A European Approach to the Utilisation of Spacelab

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ABSTRACT

The Spacelab Utilisation Programme conceived in Europe to encourage the use of Spacelab and to provide a ready access to space for European experimenters is summarised in concept and content. Within this programme four Demonstration Missions are planned to illustrate the usefulness of Spacelab and these are briefly described. In addition, considerable work has been done in Europe on possible payloads for Science and Applications. Some examples of these are provided.

INTRODUCTION

Spacelab represents a considerable investment in manned space activities for the European Member States of ESA. Its utilisation, therefore, is an essential element of the return on this investment. To encourage the widespread use of Spacelab, it is important that no obstacles are placed in the path of potential users who must be guaranteed a ready access to space. This philosophy, readily adopted by ESA, has led to considerable preparatory analyses in Europe, under the aegis of ESA itself and the many national agencies of its Member States.

As a result of these activities, ESA is proposing a Spacelab Utilisation Programme that would involve the organisation and support for flight of European-developed payload elements. Initially, the use of Spacelab is seen as a demonstration of its future role in science, applications and technology; later, routine use by scientists and engineers is foreseen. The former is the subject of this paper.

THE SPACELAB UTILISATION PROGRAMME

ESA sees its role in Spacelab utilisation as one of co-ordinating and planning European payloads. The latter would be supplied by Organisations within the Member States and, in some cases, by experiments from ESA or by ESA-sponsored experimenters. ESA's main responsibility would rest in establishing suitable mission opportunities, supporting the experimenter during all phases of the instrument development and the integration (analytical and physical) of the individual experiments into a payload entity. To this end the Spacelab Utilisation Programme (SLUP) has been proposed and accepted, in principle, by the ESA Member States.

The objectives of SLUP are enumerated in Fig. 1. The overall aim is, of course, to stimulate the effective use of Spacelab by Europeans. To achieve this, the elements shown in Fig. 2 have been identified to cover both the payload definition and the mission preparation activities. The following characteristics should be stressed:

- It is an optional programme in that Member States participate (i.e. provide funding) in a particular mission according to their interest. Participation in one mission does not commit the Member State to subsequent ones.
- It comprises two distinct aspects: (1) an access service wherein ESA provides services for the preparation and execution of missions at the request of users, and (2) missions instigated and funded by the Agency.
- It provides an Instrument Pool for the use of experimenters throughout Member States (and possibly NASA) but managed by ESA.

The so-called Instrument Pool is a particularly important aspect of SLUP and some of its main characteristics are summarised in Fig. 3. The overall intent is to save money for the users by establishing a pool of instruments, GSE and other common equipment (e.g. mechanical supports) which may be used by all experimenters if and when required. It is envisaged that the assigner of equipment to the Pool will specify the conditions for its reuse whereas the financial responsibility for maintenance and refurbishment would be appointed in some way to the later users.

The execution phase of a mission, including the management of the Instrument Pool has been assigned to SPICE (Spacelab Payload Integration and Co-ordination in Europe). This ESA management and operational team, located at Porz-Wahn, Germany, was specifically created to co-ordinate the ESA-related payload hardware activities. SPICE functions are given in Fig. 4.

The demonstration of the effective use of Spacelab in scientific and applications fields is an important aspect of SLUP and currently four such missions are foreseen as described below. These missions are in addition to the joint ESA/NASA payload planned for the first Spacelab flight (FSLP or Spacelab-1).

DEMONSTRATION MISSIONS

Adopting the "à la carte" approach of SLUP, in which the level of participation by a Member State is strongly influenced by the demands of the users, the Demonstration Missions are planned to stimulate the use of Spacelab throughout the 80's. ESA in co-operation with the German space authorities is supporting four missions for the purpose of demonstrating Spacelab to a wide field of known and unknown potential users. These missions, which are open to participation by all European experimenters are planned to be carried out in the time frame 1982-1984. The characteristics of these missions are given in Fig. 5. It can be seen that three basic operational modes of Spacelab are covered viz,

- Microgravity;
- Earth oriented;
- Deep space oriented.

