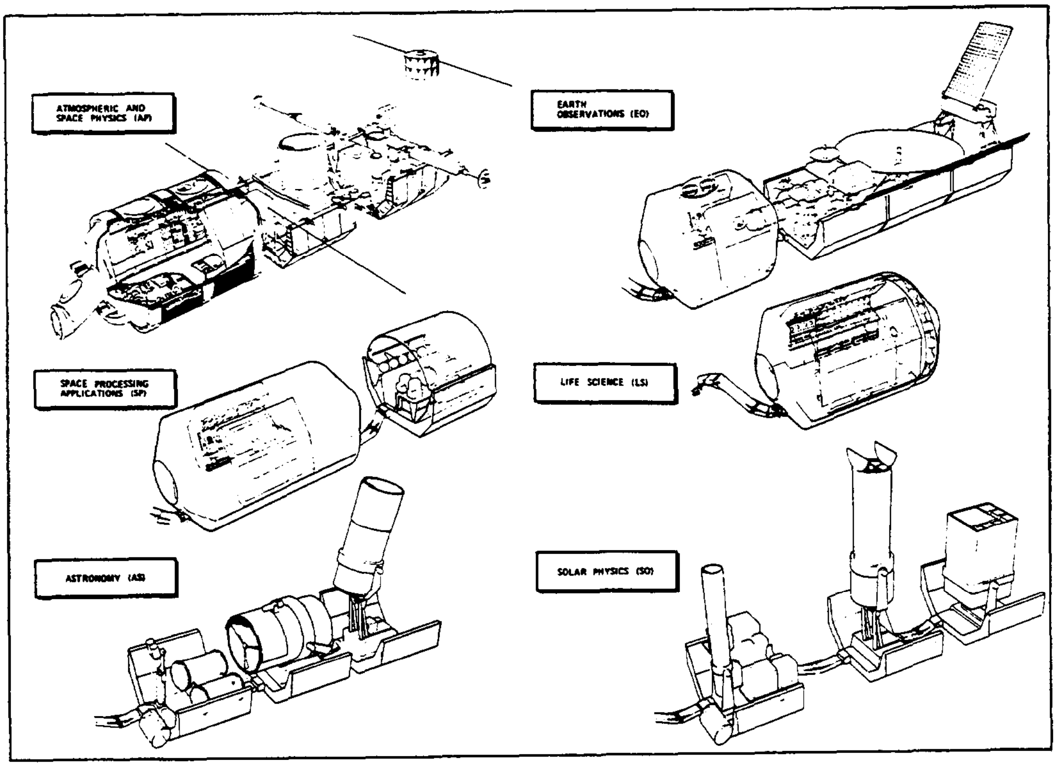

Figure 3

Scientific and application areas for Spacelab utilization (ESRO Annual Report, 1974, p. 143)

