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European Use of Space Shuttle

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ABSTRACT

Europe's association with the Space Shuttle started in 1973 when the European Space Agency (ESA) signed a Memorandum of Understanding with NASA for the development in Europe with European funds of Spacelab. In addition, it was agreed that ESA would provide approximately one half of the first Spacelab payload which will be carried on the SL-1 mission in September 1983. Further usage of Spacelab is foreseen either in missions dedicated to European countries or in missions shared with NASA. Also, it is anticipated that European space projects will make use of the launch and recovery capability of the Space Shuttle when these services are considered to be cost attractive. Finally, augmentation of the Shuttle's capabilities is another likely area of participation through the provision of a European-built upper stage.

This paper summarises these activities both from an ESA-NASA point of view and from the outlook of bilateral (i.e. NASA-ESA Member State) co-operation.

INTRODUCTION

European involvement in the advanced Space Transportation System (STS) commenced in the early 1970s. In response to an invitation from NASA to partake in the programme and after studying a number of options, ESA chose the orbital laboratory, now called Spacelab, as its contribution to the STS. The flight hardware of this system has now been delivered to NASA. Its development provided ESA and European industry with an opportunity to join in an advanced technology programme and furnished Europe with an opportunity to become involved in manned spaceflight.

Having developed such a sophisticated system as Spacelab the next natural step is to use it. ESA has conducted numerous studies on Spacelab utilisation and intends to use the unique environment provided by Spacelab to advance its investigations in science, applications and technology. This use of Spacelab will start with the first flight in late 1983 with a 50% contribution to the joint ESA-NASA SL-1 payload and continue, hopefully, through this decade. The ground-work and experience provided by Spacelab in manned systems technology has led ESA to consider contributing to the next step in orbital systems development and a desire exists in Europe to be part of the next evolutionary step.

Of course, the Space Shuttle will carry other payloads than Spacelab - satellites, upper stages and so on - and again any advantages provided by the Shuttle as a launch vehicle will be an important consideration in Europe's evolving space programme. Thus, Europe's use of the Space Shuttle is foreseen as taking advantage of those features - reusability, recoverability and high carrying capability - that can enhance its future space endeavours.

This paper provides a summary of potential uses of the Space Shuttle by Europeans and covers the many aspects of involvement. It should not, however, be taken as a plan and no commitment to any of the ventures quoted is intended.

ESA AND ITS MEMBER STATES

In order to fully understand the European approach to space it is necessary to know the relationships that exist between the European Space Agency, ESA, and its Member States. The latter are shown in Figure 1 and are: Belgium (B), Denmark (DK), France (F), Netherlands (NL), Italy (I), Switzerland (CH), Spain (E), United Kingdom (GB), Ireland (IRL), Germany (D) and Sweden (S). In addition, Austria (A), and Norway (N), are Associate Members and Canada (CND) is closely associated with some of the Agency's programmes. Each Member State provides for ESA's budget and may partake, according to its financial contribution to Agency programmes approved by the Council. This ensures that the smaller States get a chance to take part in large, high technology programmes which they could not afford on their own.

In addition, however, each Member State may wish to pursue a National Space programme of its own and this is particularly true of the larger Member States - Germany, France, United Kingdom and Italy. Co-operation with other space bodies is encouraged so that international co-operation is possible at the level of ESA itself, bilaterally or among any number of motivated countries or Agencies. In fact, co-operative support of a Member State national programme by ESA is also possible.

In the following descriptions, many of these co-operative ventures may be discerned. In this context one might cite the following joint actions: ESA-Germany on the Spacelab D-1 mission, ESA-NASA on the Spacelab SL-1 mission and NASA-Italy on the IRIS project.

USE OF SPACE SHUTTLE AND SPACELAB

Spacelab

The Spacelab programme is a co-operative ESA-NASA venture. ESA* funds the design and development of Spacelab whereas NASA is responsible for its launch and operational use. Spacelab is, in fact, a basic element of the Space Transportation System. It is modular in construction, so that its configuration may be adjusted to best meet the mission requirements and is reusable. It is an integral part of the Orbiter in that it is carried to and from low-Earth orbit in the cargo bay and remains there throughout the mission. Exposure to the environment is obtained through opening the cargo bay doors and the desired view angle is provided by the Orbiter vehicle orientation.

Spacelab consists of a pressurised module - the laboratory within which man-tended experiments may be performed - and a pallet - the observatory for carrying instruments for direct exposure to space. The latter may be operated from the Orbiter, the module or from the Payload Operations Control Center (POCC) on the ground. The Spacelab module is composed of two identical cylindrical shells (2.7 m in length) enclosed by two end cones whereas the pallet comprises up to five segments, each approximately 3 m in length. Spacelab may be flown in the module-only, module + pallet or pallet-only configurations. It provides subsystems to ensure basic experiment support supplied through standard interfaces including physical accommodation, power, thermal control and data management.

An Engineering Model and Flight Unit have already been delivered to KSC (Figure 2) and integration and test procedures are currently proceeding. In fact, Spacelab programme hardware has already flown on the Shuttle, since Engineering Model pallets were used to carry both the OSTA-1 and OSS-1 payloads into orbit (Figure 3).