Particular emphasis is given to the new (for Europe) fields of research - life sciences and material sciences. Also many of the facilities flown on SL-1 (which represents the first steps of an Instrument Pool) will be reflown in an environment not conditioned by the testing requirements of the first flight. Also, the promotion of Spacelab utilisation will be strengthened by the inclusion of two types of experiments dedicated to the younger generation and flown free-of-charge. One takes advantage of the unique Spacelab environment for carrying out experiments that demonstrate fundamental laws of physics in a way impossible on Earth. Films of these phenomena will be integrated into the education courses used in Europe. The second type of experiment concerns the proposals of young people for small-scale research. These youthful protagonists will be able to prepare and carry out experiments for themselves.

Some 250 responses have been received to the Call for Proposals covering all Member States and ESA. Mission analyses are currently being performed by ESA on DM-1, DM-2 and D-4 and by the German space agency DFVLR on D-1. Preliminary results of these analyses imply that the most compatible launch sequence is, in fact, D-1, DM-2, DM-1 and D-4. To accommodate the proposed experiments more efficiently, the corresponding Spacelab configurations should be LM+1P, 3 or 4P, LM only and 4 or 5P. The analyses also underlined the need for pointing mounts (in addition to IPS) on DM-2 and D-4, a requirement for high power levels on DM-1 and the high data rates associated with DM-2. Typical of the instruments which might be used on the ESA-analysed missions - either suggested by ESA as core instruments or proposed by the prospective experimenters - are the following:

TABLE 1.

Micro-gravity (DM-1)	MSDR (Material Science Double Rack)
	SLED
	Biorack
	Chemistry Laboratory
Earth Oriented (DM-2)	GIRL (German Infra-Red Laboratory)
	Grille Spectrometer
	Solar Package
	Metric Camera
	Synthetic Aperture Radar
	Microwave Remote Sensing Instrument
	Airglow Measurement Package
Deep Space Oriented (D-4)	GIRL (with IPS)
	Wolter Telescope (with IPS)
	Submillimetre Telescope (STAAR)
	CIRBS (Cosmic Background Experiment)
	High Energy Imaging X-Ray Telescope
	X-Ray Spectroscopy Package
	Very Wide Field Camera
	FAUST (Far uv Space Telescope)
	Double Compton Telescope
	UTEX (uv Telescope for Wide Fields and X-Ray Stars)

LARGE SPACELAB PAYLOADS FOR SCIENTIFIC RESEARCH

The idea of large facilities on Spacelab dates back to the time of the early thoughts on the future utilisation of the Space Transportation System and of Spacelab in particular.

In the areas of astronomy and solar system science the use of Spacelab will allow observations for extended periods free from atmospheric limitations, with instruments larger than can be practically operated on aircraft sounding rockets and balloons or launched as free flyers.

The four following Spacelab-borne facilities have been identified by ESA for detailed feasibility studies:

1. LIRTS - Large Infra-red Telescope for Spacelab (Fig. 6)

This 2.8 m Cassagrain-type telescope combined with focal plane instruments such as photometers, spectrometers and heterodyne receivers can provide infrared observations in the wavelength region between 1 and 1000μ of galactic and extragalactic objects with very high spatial and spectral resolution. The LIRTS telescope and its associated "behind-the-focus" instrument are mounted on the Instrument Pointing System for arc sec pointing and stability. The telescope itself will not use cooled optics although some focal plane instruments will require cryogenic cooling. The on-board computer will be used for limited data reduction and to drive the operational sequence.

