The European Space Research Organization

Ten countries have pooled their efforts in space research and planned a program for the first 8 years.

R. Lüst

In the field of space research, as in other fields such as nuclear and atomic research, an international organization has been formed to promote cooperation among European nations. The European Space Research Organization (ESRO), which has officially been in existence only a little over a year, now has ten members, Belgium, Denmark, France, Germany, Italy, the Netherlands, Spain, Sweden, Switzerland, and the United Kingdom. As expressed in its convention, which has been in force since 20 March 1964, the purpose of ESRO is "to provide for, and to promote, collaboration among European States in space research and technology, exclusively for peaceful purposes."

The preparation for this organization and the planning of its work began 3 years before the convention entered into force. To carry out the planning, the states involved had established a preparatory commission (COPERS).

An important factor in the planning of the future work was the decision that there should be a financial ceiling for the first 8 years. This ceiling, which amounts to 1500 million French francs ($300 million), sets the boundary condition for the planning.

Of course it is not possible to establish a detailed scientific program for a period as long as 8 years. But on the other hand, it is necessary to envisage a possible program in order to plan the facilities which the organization will require and to assure the member states that a useful program can be carried out within the agreed financial limit. Furthermore, 2½ to 5 years are required for the completion of some projects, and therefore some parts of the program, at least in broad outline, must be decided early. The initial scientific assessment of a complex spacecraft project, for instance, is of considerable importance, for it can affect the scientific aims of the organization for many years.

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Scientific Aims of ESRO

The scientific work and the financial responsibility for space-research projects will be divided among ESRO and its members. Although the organization will have a number of establishments for different purposes, the main scientific activities will be carried out by research groups in the member states. This means in practice that the planning of experiments, the design and construction of scientific instruments, and the intrepretation and publication of scientific results will be done and paid for not by the organization but by the individual research groups at universities and research institutes in the member states. Only in major programs such as that associated with a large astronomical satellite will the main scientific instruments be developed, constructed, and financed under the control of ESRO. The possibility of incorporating secondary experiments from national research groups is not, of course, excluded from such programs.

The aims which ESRO and its members will try to achieve have, quite naturally, emerged as a result of the analysis of proposals made by the various national groups for experiments with sounding rockets and spacecraft. Interest has been expressed in almost all scientific fields related to space research. Investigations of ionospheric and auroral phenomena, observations of the sun, stars, and the interplanetary medium, and studies of cosmic rays and trapped radiation have given rise to a large number of proposals for experiments. All these planned investigations will complement and extend those which have already been carried out. Particular emphasis is given to space research in the auroral zone because of its importance for a better understanding of the interaction of solar activity with the atmosphere of the earth, as well as because of the traditional and continued interest of European scientists in auroral research. As a result of this interest, ESRO's own launching range for sounding rockets is being established near Kiruna, in the auroral zone in northern Sweden.

So far, scientific groups in the member states have made proposals for about 100 experiments with sounding rockets, and the same number for satellites and space probes. Before these proposals are accepted and instruments to carry out the proposed studies are included in certain payloads, the proposals will be reviewed by certain advisory groups composed of experts in the appropriate fields. To be accepted, a proposal must meet a number of criteria. Particular importance is given to (i) the scientific merit and novelty of the proposed project; (ii) how the project, if carried out, will complement or extend other space programs; and (iii) the importance of the project for European technology and the European technological capability.

On the basis of these proposals, a general scientific program has been established. An initial program has been agreed upon in some detail, while only some broad indications can be given for the future plans.

Initial Program

The program which has been agreed upon for the initial phase of ESRO comprises a number of sounding-rocket and satellite payloads and one large astronomical satellite.

Especially during the initial phase, the sounding-rocket program will play a dominant role, since it will enable the scientific groups in the member states not only to carry out certain scientific experiments or measurements, but at the same time to obtain experience essential for deciding what should be included in the payloads in the satellite program. But the sounding-rocket program in itself will be an essential part of the activity of ESRO and will amount to roughly 15 percent of the operational budget. Investigations of the atmosphere of the earth below about 200 to 300 kilometers are carried out predominantly with sounding rockets, since the lifetime of satellites in these altitudes is rather short. Furthermore, sounding rockets are also very useful for higher altitudes when only single experiments, rather than continuous measurements, are intended.