The First Spacelab Payload (FSLP)

The ESA-NASA Memorandum of Understanding concerning the Spacelab programme states that "the co-operative use of the first Spacelab Unit will be encouraged throughout its useful life although not to the exclusion of cost reimbursable use"**. This co-operative use will start with the first Spacelab flight, which will utilise the long module + one pallet configuration, following the joint planning of objectives and of the mission itself. The NASA and ESA complements of the SL-1 payload will share the resources available.

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* All ESA Member States (with the exception of Ireland and Sweden) and Austria contribute to the Spacelab programme.

** Note, any subsequent Spacelabs desired by NASA will be purchased in Europe; a second Spacelab unit is presently on order.

Following an Announcement of Opportunity in Europe some 60 experiments were chosen to represent the disciplines of Atmospheric Physics and Earth Observations, Space Plasma Physics, Material Sciences, Astronomy and Solar Physics and Life Sciences. Some 35 of these experiments are in the field of Material Sciences and 32 of which are accommodated in the Material Sciences Double Rack facility (Figure 4) which, for example, permits investigations in solidification of alloys, crystal growth, thermodiffusion and hydrodynamics. Investigators from all ESA Member States, with the exception of Ireland, and Austria, are represented in the FSLP and a European Payload Specialist will be on-board during the flight. The experiment equipment weighs 1392 kg. All this equipment, together with the necessary support equipment and software are now ready and all the FSLP experiments have been tested and integrated into a payload. Figure 5 shows those FSLP experiments to be flown on a bridge which will be mounted on the pallet. In addition, some experiments will be accommodated in the module. Prominent is the 2 m antenna of the Microwave Remote Sensing experiment which will provide ocean and surface data for nearly 50 research groups throughout the world.

The delivery date for FSLP at the Kennedy Space Center is 24 May 1982, for a launch in September 1983 into a 57 deg, 250 km orbit. The interim period will see the combination of FSLP with the NASA complement and the assembly and check-out of the total SL-1 payload. During the 7-day mission, European Investigators will work in the Payload Operations Control Center at Johnson Space Center, playing their role in the SL-1 mission which promises rich rewards for science and will demonstrate the capabilities of Spacelab in many and varied science and applications fields.

German D-1 Mission

This German national mission is the subject of a paper presented at this Congress (Ref.1) and will not be described in detail. It represents a bilateral co-operative activity between Germany and NASA but ESA, on behalf of its Member States, will also make a significant contribution by supplying the Space Sled, Biorack and an advanced version of the Fluid Physics Module to the D-1 payload. German contributions include a Materials Laboratory, Process Chamber, Material Science Double Rack and Navigation Experiments (NAVEX). Experimenters originate mainly from Germany but many other European countries are represented.

The Spacelab configuration chosen is the long module plus a simple support structure and launch is scheduled for mid-1985. The orbit altitude is 295 km. and an inclination of 57 deg. is planned. A German mission manager will be responsible for the payload and its integration, and experiment control will be executed from the German Space Operations Centre at Oberpfaffenhofen. The flight crew will include three Europeans.

Spacelab Facilities

The reusability of Spacelab and its equipment gives rise to an attractive feature for experimenters, that is the use of facilities by experimenters who need only supply "behind the focus" type equipment. In this way "small" experiment groups will have access to powerful (and often expensive) specialised equipment. The latter are called Spacelab facilities and may be supplied by international or national groups for the use of experimenters anywhere. The following are some typical facilities to be provided by Europe.

Space Sled. This facility has been developed by ESA and one flight unit and one training model are available. The Space Sled permits a human test subject to undergo a pre-programmed acceleration in the weightless environment of Spacelab. Various physical stimuli may be applied and the subjects physiological reactions can be recorded. In FSLP this is effected by a specially designed, DFVLR-supplied helmet. Such measurements, supplemented by indications of perceptual thresholds and illusions, can provide important data for vestibular research and may help considerably in the study of space motion sickness. The Sled consists of a seat which can move on a rail mounted on the floor of the module. Control of the Sled is accomplished by a crew member who operates the electronics unit contained in a standard Spacelab rack at the aft-end of the module. The Sled facility is illustrated in Figure 6.

Biorack. The Biorack is currently under development by ESA and will fly for the first time on the German D-1 mission. It composes a freezer ($-15^{\circ}C$), a cooler ($4^{\circ}C$), two incubators (range 18 to $30^{\circ}C$ and 30 to $40^{\circ}C$), a glove box, together with accessories such as a microscope and 1 g centrifuges. All these items are housed in a single Spacelab rack and provided with the necessary power, specimen containers and thermal control. Biorack will be available for studies in cell and development biology, radiobiology and plant biology, when specimens are exposed to the space environment of Spacelab. Up to about 10 experiments per flight can be visualized.