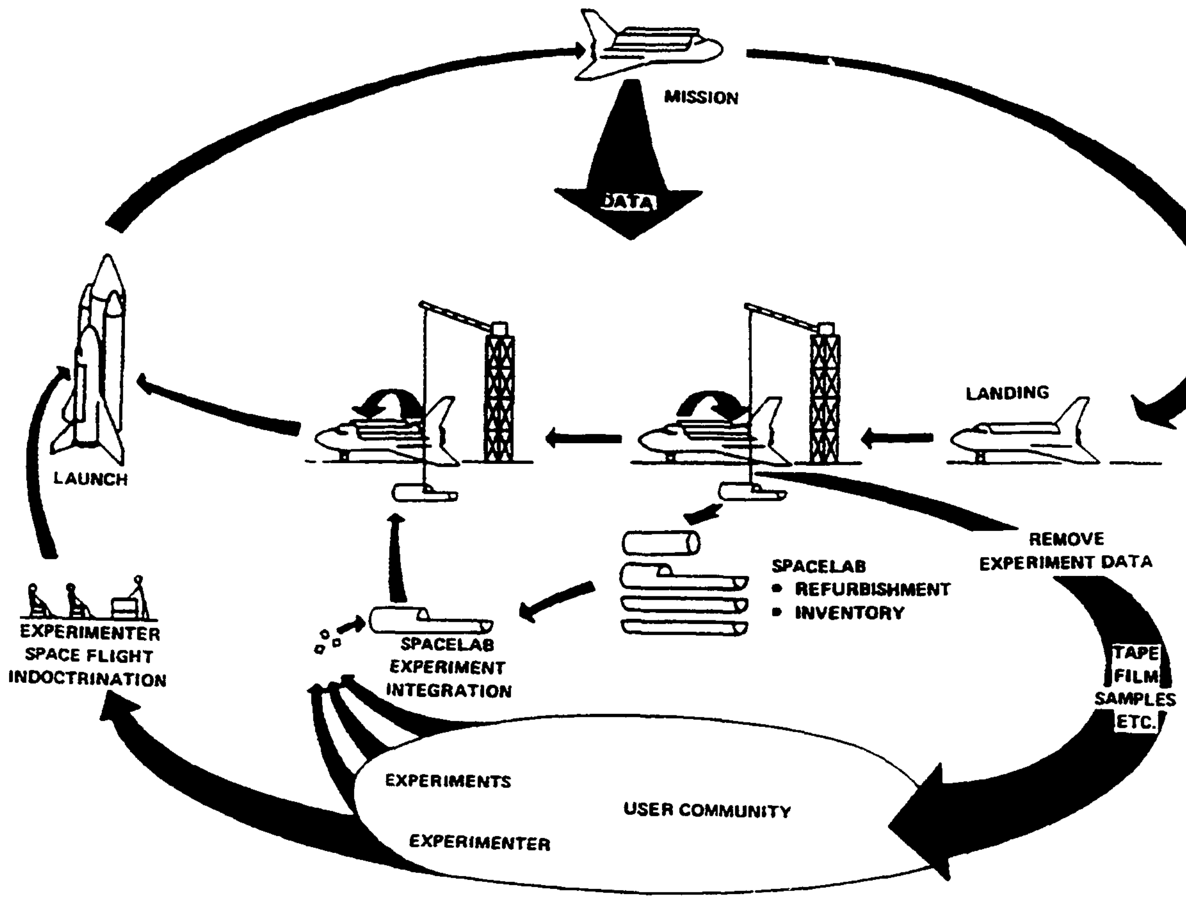

Figure 4

Shuttle–Spacelab flight profile [Lord (1984), p. 489]