It is foreseen that during the first two years of ESRO 52 sounding rockets will be launched which will carry 26 different kinds of payloads, two rocket launchings being allocated for each type of payload. Two different solid-propellant sounding rockets will be used, namely, the French "Centaure" and the English "Skylark." The Centaure can carry a payload of about 20 kilograms to an altitude of 210 kilometers, or a payload of about 68 kg to about 135 km, while the Skylark (boosted version, Raven VIIa with Cuckoo booster) has the capacity to bring 80 kg to an altitude of 240 km or 190 kg to 170 km. These launchings can be grouped according to their purposes as follows: nine types of payload for atmospheric research, eleven for ionospheric research, three for stellar astronomy, one for solar research, and two for investigations of comets.

At present, payloads for two small satellites, ESRO I and ESRO II, have been agreed upon and are in preparation. These two satellites will be used in projects carried out jointly with the United States. The National Aeronautics and Space Administration will provide and launch the Scout vehicles in this cooperative program. According to the agreement between NASA and ESRO, ESRO II is to be launched in spring 1967 and ESRO I at the end of 1967, both from a U.S. launching range.

ESRO I will contain equipment for six investigations of the ionosphere and auroral phenomena. In this integrated payload the different investigations will supplement each other in such a way that the different particle fluxes arriving in the auroral zone can be measured and the effects of these particles within the atmosphere can be studied. The particles (protons and electrons with energies mainly below 1 Mev) come either from the radiation belts or directly from the sun and have several effects, for example, visible light (aurora), heating and ionization of the upper atmosphere, and magnetic disturbances. Therefore the instruments in the planned spacecraft will measure the flux and energy spectrum of the incoming protons and electrons, the density and temperature of the electrons in the ionosphere, the mass spectrum and the temperature of the positive ions, and the auroral radiation in the visible spectral range.

ESRO I will have a polar orbit with an apogee of 1500 km and a perigee of 275 km, which should insure a lifetime of at least 6 months. The total weight should be of the order of 85 kg, including the 20 kg for the scientific instruments.

The ESRO II satellite will carry out six experiments for measurements of solar x-ray radiation with a wavelength between 1 and 60 angstroms, and the particle radiation in the radiation belts from the sun and from outer space, including primary electrons of the cosmic radiation. The plane of the orbit will remain more or less perpendicular to the earth–sun line. For this reason, the orbit will have an inclination of 78 degrees with respect to the equator of the earth. Since for such an orbit the orbital plane will rotate 1 degree per day in the direction of the earth's rotation, the satellite will remain in the sunlight for almost its entire lifetime. The apogee of the orbit will be 1100 km and the perigee about 300 km, and the weight of the satellite will be about the same as that of ESRO I.

The proposals submitted by the scientific groups have indicated a strong desire for satellites with some kind of stable orientation, in particular for astrophysical studies. The medium-sized satellites proposed are of a size and weight suitable for such stabilization and for launching by the Thor-Delta vehicle. For astrophysical work a satellite weighing about 200 kg (including about 50 kg for scientific instruments) could be put into orbit at an altitude of about 500 km. (A heavier payload can probably be carried if the advanced version of the Thor-Delta vehicle is used.)

The first payload will contain astronomical instruments: an ultraviolet telescope with broad-band filters and infrared detector, an ultraviolet telescope with a grating spectrograph, a proportional counter for measuring celestial x-rays, and a spark chamber for measuring cosmic gamma-rays. This satellite should be launched in 1968 or 1969.

For the investigation of the interplanetary plasma and the interplanetary magnetic fields the development of a satellite with a highly eccentric orbit (apogee at least 30 earth radii) is planned. The payload of this satellite will consist of measuring instruments for low- and high-energy protons, for primary electrons, for the magnetic field, and for the interplanetary plasma. Furthermore, an ion cloud will be ejected from the same spacecraft so that the interaction of the cloud with the solar wind can be studied. The satellite will be brought into orbit by a Thor-Delta vehicle, and the weight of the scientific payload will be of the order of 20 kg. The launching should occur during the time of the maximum of solar activity at the end of 1968 or at the beginning of 1969.

Large Astronomical Satellite

One of the major projects of ESRO will be the development of the large astronomical satellite. The plans for such an instrument were first discussed by an *ad hoc* group of European astronomers and astrophysicists and then in spring 1964 at a colloquium attended by a large number of astronomers. These discussions finally led to the formulation of the following requirements: The main scientific objective should be to obtain spectra of stars in the range 900 to 3000 Å, with a resolution of 1 Å or better. In addition, a broad-band x-ray recording instrument and a gamma-ray telescope are proposed for the payload. First preliminary design studies for the spacecraft have been carried out with a European vehicle which is to be developed by another organization, the European Launcher Development Organization (ELDO). At the beginning of these design studies, it was stated that the ELDO A vehicle should be able to carry in its nose cone a cylinder 2 meters in diameter and 3 meters long and weighing about 1000 kg to a polar circular orbit at an altitude of 600 km. The launching range is to be Woomera in Australia. According to the specifications, it may be possible to put a mirror telescope with a diameter of 80 centimeters into orbit.