Material Science Double Rack (MSDR). This facility (see Figure 4) was developed by Germany and incorporates sub-facilities provided by France and Italy. It composes isothermal, gradient and mirror furnaces and a fluid physics module. Materials contained in cartridges may, therefore, be exposed to adjustable thermal profiles with temperatures up to $1600^{O}C$. The rack currently incorporates an ultra-high vacuum chamber (to study adhesion forces), capillarity measurement equipment (to measure liquid surface effects) and a cryostat (to explore protein crystal growth). Power, vacuum and gas systems are provided and the various constituents are controlled and monitored by means of a central console. These facilities may be used by experimenters to study metals, composite materials, crystals and transport phenomena. The MSDR will fly for the first time on SL-1 with experiments from Germany, France, Italy, United Kingdom, Belgium, the Netherlands, Spain, Sweden and Denmark. A repeat flight is scheduled for the D-1 mission.

Metric Camera. The metric camera uses a Zeiss RMK A30/23 camera with its own microprocessor for experiment control, filters and film magazines. It is mounted on the optical window and film magazines are changed by the Payload Specialists. High resolution imagery (ground resolution better than 20 m) on 24 cm wide, aerial film can be obtained for compiling topographic maps in inaccessible regions and updating those for more developed regions of the Earth. Pictures taken throughout the world during SL-1 will be widely distributed to experimenter groups in the developing world. This facility has been developed by DFVLR of Germany and developments, including an instrument for pallet operation, are foreseen.

Microwave Remote Sensing. This instrument consisting of 2 m x 1 m antenna with associated electronics is housed partly on the pallet (antenna, support tower and amplifier) and partly in a module rack (frequency generator, processor, etc.) It is a radar facility operating in the X-band (9.65 gigahertz) and was also developed by the German DFVLR. The instrument will provide all-weather sensing capability and can be operated as a two frequency scatterometer, a synthetic aperture radar or a passive microwave radiometer. Data generated during SL-1 will be widely diffused.

Fluid Physics Module. An Italian contribution to the STS programme is the development of a Spacelab facility to investigate under microgravity conditions the effects on fluid rods when stimulated with heat, rotation and vibration. This facility is named the Fluid Physics Module (FPM).

A general layout of the facility, which will be flown in the first Spacelab mission, is presented in Figure 7. The system has been developed by the Centro Ricerche FIAT. Six experimenters will use the FPM on the first Spacelab mission. The major characteristics of the FPM are given in Table 1.

Cryostat. This facility is under development by ESA. It provides a thermal environment of less than $2^{O}K$ for low noise detectors such as those used in infrared astronomy. It also has applications in the study of fluid physics phenomena at very low temperatures. The cryostat is being designed to accept an average heat load of 40 mW while keeping the low temperature for about 30 days. The cryostat, which uses superfluid helium, can accept experiments of up to 15 kg with dimensions of 20 cm (dia.) and 55 cm in length. Two engineering models of the cryostat have been built and mechanically and thermally tested.

GIRL. The German Infrared Laboratory (GIRL) is presently under development. The main elements of GIRL (Figure 8) are a telescope and four focal plane instruments installed in a cryostat containing 300 litres of superfluid helium. The project has as its scientific objective the implementation of astronomical and aeronomical observations in the wave range 2-300μ. To this purpose, GIRL is mounted on the Instrument Pointing System (IPS) and is aligned according to the measuring instruments' requirements.

IPS and GIRL are accommodated on 2.5

pallets in the Space Shuttle cargo bay. GIRL is a payload element of the originally planned German D-4 mission which is scheduled for launch in March 1987.

In addition to the above, Germany is developing a Process Chamber and a Material Science Double Rack for Experiment Modules and Facilities (MEDEA) for use on the D-1 mission. The Process Chamber will provide optical facilities for the study of transport phenomena and other physical and chemical fundamental effects under reduced gravity. MEDEA is a multi-purpose facility providing thermal environments for the study of composites and crystals (see Ref. 1).

The Tethered Satellite System (TSS)

This Italian-NASA collaborative programme is worthy of particular mention because of its scientific importance and the technical ingenuity applied to its execution.

The TSS mission involves the deployment and the retrieval from the Orbiter of a 100 km kevlar tether wire, which carries at its end a spacecraft (Figure 9), called the subsatellite, equipped with many scientific and application experiments. The tether deployment and retrieval can be accomplished either by a passive mode or an active mode. The passive mode is accomplished by controlling laws employing the tether tension control system of the deployer mechanism and the Orbiter's OMS and RCS systems. The active mode is performed by thrusters mounted on board the subsatellite and acting along the tether line.

A NASA concept study for the deployer, considers a system consisting of the tether drum, the reeling and tension control mechanism, an extendable deployment and retrieval boom and of the power supply, avionics and heat control to be mounted on a Spacelab pallet. In the Orbiter, the satellite is housed in a cradle mounted on top of the extendable boom.

The TSS development is carried out at the present time through a letter of Agreement between NASA and CNR/PSN*. NASA will study and develop the retrieval mechanism and CNR/PSN will develop the subsatellite and perform the experiments integration.

The TSS will enhance the STS capability because it will make possible experiments and observations 100 km downward or 100 km upward with respect to the Orbiter's nominal 120 n.m circular orbit.

A large number of experiments can be carried out by employing the TSS. These concern electrodynamic and plasma investigations including such observations as magnetospheric potential difference, ionospheric conductivity and structure, plasma-body interaction studies and plasma wave generation and propagation.

