spectra of stars of all spectral types, to study the gas streams in and around some binary star systems, to examine with lower resolution spectra of faint stars, galaxies and quasars, to make repeated observations of objects known to show features which vary with time, and to define more precisely the way in which starlight is modified by interstellar dust and gas.

The IUE space observatory will have, by virtue of its geosynchronous position, a big advantage over previous astronomical satellites in lower orbits.

EXOSAT

The spacecraft EXOSAT, due to fly around 1980, will determine the position and examine the structure of celestial X-ray sources. In one mode it uses lunar occultation to examine source structure and the resolution thus obtained should yield information on binary stellar systems within which many cosmologists believe one of the stars to be a black hole.

Part 4

Future Scientific Projects

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The European Space Agency is presently conducting several feasibility studies. It may be recalled that such studies concern missions which have been recommended by ESA's various scientific advisory committees but which have not yet been approved by the Science Programme Committee : a project is approved on the basis of its feasibility study, which, of course, includes an evaluation of the cost.

Out-of Ecliptic and Solar Stereoscopic Mission

Proposed as a joint ESA/NASA venture, two spacecraft would be sent out of the ecliptic plane with the help of Jupiter's gravitational field. Each spacecraft would then fly over the sun almost at its North and South poles. Since all planets explored so far travel very close to the ecliptic plane, this mission would represent the first exploration of the solar system's third dimension, in a nearly symmetrical way with respect to the solar equator. Properties of particles, electric and magnetic fields would be studied, not only in the interplanetary medium but also close to Jupiter while both spacecraft swing around this planet. In addition, instruments such as a coronagraph, placed on board one of the spacecraft, would perform solar observations which, combined with terrestrial observations, would allow the study of various transient phenomena in the sun's atmosphere in a stereoscopic fashion. ESA and NASA would each build one of the spacecraft, with NASA also providing the launcher (Space Shuttle + Interim Upper Stage) and the deep space network. If the above mission were not fully accepted, a fall-back mission could consist of only one spacecraft provided by ESA, the launcher being supplied by NASA.

2.4 m Space Telescope (ST)

This is a major future project currently under study by NASA. In summary, the telescope would have a main mirror with a diameter of 2.4 m and an array of instruments including a low resolution spectrograph for faint objects, and a high spatial resolution camera. Due to the absence of atmospheric absorption, scintillation and scattering, the ST would have a unique capability to concentrate light falling on a large aperture into an image approximately 0.1 arc seconds across in the ultraviolet and the visible spectrum (and somewhat less good images in the infra-red). This would greatly benefit many areas of astronomy, including planetary, galactic and extragalactic studies, and particularly in studies in cosmology and evolution of galaxies.

Launched by the Shuttle, the ST is intended to last as long as 15 years, and replacement or refurbishment of some of its parts could be done by later Shuttle missions.

ESA has been invited by NASA to consider a possible participation in the ST project. Besides some pieces of hardware, such as the electric power system or a share in the scientific operations of the ST, ESA's possible contribution could consist of a faint object camera and a two-dimensional photon counting detector: feasibility studies have been started in these areas.

Large Infra-Red Telescope on Spacelab (LIRTS)

This is a large diameter telescope (in the range 2-3 m diameter) which is intended to observe celestial objects in the infra-red part of the spectrum in the range 20 to 300 μm : this spectral region cannot be observed from the ground because of the atmospheric absorption. Such a telescope, which would be placed on board Spacelab, would have an excellent capability to carry out high sensitivity photometric observations with high spatial resolution, as well as to measure atomic and molecular lines in the far infra-red with very high resolution. Polarimetric observations would also be performed with this instrument.

The duration of each mission is rather short, that is from 7 days up to possibly 30 days, but the possibility to refly an instrument several times, and therefore to modify or improve it, is precisely one of the unique capabilities of Spacelab.

The major problems related to this project are the thermal control of the uncooled telescope, the cryogenic system for the focal plane instrumentation, the contamination induced by Spacelab and the capabilities of the Instrument Pointing System, especially due to the weight of the LIRTS, during launching and landing.

X-Ray Spectropolarimetry on Spacelab (EXSPOS)

This mission consists of a set of instruments to be flown on Spacelab to study the spectra of cosmic X-ray sources and detect polarised X-ray emission. So far, very little emphasis has been placed on X-ray high resolution spectroscopy and polarimetry. The energy range to be studied extends from 2 to 10 keV. High sensitivity (and, therefore, good time resolution for the brighter sources) spectrometry and polarimetry, good spatial resolution, broad band spectroscopy are among the features of the various instruments. Since the proposed payload places only light demands on the Spacelab resources, it would be well suited for a great number of Spacelab missions. In about 8 missions of 7 days, this experiment could perform the desired observations of all relevant X-ray sources of the Uhuru catalogue.