The detailed requirements for such a satellite are still being studied. It is likely that several of these large astronomical satellites will be launched. They would form part of an integrated scientific program in astronomy, which will also include experiments to be carried out by stabilized sounding rockets and medium-sized stabilized satellites. Proposals for the various scientific instruments (mirror telescope with different spectrographs) have been developed by three different European groups. How rapidly the development of these large astronomical satellites will proceed depends at present on the uncertainties of the ELDO A launcher. Originally it was planned that the first Large Astronomical Satellite (LAS) should be launched in 1970.

Future Plans for Spacecraft

The scientific program outlined here gives an indication of the immediate aims of ESRO, and the projects discussed are those which have been agreed upon by the Council or recommended to it. In the coming years, other sounding rockets and satellites will be launched. For the purpose of planning it has been assumed that each year about 50 sounding rockets will be launched. Furthermore, more medium-sized stabilized satellites and more satellites with highly eccentric orbits might be available for other scientific experiments.

In addition, proposals that ESRO engage in a second large project are being assessed. The possible projects include a lunar mission, soft landing of instruments or a lunar satellite, and a "fly-by" mission to a comet or planet. In particular the "fly-by" mission to a comet is being studied in more detail. The development of a highly stabilized satellite for solar observations has also been proposed recently.

In summary, it is expected that about three to four spacecrafts will be launched per year from about the fifth year on.

ESRO Establishments

For carrying out its program ESRO will have a number of establishments where it will provide the necessary technological and administrative facilities. In addition some research associated with the ESRO spacecraft program will be done in two establishments.

The main establishment of ESRO will be the European Space Technology Center (ESTEC), to be located in Noordwijk, Holland. Here the technological work will be carried out and contracts with the European industry will be supervised. ESTEC will be responsible for the design, development, and construction of the spacecraft, including the integration of the scientific payload into the spacecraft. Applied research on technological problems related to space research will also be carried out by ESTEC.

The total staff will be about 800 persons; about 300 are already working at Delft in the preliminary set-up of ESTEC.

Furthermore, ESTEC will control the ESRO network of telemetry and tracking stations (ESTRACK) from its control center. ESRO will have four stations located near Brussels, Spitzbergen, Alaska, and the Falkland Islands. These stations are set up in such a way that they complement the network of the French Centre National d'Etudes Spatiales.

For the work on sounding rockets, ESTEC will operate a rocket range (ESRANGE) which will be established at Kiruna, Sweden. The total staff will be about 100. The range there will have two launching pads with the necessary tracking, telemetry, rocket-preparation, and safety facilities. Operation will begin at Kiruna in 1966. Also other national ranges will be used which are already available now. At present, sounding-rocket launchings are carried out mainly from Sardinia, but also arrangements have been made for use of the French range at the Ile du Levant and the Norwegian range at Andoya.

In the immediate neighborhood of ESTEC another scientific laboratory, the European Space Research Laboratory (ESLAB), will be created. It will have three main functions:

1) It will enable scientists from national research laboratories to work on space projects for a limited time as ESRO fellows, particularly when adequate facilities are not available in the scientists' own countries.

2) There will be a small group of scientists who will coordinate the work on the large astronomical satellite carried out by the scientific groups. This group might even develop a scientific payload for one of the major projects of ESRO.

3) Finally, another group of scientists at ESLAB will coordinate the other projects for sounding rockets and satellites. This third group will be the necessary link between the scientific groups in the member states and the project group at ESTEC. The total staff has not been fixed, but might be around 80.

The European Space Data Center (ESDAC), located at Darmstadt, Germany, will be mainly concerned with the processing of data obtained from sounding rockets and spacecrafts. However, it will carry out a limited program of research associated with its computer facilities, for example, in celestial mechanics and more detailed analysis and correlation of scientific results. This center will have a staff of about 80.

Finally, there will be a small scientific institute, the European Research Institute (ESRIN), located in Italy. It is set up to carry out laboratory experiments. The activity at this laboratory will be predominantly in the fields of particle reactions, electromagnetic radiation, and low-density plasma physics. The laboratory will have about 25 scientists, with a total staff of about 85.

Organization of the Work

The planning and execution of the program require special organizational and administrative facilities and also certain committees to represent the outside scientists and member states.