GRIST

Another possible ESA Shuttle-Spacelab payload which might result from an ESA-NASA co-operative programme is GRIST (Grazing Incidence Solar Telescope) which would be flown simultaneously with NASA's SOT (Solar Optical Telescope). These telescopes would use Spacelab elements, particularly the pallet for mounting the module, for control electronics and the IPS for pointing. This mission is currently under study.

Payload Integration

ESA has set up a special group for the integration of Spacelab experiments into payloads. This group - SPICE, for Spacelab Payload Integration and Co-ordination in Europe - is situated at Porz-Wahn near Cologne in Germany. This small management team performs payload accommodation, system analyses, supports the payload by providing special software and hardware and manages the physical integration of the experiments and their associated software. The testing and check-out of experiments and ensuring compliance with safety and mission requirements is another important function. SPICE also provides support of ground operations in the US, launch, flight operations and post-mission activities.

The many interfaces involved in getting an experiment on-board Spacelab (e.g. experimenters, industry) and the vital links with NASA are maintained by SPICE. The group also supervises the European crew training activities and assists in the generation of flight time lines and familiarisation and training of the experimenters with POCC activities.

* Consiglio Natzionale Ricerche/ Piano Spaziale Natzionale.

ESA Flight Crew

In cases where a particular organisation or country provides at least 50% of a Spacelab payload, that organisation or country may also provide a Payload Specialist. To cover such cases, ESA, in 1977, selected three Payload Specialists from over 2000 applicants in Europe. Apart from satisfying the agreed NASA medical standards (Class III) these Payload Specialists who originate from Switzerland, the Netherlands and Germany, respectively, possess high scientific and engineering capabilities.

Two of the originally selected Payload Specialists are now under training for the first Spacelab flight while the third is undergoing Mission Specialist training at Johnson Space Center. These three astronauts are ESA staff members and, if possible, it is intended to use them on future ESA or ESA Member State missions. Immediate targets are the SL-1 and D-1 missions.

Through this policy, it is expected that Europe will have available an international flight crew. Further, it will ensure a European presence in future manned space flight and provide European scientists and technologists with trained experiment operators of proven experience.

Microgravity Programme

ESA has just embarked on a Microgravity Research Programme to promote the conduct of material and life sciences in ESA Member States. The programme will involve the performance of experiments in the space environment to gain an understanding of the part which gravity plays at all levels of life. As part of this programme it is intended to fly at least partial payloads on Spacelab and sounding rockets. Many single experimenters and experimenter groups in Europe will, therefore, be given flight opportunities using tried equipment through reuse of the appropriate facilities. The following elements will be used:

- Material Science Double Rack or its component facilities;
- Space Sled;
- Updated Fluid Physics Module (an improved version of that to be flown on SL-1);
- Biorack;
- Equipment developed for the European rocket programme TEXUS.

The first two elements have already been developed whereas the remainder will be produced within the Microgravity Research Programme.

Presently, flight opportunities of about once per year are foreseen (the funding amounts to about 10M$ per year) but the demand may grow if initial results are considered to be of great significance. Spacelab presents the first opportunities for prolonged experimentation under microgravity conditions and the European material and life sciences communities are eager to take advantage of these opportunites through ESA's Microgravity Research Programme.

In addition, it should be mentioned that some European countries, e.g. France with its Mephisto alloy solidification experiment for MEA, will also participate on a bi-lateral basis in NASA microgravity projects.

Spacelab-2 and -4

Although strictly a NASA mission, the second flight of Spacelab in the form of three pallets plus an igloo will see the Space Shuttle carrying two European experiments into space. These experiments originate from the United Kingdom and represent a significant portion of the payload. They are:

- Coronal Helium Abundance Experiment;
- Soft X-ray Imaging Telescope.

These experiments were chosen by NASA for SL-2 as the result of an Announcement of Opportunity and are typical of the collaborative projects an ESA Member State may have with NASA quite independent of ESA. The choice is illustrative of the considerable experience and experimental talent that exists in the United Kingdom astronomy community. The flight is scheduled for November 1984.

Additionally, an experiment originating from the United Kingdom entitled "Post Illumination Onset of Plant Mutation at Zero Gravity" has been selected as part of the payload for SL-4. This mission is devoted to Life Sciences, and the launch is set for October 1985.

USE OF SPACE SHUTTLE AS A LAUNCH VEHICLE

The large lifting and volume capability of the Space Shuttle means that it is an attractive means of putting payloads into orbit - if the cost and orbital conditions are considered favorable to a particular project. Of course, Europe has its own launch vehicle - Ariane - so that each project must be examined on a case-by-case basis. For ESA-NASA collaborative ventures, which play a large part in ESA's scientific programme, the Space Shuttle is a particularly attractive prospect.