2. EXPOS - X-Ray Spectropolarimetry from Spacelab (Fig. 7)

This instrument consists of a number of large area Bragg spectrometers, each selected for high resolution studies of particular X-ray features in the energy range between 0.5 and 10 keV. In this energy range high resolution is obtained by using X-ray gratings with a large area grazing incidence mirror. The overall facility weighs about two tons (including IPS) and requires one pallet. It places only light demands on Spacelab resources and due to its modular design, it can be flown in a variety of configurations with selected experiments. The version illustrated contains the Bragg spectrometer and polarimeter together with broad band spectrometers and a non-dispersive spectrometer.

3. GRIST - Grazing Incidence Solar Telescope (Fig. 8)

This is a large telescope facility (5m long) with interchangeable instruments at its focal plane. Because of its large size GRIST offers a major improvement in the detail with which solar features can be observed. The telescope is designed to operate in the relatively under-exploited X-ray and EUV range of wavelengths (90 Å to 1700 Å). This is an important part of the spectrum which can yield information on many basic physical processes operating in the quiet and active sun. An observation time of a few weeks would provide a wealth of valuable data.

The telescope would be pallet-mounted with its control electronics contained in the module. It would use the IPS but, in addition, contain an internal attitude measurement and control system to provide the necessary stability (better than 0.2 arc sec over a 30 minute period) and spatial resolution (1 arc sec).

4. Sub-Satellites (Fig. 9)

Small instrumented platforms deployed at a distance from Spacelab and communicating with the Shuttle/Spacelab system have been studied. They are designed primarily for plasma physics and aeronomy experiments and offer either multi-point measurements of the space environment or the possibility of interactive investigations where signals are propagated between Spacelab instruments and the sub-satellite. A family of cheap, short-lived, battery-powered sub-satellites of a wide range of complexity has been considered. The sub-satellites would be stored on the pallet and, after release, might attain distances of up to 3000 km from the Shuttle. The sub-satellite shown in Fig. 4 has a diameter of 45 cm and contains 24 kg of experiments together with batteries, antenna, encoder and transmitter system.

The feasibility studies of these facilities have shown that the scientific requirements can be achieved. Unfortunately, because the associated launch and operation costs are high compared to the development costs, presently no plans exist to the realisation of any of the above-mentioned facilities.

TYPICAL APPLICATIONS PAYLOADS

In the field of applications, the Spacelab is, for the time being, mainly planned to be utilised as a test bed for instrument/techniques to be used later on free flying systems. Some examples of experiments carried out in the field of earth observation on board Spacelab illustrate this approach.

Two remote sensing experiments are planned to be flown on the first Spacelab flight and will be used as facilities for later missions. These are:

- the Metric Camera;
- the Microwave Remote Sensing Experiment.

Both experiments are provided to ESA by the Federal Republic of Germany as general instrumentation for Spacelab. The German Space Agency (DFVLR) will be responsible for the development of the experiments, and ESA will be responsible for relations with the experimenters, monitoring of acceptance tests, etc.

Metric Camera. The prime objective of this experiment is to test the mapping capabilities of high-resolution space photography on large film format (23 x 23 cm). The high-

TABLE 2.
Zeiss Camera Characteristics
and Experiment Parameters

Characteristics	
Lens:	Topar F = 305
Distortion:	Max. 5 μ
Resolution:	40 LP/MM over the whole image size (with aviphot pan 30PE with a speed of 21° din and perufin developer)
Field of View:	Diagonal 56° Across 41.2°
Shutter:	Aerotop Rotating Disc Shutter (between the Lens Shutter) Exposure 1/100, 1/250, 1/500, 1/1000
Apertures:	1:5.6 1:8 1:11
Shortest Cycling Time:	2 sec (interval between two exposures)
Image Size:	$23 \times 23cm^2$
Film Width:	24cm
Film Length:	120-150m depending on film thickness
Experiment Parameters	
Scale of the Images:	1:820 000
Image Size:	$23 \times 23cm^2$
Ground Coverage of one Image:	$188.5 \times 188.5km^2$
Spacelab Velocity:	7.7km/sec
Image Motion:	At 1/500 sec Exposure time: 18 μ (≡ 16m on the ground) At 1/1000 sec Exposure time: 9 μ (≡ 8m on the ground)
Base to Height Ratio at 60%:	1:3 (every second photo at 80% overlap)

resolution data will also be evaluated with respect to other applications (e.g. land-use studies and geology).