In an international organization like ESRO it is particularly important that each member be able to express its views, but the machinery must be such that the execution of work is not unnecessarily delayed. Since the establishments are located in different countries, a headquarters has been set up in Paris to direct and coordinate the work of the establishments and to establish the link to the member states. The directorate of ESRO is made up of the director general (P. Auger), the scientific director (B. Bolin), the technical director (A. W. Lines), the administrative director (J. Crowley), and the director of the secretariat (J. A. Mussard). The total staff of the headquarters is about 150.

The director general is responsible to the council, which is the representative body of the member states. The council determines the policy of ESRO in scientific, technical, and administrative matters. It approves the program and the budget. Each member state has one vote in the council. The president of the council until 1965 was

Sir Harrie Massey (United Kingdom). For 1965 A. Hocker (Germany) is president, and H. C. van de Hulst (Holland) and M. Golay (Switzerland) are the vice presidents. The work of the council is prepared by two committees, the Scientific and Technical Committee (chairman for 1965, R. Lüst, Germany) and the Administrative and Finance Committee (chairman for 1965, E. Ferrier, Holland).

An essential part of establishing the scientific and technical program is carried out by the four-man Launching Programme Advisory Committee (R. Lüst, chairman), which advises the Scientific and Technical Committee, especially on proposals for payloads. The Launching Programme Advisory Committee prepares these payloads with the help of a number of *ad hoc* working groups. At present there are six working groups: (i) Structure of the atmosphere (chairman, R. Frith, U.K.); (ii) Ionosphere and aurora (B. Hultquist, Sweden); (iii) Solar physics (C. de Jager, Holland); (iv) Planets, moon, comets, and interplanetary medium (L. Biermann, Germany); (v) Astronomy (P. Swings, Belgium); and (vi) Cosmic rays and trapped radiation (B. Occhialini, Italy). All proposals for investigations to be carried out by sounding rockets or satellites will be first discussed by the appropriate working groups.

Summary

The European Space Research Organization, which was established in 1964 for the purpose of promoting collaboration in space research among European nations, has made plans for its initial program. The projects already agreed upon include the launching of sounding rockets for investigations of a variety of phenomena, two small satellites for studies of ionospheric and auroral phenomena, a medium-sized, stabilized satellite and a large satellite for astronomical investigations, and a satellite with a highly eccentric orbit for studies of the interplanetary plasma and magnetic fields.

Although most of the scientific activities connected with its projects will be carried out by research groups in the member nations, ESRO will have, in addition to its headquarters in Paris, establishments in Holland, Sweden, Germany, and Italy.

It is to be hoped that this new European Space Research Organization will make important contributions to space science and space technology. The work has started, and the first sounding rockets have been launched. The outlined program is certainly not a final one, but must be kept flexible. It will open new possibilities for the scientists in Europe and certainly will enable the member states to build up space research in their countries. The success of the organization will depend on its scientific work and on good cooperation among its members.

What Are We Doing to Engineering?

By government support we are inadvertently alienating engineering education from the civilian economy.

J. R. Pierce

It is a commonplace that the federal government provides the major support of research and development in the United States. In terms of total dollars, this is true. In 1963 federal support of research and development in all sectors was 65 percent of a total of about $17.4 billion. But this percentage is by itself very misleading, as we can see from Table 1. Here industries are ranked from top to bottom in terms of net sales. Most large industries have a substantial company-supported research and development effort, aimed at improving old products and devising new ones. Government-supported research and development are concentrated in a few fields (for example, see Table 2) and are larger than company-supported research and development only in the fields of electrical communications and equipment and aircraft and missiles. Further, it appears that such government-supported research and development have not displaced a reasonable company-supported research and development, even in these industries.

This huge government expenditure for research and development in a few particular industries has been dictated by overriding and highly specialized needs or goals of extreme urgency, in space and in defense. Thus federal support of research has caused us to reach ahead, at great cost, in certain urgent directions, rather than affecting industry as a whole. This has led to achievements in nuclear submarines, supersonic aircraft, in radar and guidance, in ballistic missiles and atomic warheads, which are as astonishing as they are necessary, and to magnificent achievements in space.

The Civilian Economy

However, defense and space are only special aspects of our technology. Our synthetic fibers, our excellent and varied food products, our life-saving drugs, our automobiles and the freeways on which they travel, airlines and air terminals, the electric power and the appliances in our homes, the ease with which we can talk with people thousands of miles away, the television, newspapers, magazines, and books which keep us in touch with the world, all give us advantages over earlier generations.

When we trace the history of these technological achievements, we find their origin in science—in the discovery and understanding of the laws of nature. But essential as the understanding of

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