Two important programmes that are being conducted on a cooperative basis with NASA are the International Solar Polar Mission (ISPM) and the Space Telescope. ESA's satellite (Figure 10) for the ISPM programme will be launched by the Space Shuttle and an upper stage. It will be launched in May 1986 and swing-by the planet Jupiter, after which it will make measurements of the interplanetary medium well outside the thin disc near the ecliptic plane - truly the first out-of-the-ecliptic probe. The spacecraft will later fly over the pole of the Sun to examine its structure and atmosphere, followed by a recrossing of the ecliptic plane and a traverse of the opposite hemisphere of the Sun.

ESA has a 15% share of the Space Telescope's observing time in return for an equivalent contribution by ESA to the development and operational phases. This contribution consists of provision of the Faint Object Camera and associated Photon Detector Assembly, manufacture of the solar arrays and deployment mechanisms and support of the Space Telescope Science Institute. The Space Telescope will be launched by the Space Shuttle in 1985 and revisits are planned for maintenance and repair. Retrieval and relaunch after refurbishment are also foreseen.

Missions contemplated by European countries independent of ESA include the German project ROSAT. Its main mission objectives are : First complete scanning of the sky with an x-ray telescope in the wavelength region of 6-100 Å and a localization accuracy of the x-ray sources which is better than one arc minute ; the detailed observation of selected x-ray sources (pointing) for their spatial structures, changes in time, and spectral characteristics ; and the improvement of the spatial resolution by one order of magnitude by means of a NASA high-resolution imager also onboard. A British mini-telescope also included in the mission extends the wavelength region as far as the short-wave UV. The x-ray satellite is planned for launch with the NASA Space Shuttle in 1987.

Other projects under consideration include the x-ray satellite SAX (an Italian-Netherlands-US project), an x-ray Telescope-Spectrometer System (SAPOS) for a cooperative United Kingdom/US mission and an atmospheric research satellite which could be a cooperative programme between the Netherlands, the United Kingdom and the U.S.

The Get Away Special (GAS) programme holds many attractions for Europe and it is expected that many countries will use this relatively inexpensive launch mode to put passive packages in orbit with the Orbiter. Countries known to intend using GAS opportunities include Germany, France, United Kingdom, Switzerland and Sweden. Of particular interest in this context are the German MAUS experiments. This programme, which uses the GAS together with other Shuttle mission opportunities, provides for low-cost, autonomous experimentation in material sciences. Some 12 different flight missions have been booked with NASA so far, the launch dates extending over the period 1982-1989 with a mission frequency of two MAUS modules per six months.

A further means of performing near-autonomous experiments is to use the accommodation offered by the LDEF (Long Duration Exposure Facility), which is launched and retrieved by the Space Shuttle. European countries have shown considerable interest in this facility and the United Kingdom already has two experiments on the December 1983 launch of LDEF.

USE OF SPACE SHUTTLE AS A FIRST STAGE LAUNCH VEHICLE

Many activities of the Italian National Space effort are oriented toward the use of the NASA Space Shuttle.

In particular, this includes a development in Italy of a complete launching system from the Space Shuttle based on some technologies already acquired in the country and by which it is hoped to permit Italian Industries to come to grips with basic problems related to Shuttle interfaces, Shuttle operations and Shuttle safety. The programme foresees the study, design and development of an "upper stage" to be employed in conjunction with the STS : the Interim Research Italian Stage (IRIS). IRIS is a spin stabilysed solid propellant upper stage which has the capability of putting a 600 Kg spacecraft on geosynchronous transfer orbit (GTO) ; this capability will be extended eventually to 900 Kg class spacecraft. The System consists of the Propulsion Module (PM) and of the Airborne Support Equipment (ASE). The PM is expendable, while the ASE is recoverable (see Figure 11).
The PM is a solid propellant motor of Isp = 296 sec. loaded with 900 Kg of propellant with a kevlar casing, and carbon/carbon nozzle. Moreover, the PM is equipped with sequencer, telemetry spacecraft separation system,command receiver and nutation damping system. The ASE, which occupies 1/8 length of the Shuttle bay, contains the main cradle, attached to the Shuttle longerons and keel, the spin table, the PM separation system and all related avionics interfacing with the Shuttle avionics. The launching procedures are kept completely similar to those employed for the NASA SSUS (PAM-D).
The IRIS system can perform various types of missions besides the achievement of a GTO from Shuttle circular orbit. As an example it can be employed for orbital plane changes or to attain high elliptic orbits for scientific satellites. Examples of candidate missions for the IRIS are the x-ray Italian Scientific Satellite, and a possible follow-on mission of NASA/UK/ Germany AMPTE. (Active Magnetic Particle Tracer Explorer). Moreover the possible application of the IRIS/ PM as an ARIANE upper stage is being studied. The IRIS programme has completed phase B and a further phase (B1) is planned. A memorandum of understanding with NASA has been signed for a launch in late 1985. The program is managed by CNR/PSN and it is developed in close contact with NASA HQ and NASA/ JSC. The PSN also uses for this program the consulting services from ESA/ ESTEC. The Aeritalia firm is the responsible contractor for the overall system, while the PM is developed by BPD-Difesa e Spazio of SNIA company.