Atmosphere, Magnetosphere and Plasmas in Space (AMPS)

AMPS is a programme studied by NASA, in which the capabilities of Spacelab in terms of weight, volume and power supply will be used to study simultaneously the properties of the earth's atmosphere and magnetosphere, in order to try to understand the relations that exist between them. To this effect, experimentation with the earth's unconfined and collisionless plasma environment may be directed towards understanding better the cause-and-effect links that control the magnetosphere ; these plasma experiments are also interesting in their own right. ESA is working towards a cooperation with NASA, and to this effect, is presently studying various kinds of tools that could possibly become part of the AMPS programme.

Atmospheric Sounding

The region of the Earth's atmosphere between approximately 35 and 120 km remains relatively unexplored, and several physical and chemical processes of this region are still not well understood. To this intrinsic scientific interest in studying these processes, one must add the fact that if one does not properly understand how the atmosphere functions, one will not be able to assess the possibly harmful effects of man-made perturbations of the upper atmosphere.

Active Sounding by Laser Beams (LIDAR)

In this experiment, the instrumentation consists of a powerful laser beam, a transmitting telescope, and a telescope to collect the backscattered signal which has to be analyzed by appropriate detectors. A study is presently under way to study such a LIDAR system, and its compatibility with the Spacelab capabilities. The LIDAR is a candidate for the first Spacelab mission.

Passive atmospheric sounding

There exist several powerful techniques for sounding the atmosphere by passive means (analysis of the absorption of solar radiation, or of self-emission of the atmosphere in the infra-red). Such techniques and their implementation on Spacelab are presently being studied by ESA and are candidates for the first Spacelab mission.

Subsatellites and other studies

A variety of active plasma experiments can be carried out from Spacelab with the help of simple, short-lived (and therefore cheap) subsatellites that are to be released from Spacelab. Some of these satellites can move freely and some can remain attached to Spacelab by long tethers (up to several kilometres) and eventually be retrieved at the end of the mission. In the latter case, the satellite can be very simple since power and data can be transmitted through the tether to and from Spacelab.

Besides these feasibility studies, several so-called " mission definition studies " are being conducted by ESA. The purpose of these studies is to define the scientific objectives of a mission and to provide a preliminary assessment of engineering problems related to it. From among these studies, several feasibility studies will be selected later. At a fairly advanced level of definition, there is the Grazing Incidence Solar Telescope for Spacelab, for detailed spectral, spatial and temporal observations of the sun in the X-ray spectral range. Also to be mentioned is an automatic satellite for the study of the infra-red diffuse (or " cosmic ") background, which requires an entirely cooled telescope (at liquid helium temperatures). Technological developments in the area of cryogenics are not only needed for infra-red experiments, but also for super-conducting magnets which can be used with great benefit for cosmic rays observations (magnetic fields of up to 3 Tesla are being considered). We also are carrying out studies for astrometric missions (either from Spacelab or, more likely, from an automatic satellite), a fundamental discipline which has been neglected so far in space research, and for a Solar Probe mission, whereby the probe would go into the sun or very closely around it, so that accurate measurements of the quadrupole moment of the sun could be obtained, together with in-situ measurements of the solar outer corona. It has also been recognized that there is a need for more missions that could rely on traditional launchers, in contrast to the forthcoming Shuttle era (astrometry and infra-red background belong to this class of shuttle-independent missions). A small number of such studies, presently under selection, are under way.

Finally, in addition to the " traditional " fields of space research, we should like to mention briefly the various Life Sciences disciplines, as well as the numerous experiments that are considered in the field of Material Sciences. Both of these categories of science are being considered in the context of Spacelab.

Life and Material Sciences

Following an assessment by the Life Sciences Working Group, with respect to scientific value and technical requirements, the following experiment objectives were recommended :

- various experiments on animals
- vestibular and physiological studies in zero gravity environment
- effect of hard environment, especially HZE particles, on biological systems
- studies of cell cultures in zero gravity environment
- effects of zero gravity on plant organisation.

The major piece of equipment considered so far is a sled for vestibular studies. This would consist of accelerating the sled plus a human or animal specimen seated in it, at well defined rates, in order to try to understand better the vestibular function (there are some as yet unexplained phenomena evidenced by space-sickness).

After some preliminary studies, ESA has arrived at the conclusion that it is particularly interesting to study material processes under zero gravity conditions, in the following fields : electrophoresis, crystal growth, fluid physics and metallurgy. This encompasses a wide variety of possible experiments. After some results already obtained from Skylab missions, we feel that Spacelab is undoubtedly an ideal tool for carrying out a research programme in these different fields. Research on material processes is part of the experimental objectives of the First Spacelab Flight.

Priorities

There is evidently no lack of appealing scientific missions for the future years, and nothing has been said of several other possible future missions, which are now being considered as part of a long-term planning exercise.

Obviously, the limitation of financial means requires a selection to be made, after completion of the various feasibility studies, for those projects which could be carried out within ESA,s mandatory scientific programme. Such a selection will take place in the Summer of 1976. In some cases, other sources of financing may be sought for so-called " special projects ".

As for the starting dates of new projects, the situation regarding the first Spacelab mission is pressing : decisions about the LIDAR, the vestibular sled and the various material sciences will have to be taken early enough to allow the detailed design phases of these projects to start in the second half of 1976. For projects not related to the first Spacelab mission, a new start could occur in 1977.