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First Spacelab Mission

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(one of three European Payload Specialists from amongst whom one will be selected for flying on the Mission)

From the year 1983, Spacelab will exist as a versatile tool available to scientists to perform space experiments from low earth orbit in such disciplines as *Life Sciences, Materials Science, Atmospheric Physics, Space Plasma Physics, Astrophysics, Solar Physics* and *Earth Observation.*

The laboratory, consisting of one or several pallets — experiment supporting structures — and, normally, of a pressurized module, will be built into the cargo bay of the Space Shuttle Orbiter and will be carried into orbit for missions of seven to 30 days. During the whole mission, it will remain attached to the Orbiter and will use a number of resources provided by the Orbiter, such as electrical power, heat disposal, attitude control and crew living quarters.

Among the unique features of Spacelab as a science and technology laboratory in space, is the possibility of human intervention, the recoverability of samples and experimental hardware, relatively massive equipment and adequate power supplies, permitting a variety of inter-related or independent experiments to be performed simultaneously. For these reasons, Spacelab offers a considerable attraction to experimenters in various scientific disciplines, especially to those who have not yet been involved extensively in space experimentation such as the life and materials scientists.

Spacelab is presently built in Europe, under the control and management of the European Space Agency (ESA), by a consortium of European aerospace and electronics firms led by ERNO Raumfahrttechnik in Bremen, West Germany. The engineering model of Spacelab has already been completed and is presently undergoing acceptance testing at Bremen. The first flight unit will be delivered to ESA in the middle of next year. A second Spacelab has recently been ordered by NASA.

Figure 1 is an artist's impression of Spacelab in the Space Shuttle Orbiter. The configuration shown, one of many possible, consists of the long module and two pallets. The open cargo bay doors and part of Spacelab and the Orbiter's fuselage panels have been omitted for clarity.

The Mission

The main objective of Spacelab's first mission will be to test the laboratory itself. Consequently, a substantial fraction of the time in orbit will be devoted to testing, including a study of the response of the laboratory and its subsystems to various thermal stresses, and the investigation of environmental parameters. Although scientific objectives will be given second priority for this mission, every effort will be made to maximize the scientific data output of the payload and we hope that we shall be able to prove the suitability of this concept of an experimental platform for a range of disciplines.

The configuration chosen for the mission will comprise the long module and one pallet. The module will be equipped with a scientific airlock permitting temporary exposure of instruments from the module interior to the space environment, and a high quality optical window that will be used for Earth photography.

The launch of Spacelab 1 is presently foreseen for May 1983 on the tenth Shuttle flight. Originally scheduled for December 1980, it has experienced successive slips due, mainly, to difficulties that were encountered in the development, production

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and testing of the first Orbiter "Columbia", essentially with the tiles used to provide thermal protection and with the main engines. Launched from the Kennedy Space Center in Florida, Spacelab 1 will be put into a circular orbit with an altitude of 250 km and an inclination of 57°. The mission will last seven days.

Selected Experiments

Proposals for experiments in various scientific and technical fields were invited for this flight, and from the replies a total of 76 were chosen by ESA and NASA in the beginning of 1977. They cover all the disciplines mentioned earlier, and they share about equally the Orbiter and crew resources for the ESA and the NASA parts. In the field of *Life Sciences,* several experiments will permit the gravitational influence on biological systems to be studied and, in particular, the adaptability of these systems to the zero-g environment. A number will focus on man's vestibular and cardiovascular systems. The effect of weightlessness on the human immune response will also be observed. On the pallet, a biostack will allow investigations of the influence of hard particle radiation on biological samples, sandwiched between track detectors, and another experiment will observe the effect of vacuum and solar UV radiation on micro-organisms and biomolecules.

Most of the proposed *Materials Science* experiments will be performed in the facilities mounted in the "Material Science Double Rack". These facilities will include a Fluid Physics Module and various furnaces, plus some special purpose instruments. The Fluid Physics Module is designed to investigate some properties of rotating and non-rotating fluid zones between two plates, as well as capillary forces and the dynamics of the spreading of a liquid on a solid surface. The results will be recorded on film for later evaluation on the ground. The furnaces will be used to study crystallization and metallurgical processes, the processed samples being returned to earth for analysis.

Studies in *Atmospheric Physics* take advantage of the low orbit of Spacelab and its high carrying capability to use complex instrumentation with high spectral resolution and high sensitivity. The Grille Spectrometer, for instance, is an instrument for high-resolution line spectroscopy. It will track the sun at sunrise and sunset and record absorption spectra of the atmosphere in various wavelength intervals and at various elevations above the horizon. Other instruments will study the Lyman-alpha emission of H and D, and monitor OH emission features in the high atmosphere.