THE FUTURE

Through its involvement with Spacelab, Europe has entered the manned space era and has demonstrated a capability for developing and producing high quality hardware. The future is not easy to predict at this stage, but the general attitude of ESA Member States is that the considerable knowledge and experience gained through the Spacelab programme should be used in contributing to future manned space activities. Naturally, space platforms and manned orbital laboratories are possible areas of exploitation by Europe and cooperative efforts with NASA in these fields appear to be attractive. All these activities would lead to further use of the Space Shuttle.

The future possibilities being examined by ESA include extension of the Spacelab module capabilities and the development of a free flyer based on the pallet or pallet-like concept. The latter has proved particularly attractive and is now referred to as the Retrievable Carrier. This concept which is dealt with elsewhere in this Congress (Ref.2), would be launched by the Shuttle and recovered by the Orbiter on another flight some months later. This vehicle holds considerable attraction for scientists in many disciplines, but early flights will emphasise experiments in Material and Life Sciences. Later applications to a space platform can be foreseen with the retrievable carrier carried to orbit by the Shuttle Orbiter,docked to the platform, and returned to Earth by the Orbiter at some later date. Figure 12 gives an artist's impression of one possible concept of the retrievable carrier based on a Spacelab half-pallet.

C O N C L U S I O N S

European interest in the Space Shuttle is evidenced by the many and varied uses foreseen for it. The Spacelab programme is an example of actual involvement in the STS programme by the provision of constituent hardware
Some of the applications cited, illustrate how Spacelab might be used. In particular, its use as an international

laboratory is encouraged and many useful facilities are being developed in Europe which might be used more universally. Further hardware contributions might be forthcoming as in the case of IRIS or perhaps the Retrievable Carrier. Europe also has plans for bi-lateral and multi-national use of the Space Shuttle as a launcher of experiments and satellites. Its use in this field will be very dependent on its cost attractiveness to the potential user. Whatever the means eventually chosen for future space exploration, Europe has the desire and demonstrated capabilities for playing an important role. The Space Shuttle is a key feature in these considerations.

REFERENCES

1. " The German D 1 Mission " G. Greger, 19th Space Congress, Cocoa Beach, Fla., April 1982

2. " Future Plans for Spacelab and Retrievable Carrier " R.L. Mory, 19th Space Congress, Cocoa Beach, Fla., April 1982.

TEST VOLUME (ZONE)	130 mm MAX.LENGTH, 100 mm MAX. DIAMETER
END PLATE DIAMETERS	40 AND 60 mm AT INJECTION SIDE 40, 60 AND 100 mm AT OPPOSITE END
ROTATION SPEED OF END PLATES	5 - 100 rpm ± 1% OR ± 0.1 rpm (SEPARATE OPERATION POSSIBLE)
ROTATION AXIS PARALLEL WITHIN	0.01 DEGREES
LIQUID INJECTION SPEED	0.5 6 $\dot{c}m^3$/sec
TANK CAPACITY	1.3 LITRES
OSCILLATIONS	0.1 - 2 Hz, 0.25 - 0.5 mm AMPLITUDE
LATERAL OFFSET	PRESET SPEPS OF 0.1 mm TO A TOTAL OF 2 mm
HEAT-UP CAPABILITIES	UP TO 60°C (INJECTION END PLATE)
ELECTRICAL POTENTIAL	± 100 VOC AT ONE END PLATE
PHOTOGRAPHIC RECORDING	DUAL SYSTEM WITH 16 mm CINE-CAMERA
VISUALISATION OF INNER FLOW	SOLID TRACERS ENVISAGED

TABLE I CHARACTERISTICS OF FLUID PHYSICS MODULE laboratory is encouraged and many useful facilities are being developed in Europe which might be used more universally. Further hardware contributions might be forthcoming as in the case of IRIS or perhaps the Retrievable Carrier. Europe also has plans for bi-lateral and multi-national use of the Space Shuttle as a launcher of experiments and satellites. Its use in this field will be very dependent on its cost attractiveness to the potential user. Whatever the means eventually chosen for future space exploration, Europe has the desire and demonstrated capabilities for playing an important role. The Space Shuttle is a key feature in these considerations.

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LATERAL OFFSET	PRESET SPEPS OF 0.1 mm TO A TOTAL OF 2 mm
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PHOTOGRAPHIC RECORDING	DUAL SYSTEM WITH 16 mm CINE-CAMERA
VISUALISATION OF INNER FLOW	SOLID TRACERS ENVISAGED

TABLE I CHARACTERISTICS OF FLUID PHYSICS MODULE

EUROPEAN SPACE ACTIVITIES

Fig. 2 Spacelab hardware in the high-bay area of the Operations & Checkout Building, Kennedy Space Center.

Fig. 3 OSTA-1 payload and Spacelab engineering module being integrated into the Orbiter cargo bay.

Fig. 4 Material sciences double rack facility for FSLP.