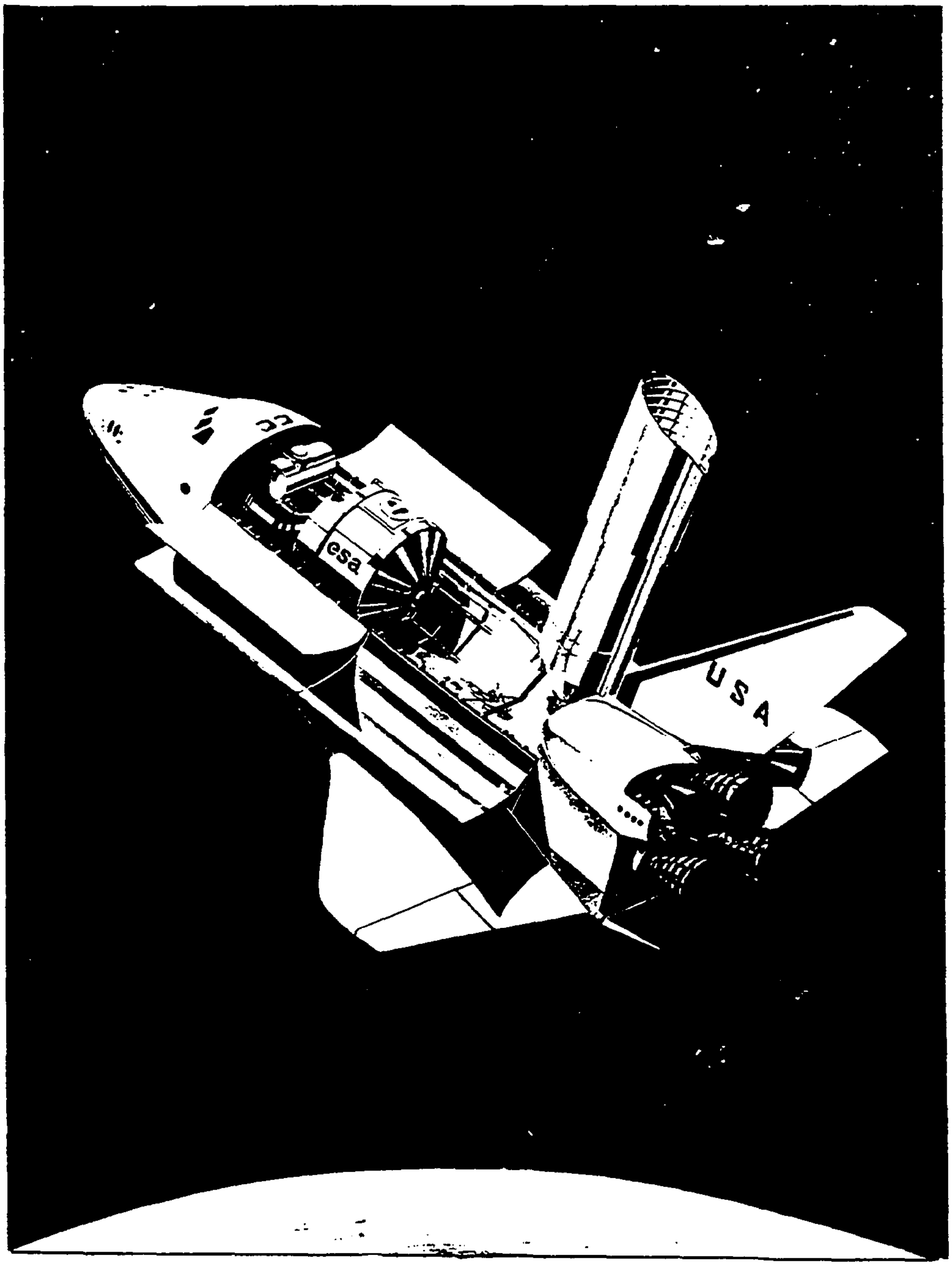

Figure 5

Artist's impression of the Large Infrared Telescope for Spacelab (LIRTS) in operational mode aboard Shuttle–Spacelab [Beckman (1977), p. 23]

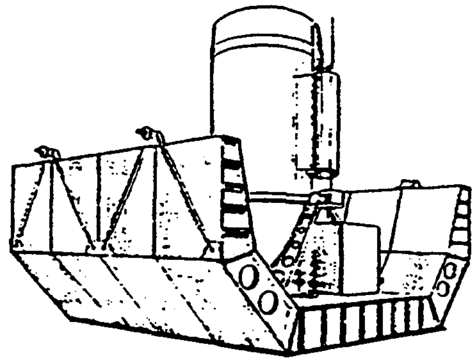

Figure 6

The Lidar configuration [ESA Annual Report, 1977, p. 31]

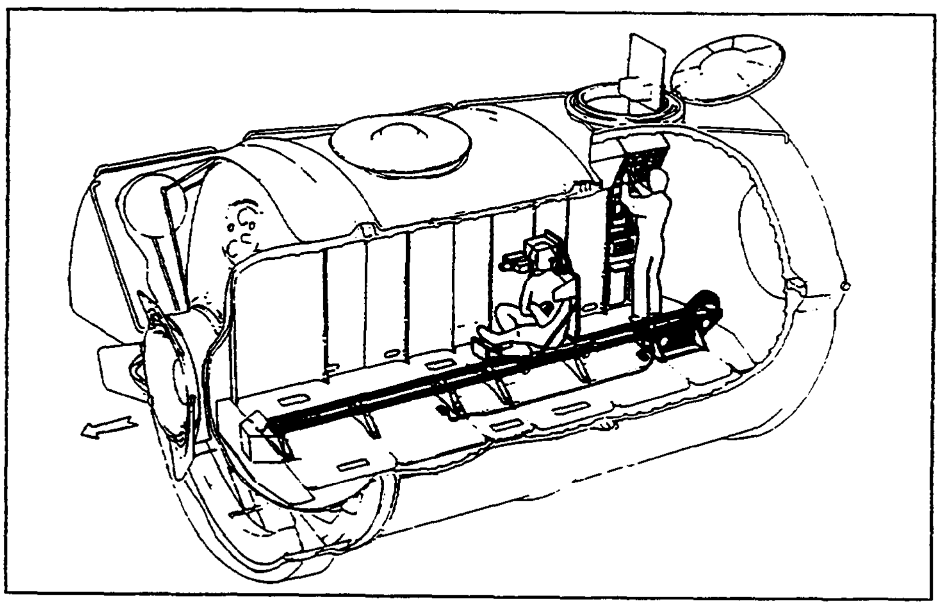

Figure 7

The Sled for vestibular studies [Steinz (1980), p. 60]

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