The Camera, a modified Zeiss RMK A30/23 Aerial Survey Camera (see Table for details) is shown in Fig. 10. The ground resolution of the images will be a function of the type of film used, but will be in the region of 10-20 m.

At the present time, various film filter combinations are under evaluation. The final selection will depend, among other things, on the amount of film (number of magazines) that can be carried. Candidate films include Panchromatic, True Colour, Infra-red and Colour Infra-red.

The Metric Camera will be stowed for launch and landing, and will be mounted at Spacelab's optical window during the flight.

For future flights, it is intended to make the Metric Camera compatible with operation on a pallet, in order to be able to embark it later on free flyers which would be visited by the Shuttle for maintenance and recovery of film.

Microwave experiment. This experiment represents one element in the development of a microwave (all-weather) sensing capability for a European Remote Sensing Space Programme. (See Fig. 11).

The design of the instrument which is pallet-mounted, enables it to operate in three different modes, as:

- 2-Frequency Scatterometer (for measurement of ocean wave spectra at wavelengths in the range 5-5000 m);
- Synthetic Aperture Rada (for high-resolution imaging of the Earth's surface);
- Passive Microwave Radiometer (for measurement of the naturally-emitted microwave energy from the Earth);

allowing a variety of experiments to be performed during a mission.

The table overleaf provides a listing of various general characteristics of the experiment.

TABLE 3.
Microwave Remote Sensing Experiment:
General Characteristics

Resolution	
• 2 FS mode	
1 DB footprint	9km x 9km
• SAR mode (depression angle 40°)	
Image Width	8.5 km
Image Length	2500 km
Ground resolution	25m x 25m
• Radiometer mode	
Surface temp. sensitivity	± 1C
Antenna	
Paraboloid section with Cassegrain feed	
• Dimensions	1m x 2m
• Frequency	9.6 GHz approx.
• Field of view	1.6 x 3.1
• Polarisation	free
• Power	~100W
Antenna Pedestal	
• Elevation angle	32 to 55
• Azimuth	+ 34 to -34
• Accuracy with respect to Orbiter	± 0.5
• Angular rate	5°/sec max.
• Axis configuration	Azimuth-elevation
• Max. dead band rate	0.01°/sec

- STIMULATE THE EFFECTIVE USE OF SPACELAB BY EUROPEAN USERS IN SCIENCE, APPLICATIONS AND TECHNOLOGY THROUGHOUT THE 1980s.
- PROVIDE AN EASY ACCESS TO SPACE FOR EUROPEAN USERS.
- ESTABLISH OPTIMUM RELATIONSHIPS BETWEEN ESA AND POTENTIAL USERS THROUGHOUT EUROPE I.E. MEMBER STATES, NATIONAL AGENCIES, UNIVERSITY GROUPS, ETC.
- ENCOURAGE AND GUIDE EUROPEAN PARTICIPATION IN FUTURE MANNED SPACE ACTIVITIES.
- HELP THE EXPERIMENTER TO DEVELOP AND FLY HIS EQUIPMENT.
  - SET UP AN INSTRUMENT POOL FOR COMMON USE BY EXPERIMENTERS
  - PERFORM NECESSARY INTEGRATION ACTIVITIES IN EUROPE
  - EVALUATE MISSION POSSIBILITIES
  - ORGANISE TOTAL PAYLOAD ACTIVITIES
- DEMONSTRATE THE USEFULNESS OF SPACELAB TO A WIDE COMMUNITY OF USERS (TRADITIONAL SPACE EXPERIMENTERS AND OTHERS).

Figure 1. Objectives of the ESA Spacelab Utilisation Programme

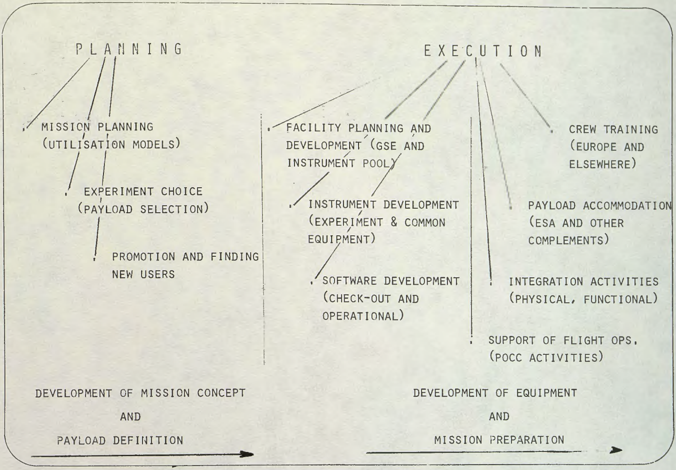

Figure 2. Constituents of Spacelab Utilisation Programme

PURPOSE

- TO ASSURE AVAILABILITY OF EXISTING EQUIPMENT TO ALL EUROPEAN USERS, THEREBY ENSURING COMMON USAGE AND COST SAVINGS
- TO PROVIDE 'SMALL' EXPERIMENTERS WITH ACCESS TO FACILITY-TYPE EQUIPMENT
- TO FACILITATE EXPERIMENT INTEGRATION AT USER SITE

OPERATION

- GROUND RULES AND CONTENT ESTABLISHED BY STEERING GROUP (REPRESENTATIVES OF USERS)
- ESA MANAGED, BUT LOCATION OF INSTRUMENTS NOT CENTRALISED
- EQUIPMENT ASSIGNED BY ESA OR ORIGINAL USER
- FINANCIAL RESPONSIBILITY FOR MAINTENANCE AND REFURBISHMENT RESTS WITH USERS
- ADAPTATION IS FINANCIAL RESPONSIBILITY OF NEW USER
- SPECIFIC TERMS AND CONDITIONS AGREED BY ESA/ASSIGNER FOR REUSE
- USE FSLP-DEVELOPED EQUIPMENT AS NUCLEUS
- POSSIBLE NASA PARTICIPATION

EXAMPLES

INTEGRATION GSE E.G. MECHANICAL SUPPORT EQUIPMENT, TEST EQUIPMENT

FACILITY EQUIPMENT E.G. LARGE TELESCOPES, FURNACES, SLED

SPECIFIC EXPERIMENT EQUIPMENT E.G. POINTING MOUNTS, PHOTON DETECTORS

Figure 3. Characteristics of an ESA Instrument Pool

- OVERALL CO-ORDINATION OF ESA PAYLOAD REALISATION AND OF ITS EXPLOITATION
- ISSUANCE OF PAYLOAD SPECIFICATIONS TO EUROPEAN EXPERIMENTERS
- ACCEPTANCE AND INTEGRATION OF EUROPEAN EXPERIMENTS (PARTIAL OR FULL PAYLOAD)
- TECHNICAL ASSISTANCE TO EUROPEAN EXPERIMENTERS
- CO-ORDINATION OF TRAINING PROGRAMME FOR PAYLOAD SPECIALISTS IN EUROPE
- SUPPORT TO NASA - BEFORE, DURING AND AFTER FLIGHT (ACCOMMODATION/INTEGRATION/DATA MANAGEMENT)

Figure 4. Functions of SPICE Team

MISSION	SCIENTIFIC OBJECTIVES	MAJOR FACILITIES	SPACELAB CONFIGURATION	ATTITUDE	ORBIT
DM-1 (ESA MISSION)	MATERIAL SCIENCE/SPACE PROCESSING, LIFE SCIENCES SPACE TECHNOLOGY	MS RACKS WITH FURNACES AND PROCESS CHAMBERS, SLED, BIOLOG. FAC. CRYOSTAT	LM + 1 P	GRAVITY GRADIENT STABILISED	28.5^0-57^0 220-250 KM
DM-2 (ESA MISSION)	ATMOSPHERIC SCIENCES, EARTH OBSERVATION, GEODESY	MICROWAVE REMOTE SENSING (2 FREQ., SAR, PASSIVE), METRIC CAMERA, IR-TELESCOPE, OPTOELECTR. LINE SCANNER, MULTI-CHANNEL POLARIMETER, LIDER, SUBSATELLITES	SM + 3 P	EARTH-VIEWING	57^0 250-250 KM
D-1 (GERMAN MISSION INCL. NON-GERMAN EXPERIM.)	MATERIAL SCIENCES/SPACE PROCESS., LIFE SCIENCES SPACE TECHNOLOGY COMMUNICATIONS/NAVIGATION	SEV. MS-RACKS WITH FURNACES AND PROCESS CHAMBERS (TECH. LAB.) SLED, BIO-RACK (PLANTS) LIDAR TELESCOPE, ANTENNAS, ATOMIC CLOCK	LM + 1 P	GRAVITY GRADIENT STABILISED	28.5^0-57^0 220-250 KM
D-4 (GERMAN MISSION INCL. NON-GERMAN EXPERIM.)	ASTRONOMY, HIGH ENERGY ASTROPHYSICS, SOLAR PHYSICS	HE-COOLED IR TELESCOPE, UV/VISIBLE - WIDE ANGLE CAMERA SOFT X-RAY - WOLTER TELESCOPE COUNTER ARRAY FOR HARD X; DOUBLE COMPTON GAMMA RAY TELESCOPE	PALLET-ONLY 4 - 5 P	DEEP SPACE VIEWING	28.5^0 225 KM

Figure 5. European Spacelab Demonstration Missions
(As Visualised in Call for Proposals)

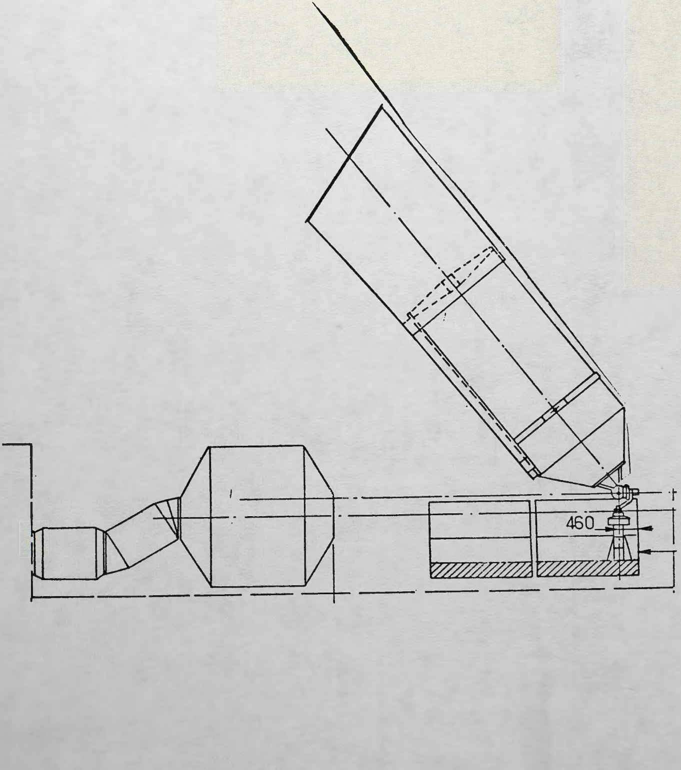

Figure 6. LIRTS mounted with IPS on Spacelab Pallet

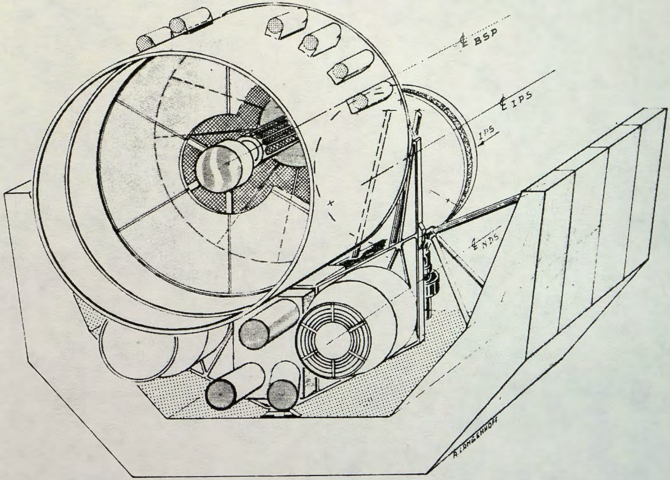

Figure 7. Accommodation of EXPOS on Spacelab Pallet

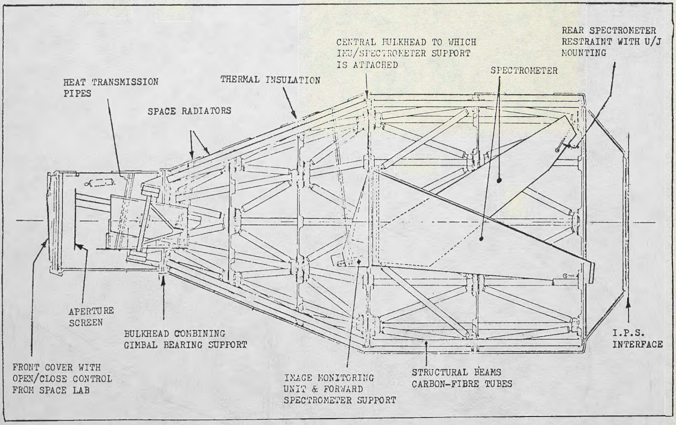

Figure 8. GRIST: Showing the Proposed Structural Elements; The Grazing-Incidence Mirrors are Gimbal Mounted

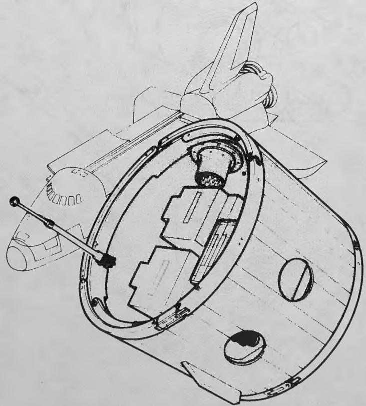

Figure 9. Spacelab Sub-Satellite, Indicating One of the Simplest Concepts Based on Sounding Rocket Technology

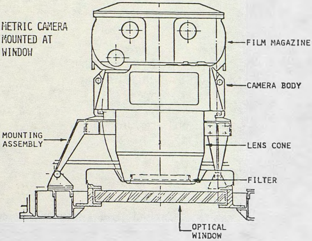

Figure 10. Metric Camera for First Spacelab Payload

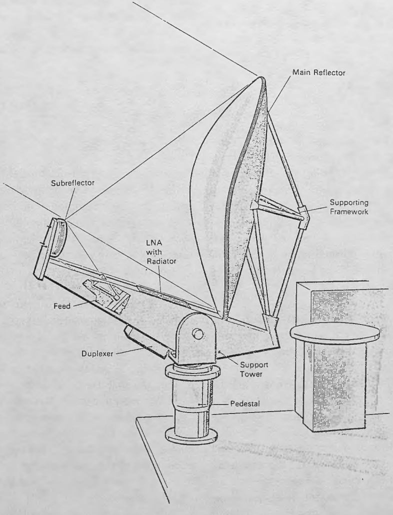

Figure 11. Microwave Remote Sensing Experiment