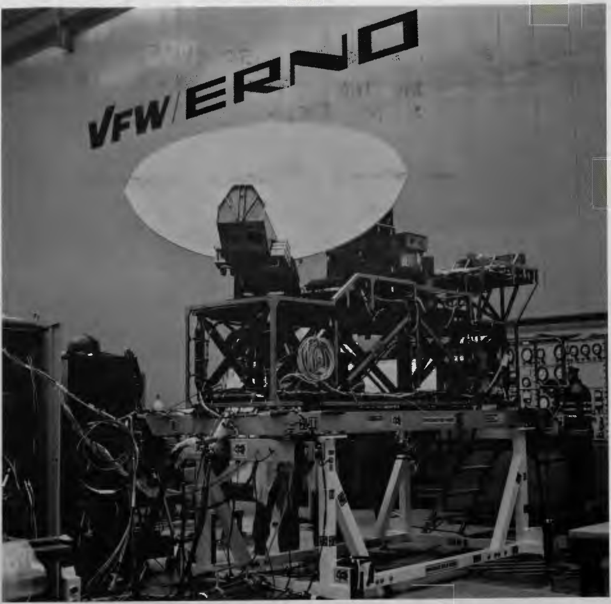


Fig. 5 FSLP experiments integrated into payload—on the European bridge assembly.

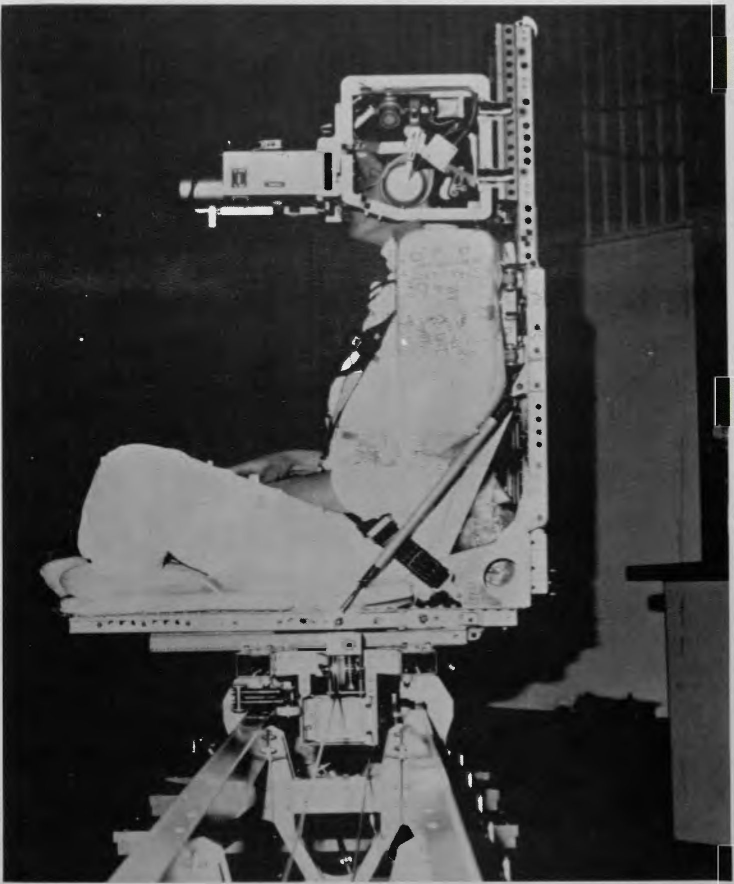
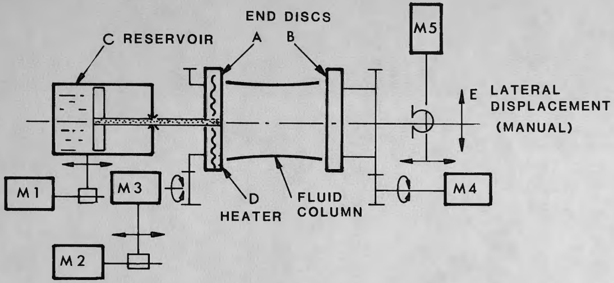


Fig. 6 Space sled facility with subject wearing helmet.



M1 MOTOR FOR TANK AXIAL DISPLACEMENT

M2 DISC AXIAL DISPLACEMENT

M3-M4 DISCS ROTATION

M5 DISC AXIAL OSCILLATION

FIG.7 SCHEMATIC OF FLUID PHYSICS MODULE

Fig. 8 The German Infra-Red Laboratory (GIRL) as it might be viewed through the rear cabin window of the orbiter.