Interesting results are expected from the group of *Plasma Physics* experiments. They will allow a detailed study of the plasma-physical processes operating in the ionosphere and magnetosphere by recording the effects (neutralisation, triggered waves, instabilities and interactions with the local atmosphere) induced by 10 keV ion and electron beams injected into space of maximum current 3 m A and 100 m A respectively. Detectors include receivers (up to 100 MHz), an RF plasma probe, an electron temperature probe and two particle energy analysers.

The first Spacelab mission is not ideally suited to studies in *Astrophysics* because of the relatively short flight duration and the lack of accurate pointing capability of the Orbiter in the absence of the "Instrument Pointing System" that will be available only on later flights. Nevertheless, two wide-field UV instruments have been selected, the Far Ultraviolet Space Telescope (FAUST), and the Very Wide Field Camera, for which the 0.1° pointing stability of the Orbiter will be sufficient. The very Wide Field Camera is a particularly remarkable instrument with its field of 60° which will allow a determination of the distribution of the diffuse UV emitted light in our galaxy as well as of other large scale radiation sources.

There will also be one X-ray spectroscopy instrument on board, as well as a cosmic ray particle detector, the "Isotopic Stack".

Three instruments will, for part of the mission, be looking at the Sun as a set of *Solar Physics* experiments. Two absolute solar radiometers will measure the total radiant energy from the Sun from the far UV to the far IR, with an accuracy of 0.1%, and another instrument will simultaneously record the solar spectrum from 1900 Å to 4 μm for identification of the spectral elements responsible for any change in the solar constant determined from the measurements with the radiometers.

Finally, two instruments will be Earth-oriented. As part of the *Earth Observation* programme, a Metric Camera will take high resolution pictures of the Earth for mapping purposes, and a large Microwave Facility will be used to monitor the wave structure of the ocean surfaces. A synthetic aperture radar mode will also be used for the same facility for surface mapping of the Earth.

The Crew

There will be six crew members on board the Space Shuttle Orbiter during the Spacelab 1 flight. Two of these will be the Commander and the Pilot, both Pilot Astronauts from the Astronaut Corps at Johnson Space Center, Houston, Texas. The duty station of the Commander and Pilot will be the Flight Deck, or upper part of the front section of the Orbiter (see Fig. 1).

Two other crew members, the Mission Specialists, have already been chosen by NASA for this mission. Owen Garriott and Robert Parker, also Astronauts from Johnson Space Center, will spend most of their time performing payload operations, but will also be responsible for the management of the Orbiter resources for Spacelab, and for the operation of the Spacelab subsystems supporting the payload.

Finally, two out of five Payload Specialists will fly on this mission, one of the two Americans, Mike Lampton and Byron Lichtenberg, and one of the three Europeans Ulf Merbold (German Fed. Rep.), Wubbo Ockels (The Netherlands) and the author (Switzerland). The responsibility of the Payload Specialists on board will be entirely in the area of payload operations. They will also, like the Mission Specialists and occasionally the flight crew members (Commander and Pilot), serve as subjects for a number of biomedical experiments. The choice of the "flight" Payload Specialists (as opposed to the "ground" Payload Specialists, who will not fly) will be made only a few months before the mission.

The Mission and Payload Specialists on board will form the "Center of Control" for the execution of the Payload Flight prepared prior to the mission, although possible modifications may be dermanded from the ground during flight. A large number of experiments will be controlled from one of the two terminals of the on-board Experiment Computer, comprising a CRT data display unit and a keyboard. By means of experiment dedicated displays, a crew member will be able to monitor the status of a substantial fraction of the payload and will also get, from some experiments, scientific data to which he will hopefully be able to react in real time. The keyboard will provide the means for the crew to change experimental parameters, as well as perform a number of other payload related commands.

Payload operations support will also be provided from the ground during the mission. This will be one of the roles of the Payload Operations Control Center (POCC) at the Johnson Space Center. The POCC will be manned by the Spacelab 1 Investigators and the back-up (or ground) Payload Specialists, among others. Digital command and data, as well as voice link will be available between Spacelab and the POCC via a set of two relay satellites permitting a coverage of about 60% of the orbit time, depending on mission profile.

The whole crew on board will work on alternating 12 hours shifts. Spacelab will be occupied 24 hours a (terrestrial) day. At any given time during the mission, at least either the Commander or Pilot will be on the Flight Deck, taking care of the attitude control of the vehicle and the health of the Orbiter subsystems, and two payload crew members (one Mission Specialist and one Payload Specialist) in the Spacelab module.