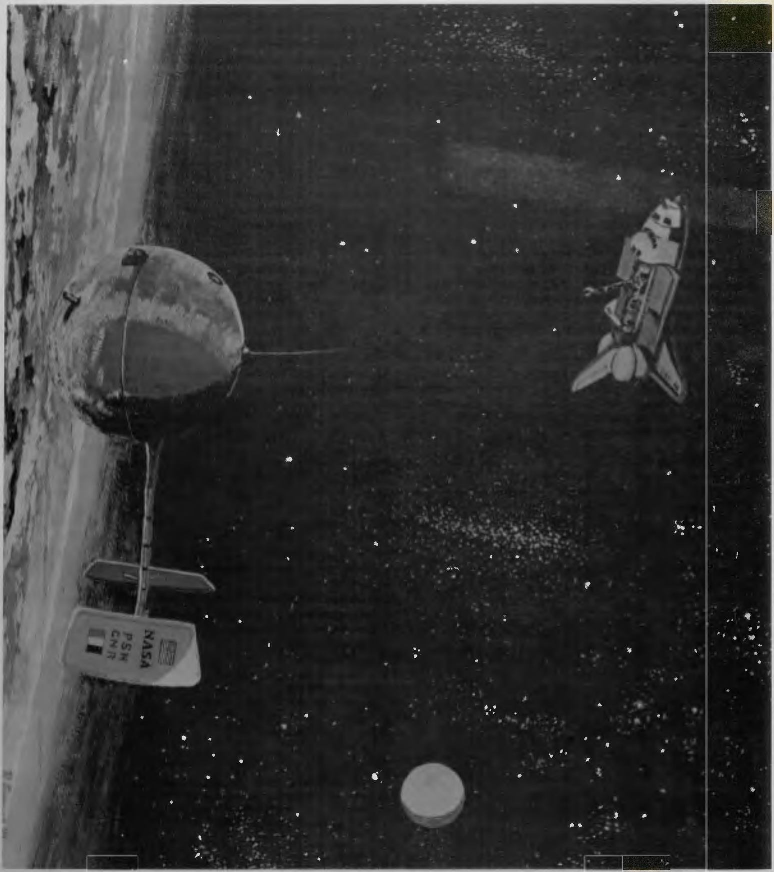


Fig. 9 Tethered Satellite System

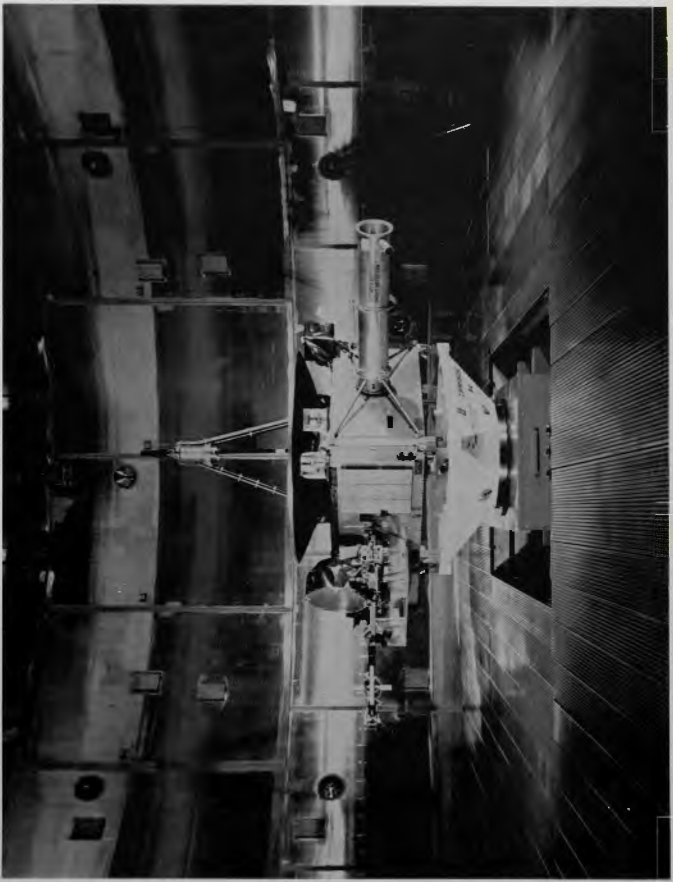


Fig. 10 ESA's International Solar Polar Mission Satellite in the dynamic test chamber at ESTED (European Space Research and Technology Centre, Netherlands).

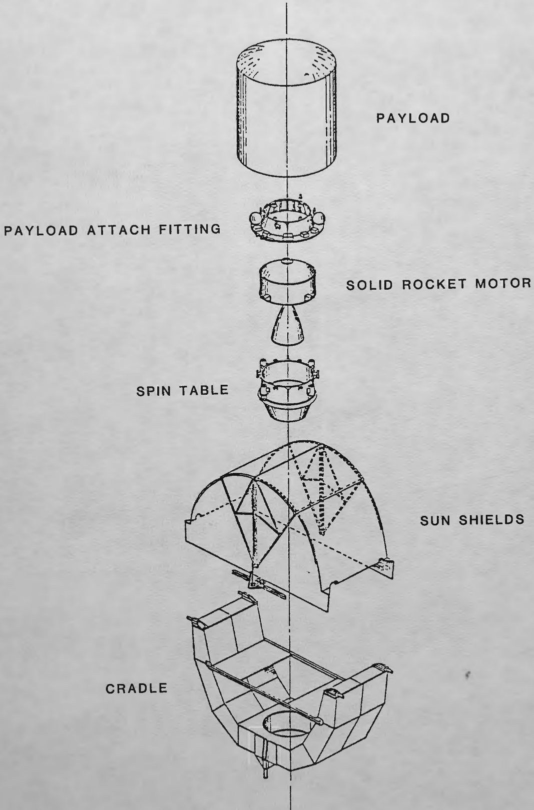


FIG. 11 IRIS SYSTEM CONFIGURATION

Fig. 12 Retrievable carrier concept based on Spacelab half-pallet.