Payload Crew Training

Our training started right after selection in the middle of 1978. In an early phase, the crew travelled to a number of research laboratories in Europe and the United States, and was briefed by the Investigators of nearly every experiment on their scientific objectives. General lectures were also given, at the request of the crew, to provide a general understanding of the various disciplines involved.

This phase was followed, from mid-1979, by what I would call an operational phase, in which the crew had the opportunity to visit, a limited number of the same research laboratories where the Investigators and their teams had, in the meantime, assembled models, prototypes or training versions of their experiments. The crew had then the opportunity of learning to handle equipment that was, for the most part, very similar to the Flight Units that will soon be delivered by the Investigators to ESA and NASA. These training sessions were very fruitful, and operational concepts and procedures evolved substantially as as result of the knowledge and experience gained.

The operational phase is not ended yet, but due to the postponement of the mission, a slippage has also occurred in the development and preparation of experiments, to such a point that a hiatus of one year has now been inserted in the training plan of the payload crew, from July 1980 to July 1981. There has been, and will be no or very little payload-related training for our mission during this period.

Following negotiations between ESA and NASA, the latter has accepted to train during this year, two European Payload Specialists (including the author) as Mission Specialists at the Johnson Space Center. This training includes academic-type courses on manned spaceflight related subjects, technical courses on the Space Shuttle, technical assignments, and extensive flight training on NASA's T-38 jet aircraft as part of operational and environmental training.

On July 1981, our payload-related training will be resumed and will concentrate on the use of an off-line crew training facility at the Marshall Space Flight Center, Huntsville, Alabama. We shall also be involved in the on-line experiment integration phases in Europe and at the Kennedy Space Center. As in the past, our interaction with the Investigators will remain active to ensure an optimization of the payload operating procedures that are likely to evolve until a few months before flight. The mission itself will be the ultimate test of the thoroughness and quality of our training.

Optical Bistability

Towards the All-optical Computer

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An optical bistable device is one which has two states of transmission for one input intensity. With increasing incident intensity it can, at a given value "switch up" to a state of high transmission and stay in this condition, even if the incident intensity is significantly reduced. On further reduction, however, a specific point is reached when it "switches down" to a lower transmission level and output intensity is dramatically cut. The transmission state of the light beam providing the "holding power" can thus be read out from the ouput intensity of a pulsed beam addressed to this "all-optical memory".

The basic element is a parallel sided Fabry-Perot resonator filled with a medium whose refractive index depends on the applied light intensity. It operates as shown in the Figure. At low incident intensity, the resonator pass frequency is detuned upwards in respect to the frequency of the incident laser beam. As the laser intensity I is increased, the optical thickness increases: $nL = (n_1 + n_2 I)L$.

The result is that the resonator pass frequency is pulled towards the laser frequency. Then as interferometer resonance is approached, the intensity within the resonator also increases which in turn changes the refractive index and hence optical thickness ever more rapidly. At first the output/input curve becomes supra-linear and then eventually acquires a negative slope. At this point the device becomes unstable and the transmission jumps discontinuously to a value near the maximum possible. On reducing the power of the incident beam, the internal field is already established and remains high down to a level that is less than that at which "switch-up" occurred. This produces the hysterisis effect required for the optical memory.

Using two input beams, with a slight detuning of the laser frequency in respect to the resonator frequency, allows the output-input characteristic to become the direct analogue of the transistor and so give signal gain. This "three terminal optical circuit element", which operates by transference of optical phase thickness, is known as a "transphasor".

Based on the principles outlined above, the range of devices which have already been produced includes memories, amplifiers, AND and OR gates, pulse clippers and power limiters so that, in principle, the all-optical computer circuit elements needed to construct an all-optical computer have been demonstrated in the laboratory.

Historically the idea of optical bistability was advanced by Abraham Szöke and colleagues from M.I.T. They attempted to demonstrate *absorptive* bistability but it was not until 1975 that Sam McCall and Hyatt Gibbs at Bell Laboratories established *dispersive* bistability in a sodium vapour-filled interferometer. Devices based on this principle are large and slow and recent progress dates from the discovery in 1978 of giant non-linear effects in the semiconductor InSb by David Miller and colleagues at Heriot-Watt University, Edinburgh. This was applied to bistability in 1979 simultaneously with the Bell group's observations in GaAs.

The use of semiconductor materials has brought a considerable breakthrough with many new experiments now possible utilising a third order non-linear susceptibility: