METRIC CAMERA

EXPERIMENT
IN SPACELAB MISSION 1
— STS 9 —

REMOTE SENSING FROM SPACE

A CONTRIBUTION OF THE FEDERAL REPUBLIC OF GERMANY

DER BUNDESMINISTER FÜR FORSCHUNG UND TECHNOLOGIE (BMFT)

Deutsche Forschungs- und Versuchsanstalt für Luft- und Raumfahrt (DFVLR)

Contents

The Metric Camera instrument has been provided to the European Space Agency (ESA) for the flight in the First Spacelab Mission as a multiuser facility by the Federal Republic of Germany. It has been sponsored by the German Ministry for Research and Technology and developed by the main contractor MBB-ERNO and subcontractors Carl ZEISS and Kayser-Threde under a contract from German Aerospace Research Establishment (DFVLR) based on an experiment proposal by Prof. Konecny, Institut für Photogrammetrie und Ingenieurvermessungen, Universität Hannover.

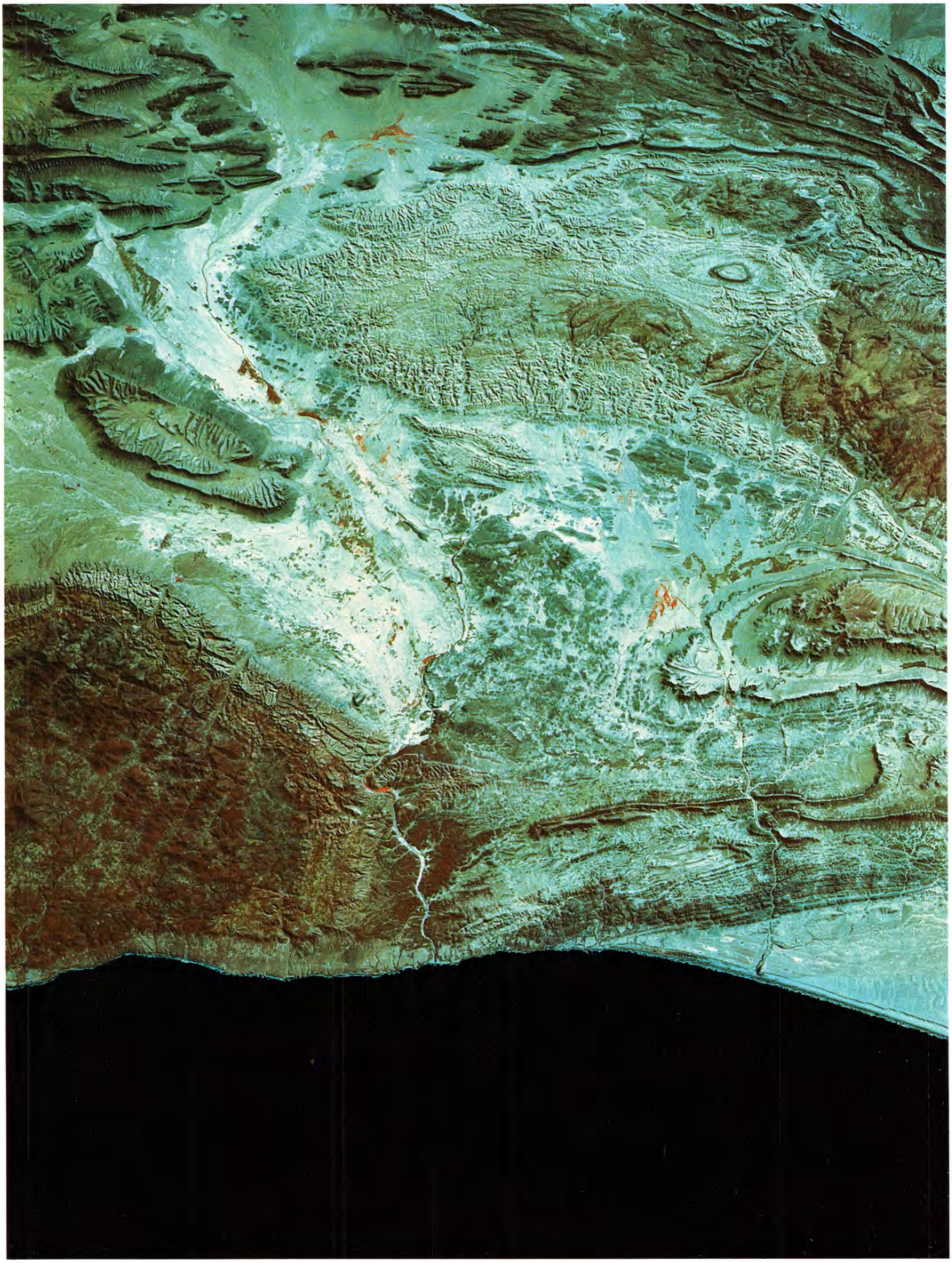
Experiment Overview

In the first Spacelab Mission which is scheduled for Oct./Nov. 1983 a Metric Camera will be flown as part of the earth observation payload. The camera will be a modified high-quality Aerial Survey Camera.

The application of Metric Cameras in Space, an area which has been neglected up to now, can effectively contribute to an improved cartographic coverage of the earth. The Metric Camera Experiment is a first step to fill this gap which can be realized by utilizing the extended capacities of the Space Transportation System.

With this experiment it will be the first time that a calibrated photogrammetric camera with the standard aerial film format of 23 cm x 23 cm is used in space to obtain high-quality photographs of the earth's surface.

The camera is a modified Aerial Survey Camera of the type ZEISS RMK A 30/23. The experiment hardware was developed jointly by the German Aerospace Research Establishment (DFVLR) and German Aerospace Industry and was provided free of charge to ESA as part of the common European experiment facilities. ESA in turn ensures the experiment's flight and coordinates distribution of the experimental data. The experiment development was funded by the German Ministry for Research and Technology (BMFT).



Exampel of Space Photograph: Photo on Colour Infrared Film taken during Skylab 4 Mission (1973) over Western Sahara

Scientific Objectives

For reasonable resources planning and management an earth atlas of all exploitable areas in the scale range of 1:50 000 to 1:100 000 is required. Even 1:250 000 mapping would be sufficient for many areas and needs. The lack of maps is particularly evident in developing countries in Africa, South America and parts of Asia.

A possible remedy is the acquisition of high resolution imagery from low orbiting space platforms using high quality Survey Camera Systems. The experiment therefore intends to test, whether high resolution mapping photography is suitable for

- **compiling topographic and thematic maps especially in unpopulated or less developed regions of the world** and
- **updating and revising topographic and thematic maps in populated and developed areas of the world.**

The selected camera is expected to provide imagery at a ground resolution of 20 to 30 m, and it is therefore considered suitable for detecting details for mapping at small scales (1:100 000 to 1:250 000) and for certain aspects, perhaps even at medium scales (1:50 000 — 1:100 000).

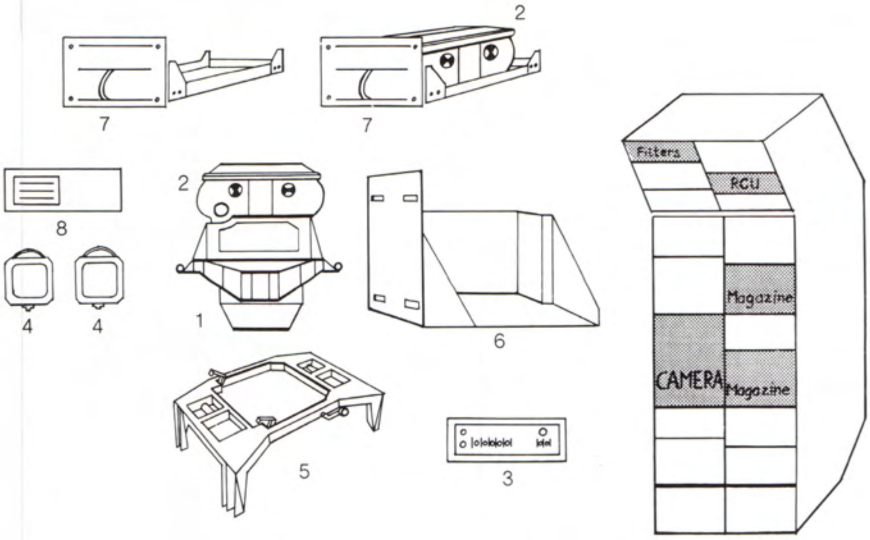
The objective of the mission is therefore predominantly to **test the mapping capabilities of high resolution space photography** taken on the large film format of 23 cm x 23 cm.

For stereoscopic evaluation the photographs will be taken with 60 % overlap.

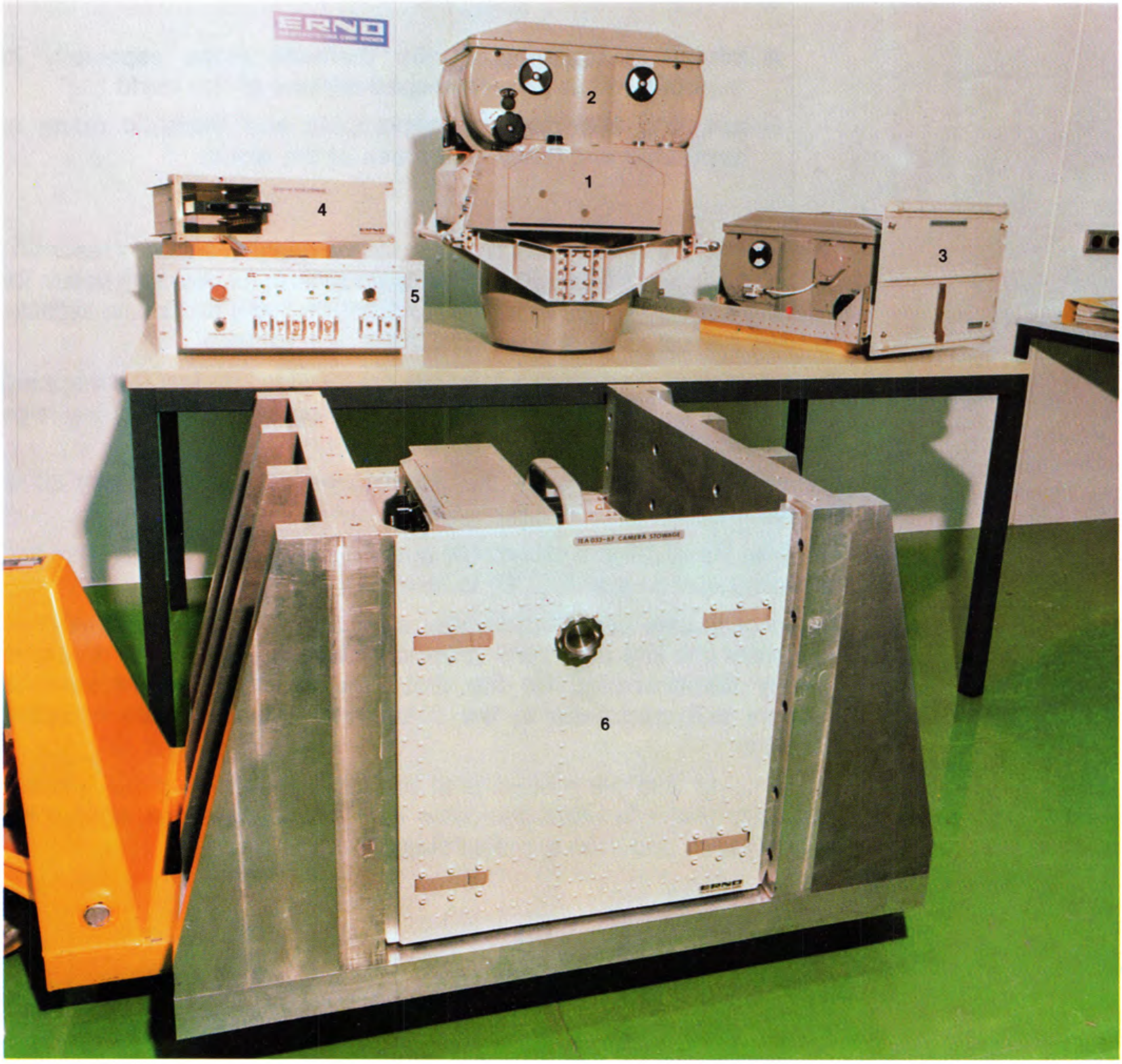
By aerial triangulation a planimetric position accuracy of ± 5 to 10 m and an elevation accuracy of ± 20 to 35 m can be expected.

The photographs can be evaluated with conventional photogrammetric equipment into **line maps** and to **orthophotomaps.** In this way **it can be exactly demonstrated for the first time to which extent satellite imagery can contribute to the solution of the worldwide mapping problem.**

At the same time the mission is to provide high resolution test imagery potentially useful to other disciplines e.g. geology, land use, agriculture, oceanography and even to meteorology.



The Metric Camera System for the 1st Spacelab Mission. 1: Camera; 2: Magazine; 3: Remote Control Unit; 4: Filter; 5: Camera Suspension Mount; 6: Camera Stowage; 7: Magazine Stowage Container; 8. Filter Container; on the right: rack for stowage of the camera system.



Metric Camera Flight Hardware: (1) Camera; (2) Film Magazine; (3) Film magazine in stowage container; (4) Filter in stowage container; (5) Remote Control Unit; (6) Camera Stowage Container. (Photo: ERNO)

The Camera System

The camera system consists of the following equipment:

- Camera body with optics
- 2 Film magazines containing aerial film of 24 cm width
- 2 Filters
- Remote Control Unit (RCU)
- Camera Suspension Mount
- Stowage Containers

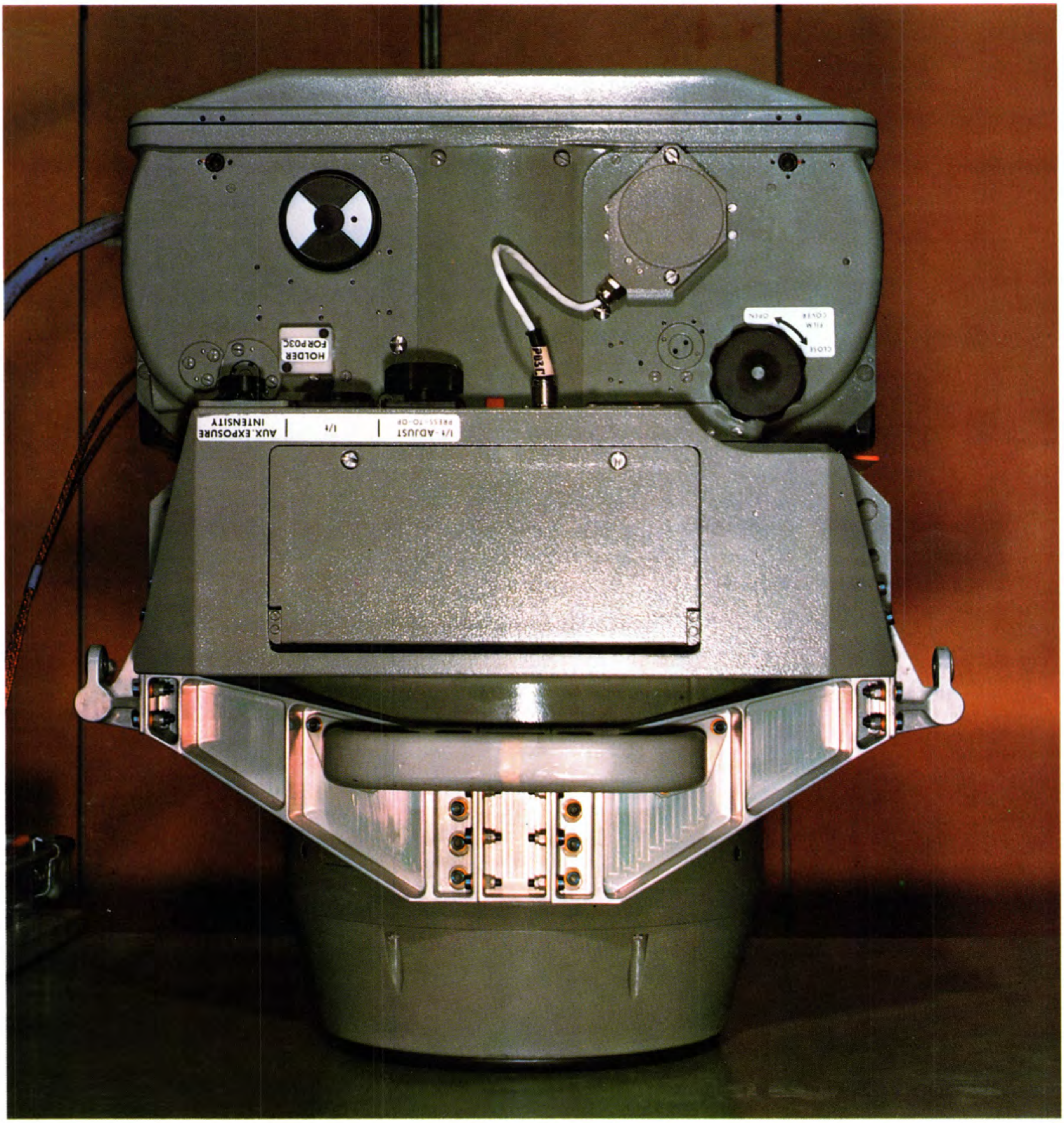
Camera, film magazines and filters are stowed in special containers in experiment racks during launch and landing. The camera interfaces to the optically flat High-Quality Window via a suspension mount which is permanently mounted to the window adapter plate. The Remote Control Unit is installed in an experiment rack and remains there during the whole mission.

In orbit, the camera will be assembled on the suspension mount, fitted with a magazine and electrically connected to the Remote Control Unit. These tasks will be carried out by the Payload Specialists onboard. Before the end of the mission they have to remove the camera and magazine from the window and stow it again in the rack for the landing phase.

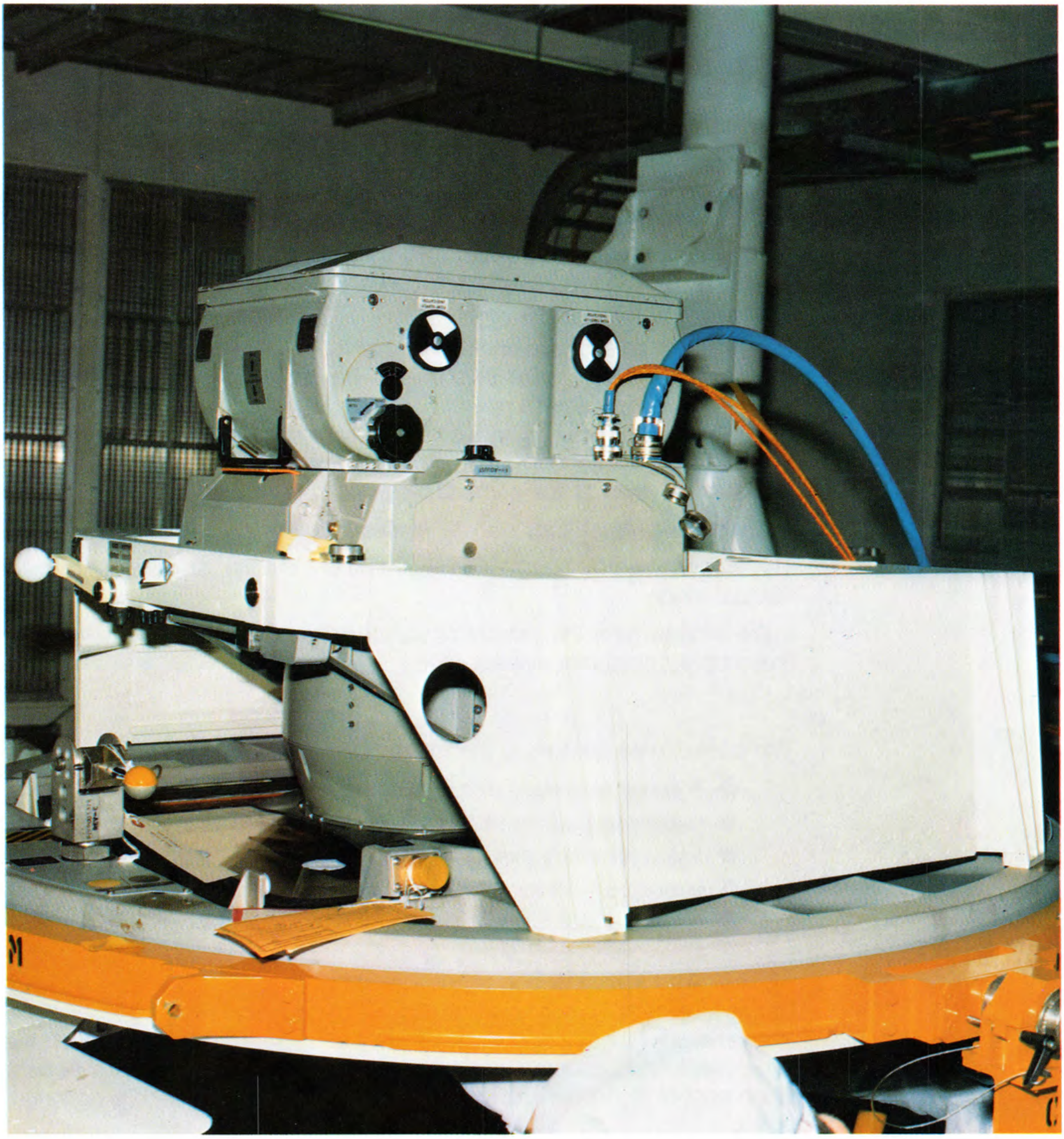
TYPE	MODIFIED ZEISS RMK A 30/23
LENS	TOPAR A 1 WITH 7 LENS ELEMENTS
CALIBRATED FOCAL LENGTH	305.128 MM
MAX. DISTORTION	6 μM (MEASURED)
RESOLUTION	39 LP / MM AWAR ON AVIPHOT PAN 30 FILM
FILM FLATTENING	BY BLOWER MOTOR INCORPORATED IN THE CAMERA BODY
SHUTTER	AEROTOP ROTATING DISK SHUTTER (BETWEEN THE LENS SHUTTER)
SHUTTER SPEED	1/250 SEC.—1/1000 SEC. IN 31 STEPS

F/STOPS	5.6 TO 11.0 IN 31 STEPS
EXPOSURE FREQUENCY	4 TO 6 SEC. AND 8 TO 12 SEC.
IMAGE FORMAT	23 CM X 23 CM
FILM WIDTH	24 CM
FILM LENGTH	150 M = 550 IMAGE FRAMES
DIMENSIONS: CAMERA MAGAZINE	46 X 40 X 52 CM 32 X 23 X 47 CM
MASS: CAMERA MAGAZINE	54.0 KG 24.5 KG (WITH FILM)

CHARACTERISTICS OF SPACELAB / METRIC CAMERA



Metric Camera for the first Spacelab Mission (Photo: DFVLR)



Alignment of Camera and Suspension Mount to the Optical Window at Kennedy Space Center. (Photo: NASA)

Operation and Control

The loading of the film magazines and their unloading after landing will be made in darkrooms on the ground before launch, and respectively after completion of the mission. Two magazines each containing 150 m of film, providing up to 1100 images, will be used. Each magazine will contain a different film type.

The films will be exposed one after the other in full length. Exchange of film magazine and filters have thus only to be carried out once by the crew during the whole camera operation period. The further duties of the crew are: initial set up of the camera at the optical window with a thorough check-out, a second brief check-out after magazine exchange, and finally, removal and stowing away of the camera system.

In the present operations plan 31 cycles of operation are foreseen.

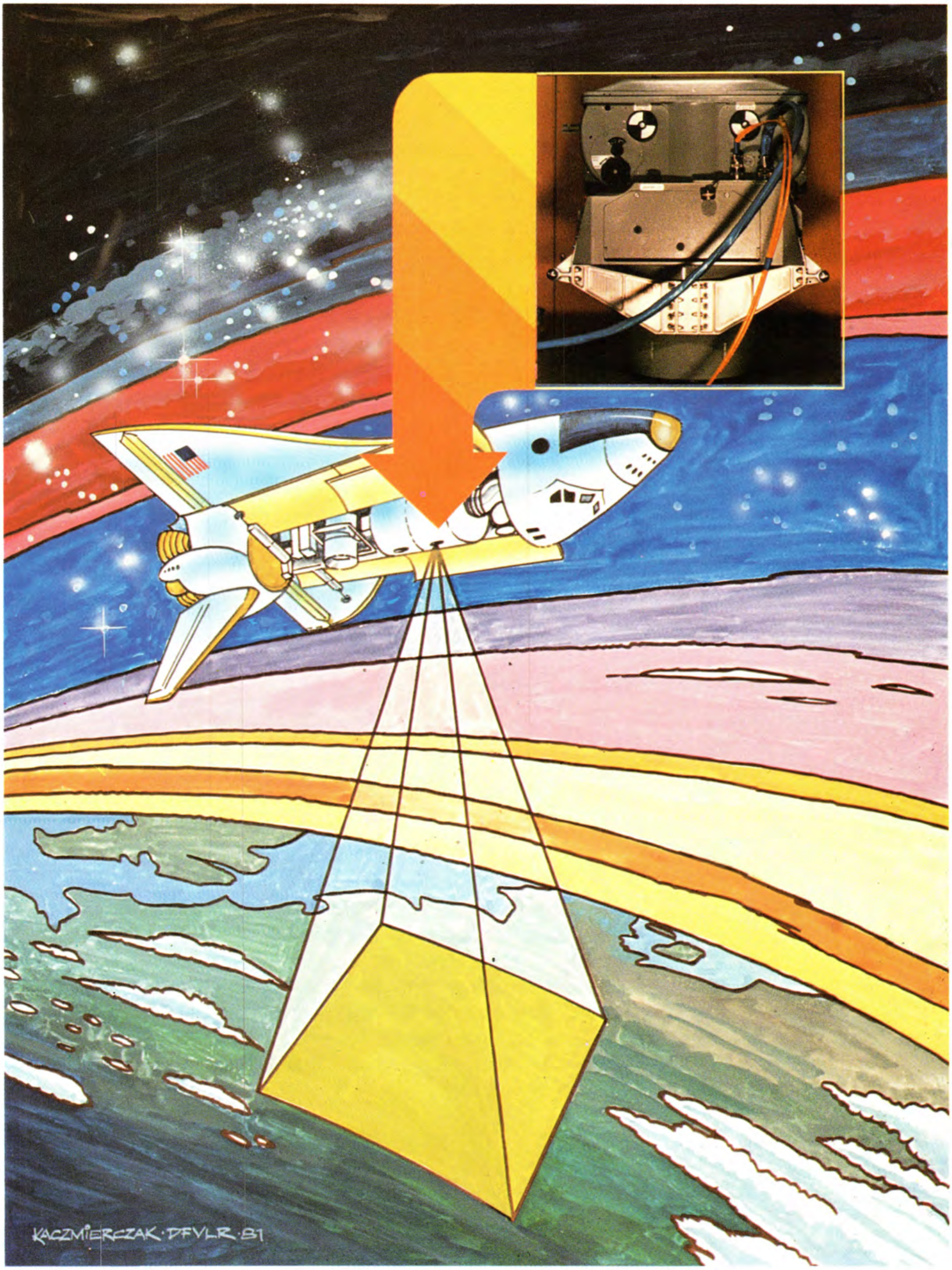
The camera can be operated in two different modes, an automatic and a manual mode.

In the nominal case the camera operation will be controlled automatically by the onboard computer system.

The control data comprises the following:

- number of images in one cycle of operation
- overlap adjustment 60 or 80 %
- f-stop for every exposure
- exposure time for every exposure
- start and stop time

During all automatic operations the crew is not involved. The crew shall only intervene in automatic operations in the case of malfunction of the experiment. Manual operations are carried out only as Contingency Actions when control of the camera via the onboard computer system is no longer possible.



SPACE SHUTTLE in earth oriented attitude for Metric Camera operations

Experiment Parameters

The focal length of 305 mm and the nominal orbit altitude of 250 km yields an image scale of 1:820 000 which results for the 23 cm x 23 cm image format in a ground coverage of approximately 189 km x 189 km per image.

During operation of the camera the Space Shuttle must be in such an attitude that the optical axis of the camera looks exactly vertical to the earth. This orientation will be done with an accuracy of 0.5 degree.

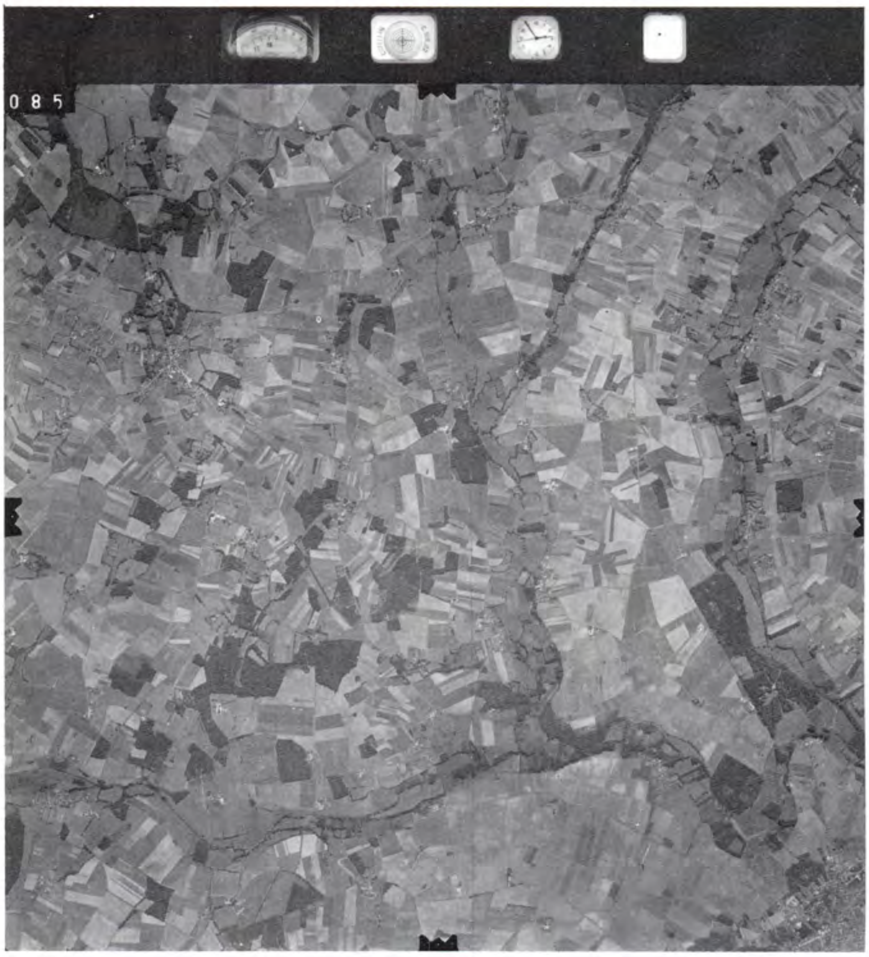
With a relative forward velocity between the spacecraft and the earth of approximately 7.55 km/sec. it becomes necessary to restrict exposure times between $1/500$ and $1/1000$ sec. in order to minimize image motion.

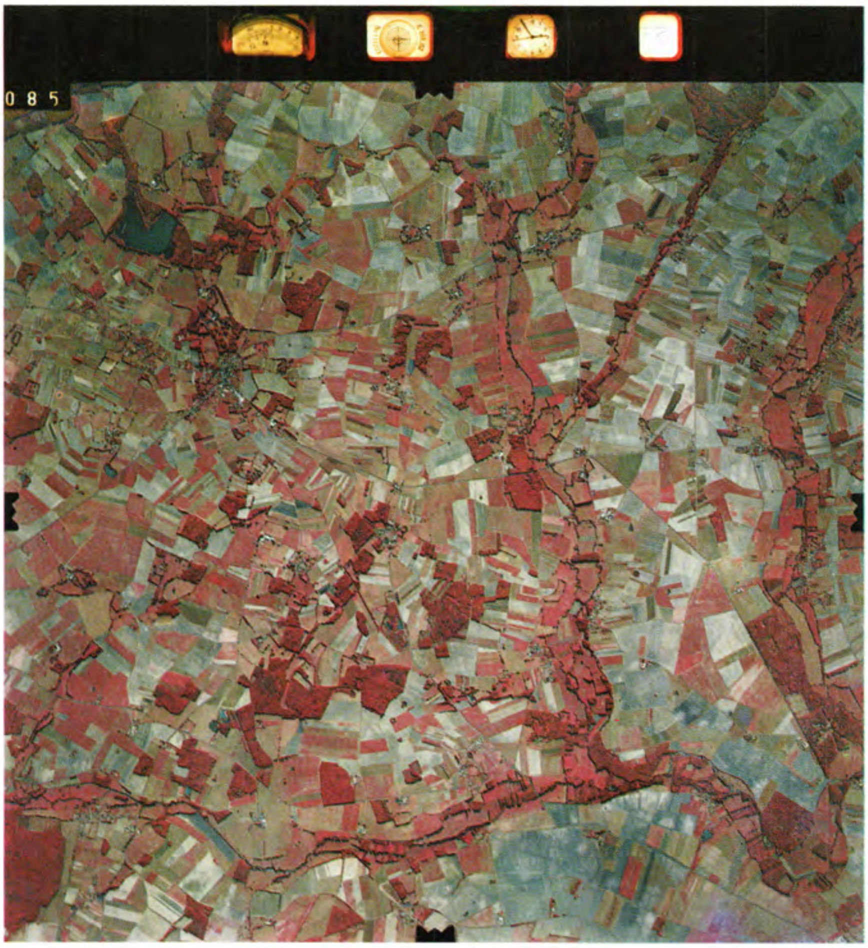
Films and Exposure Control

- Kodak Double-X Aerographic Film 2405 (black/white) and
- Kodak Aerochrome Infrared Film 2443 (colour)

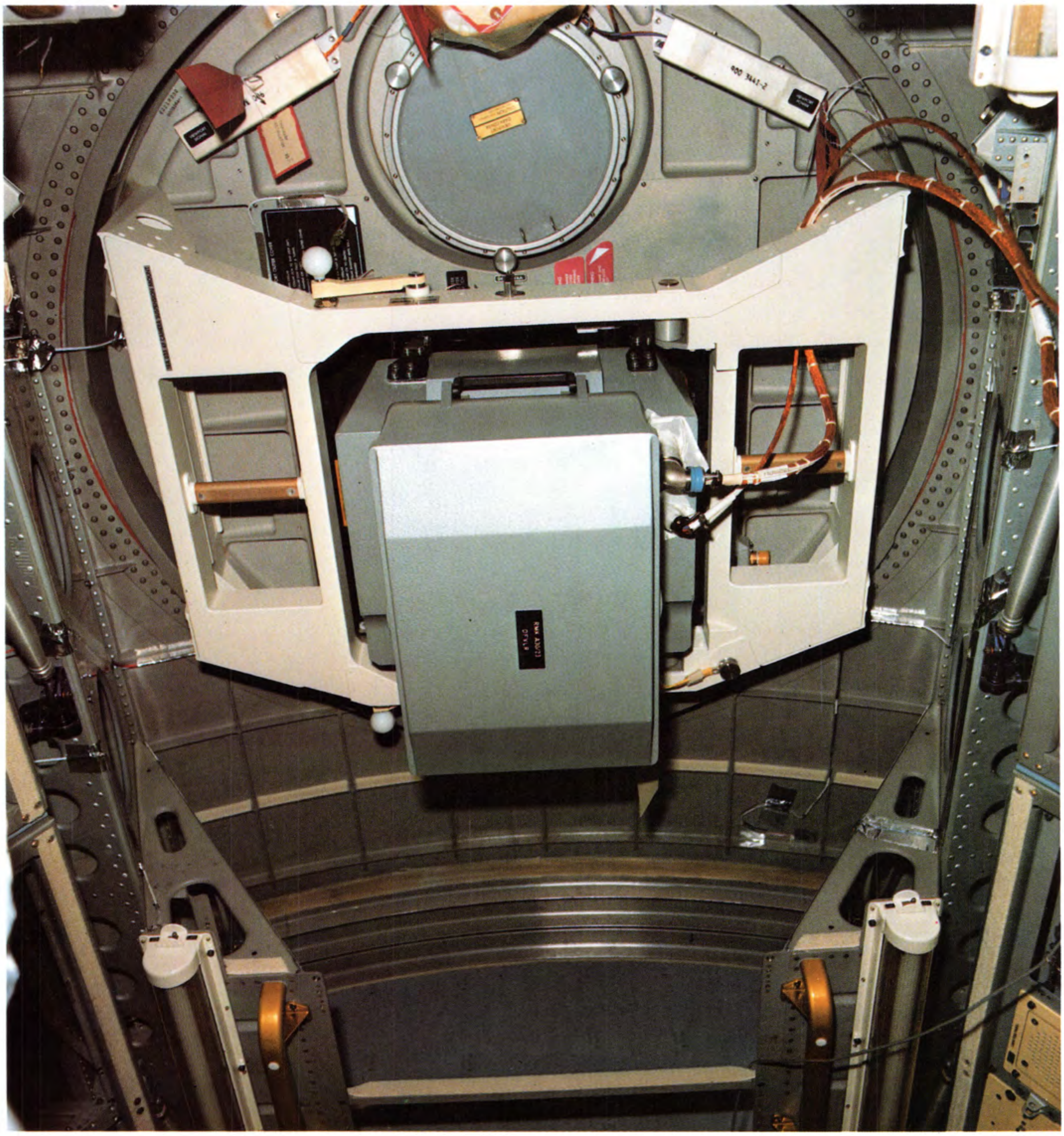
were selected for the Spacelab flight. Both films will be flown with an orange filter with a cutoff wavelength of 535 nm. For the black/white film the main application is topographic mapping and for the colour infrared film, photo interpretation and thematic mapping (see examples on next page).

Automatic exposure control with photometer is not practicable due to various amount of cloud cover in the field of view of the photometer. Therefore proper exposure has to be predetermined from theoretical formulas taking into account the illumination conditions at various sun elevations. These exposure values for each image will be stored in the onboard computer before the mission and can be updated during the mission if necessary.





Examples of black/white and colour infrared high altitude photographs of an area near Villefranche-Sur-Cher. Photos taken during a joint flight test campaign of DFVLR and Institut Géographique National, Paris (France).



Fit Check with a Camera Model at the Optical Window Inside Spacelab at NASA-Kennedy Space Center (Photo: NASA)

Areas to Be Photographed

The whole first Spacelab Mission will take 9 days of which approximately 36 h are planned for earth observations. Another limiting factor for space photography are the illumination conditions. The selected films can be properly exposed when the sun elevation is greater than 15°.

Because of the limited amount of film material only ⅔ of the indicated operation opportunities can actually be used during the mission. A final selection of the preprogrammed operation cycles will be made by ground control and will be based on global weather information. The decision which cycles to use or delete will be made about 12 hours ahead of each pass. Despite of this selection it is expected that a certain percentage of target areas will be partly cloud covered when they are to be photographed.

In total an area of 15.5 mio km^2 at a swath width of 189 km will be photographed during the mission.

Black strips on the maps indicate areas to be photographed with a black and white film; red strips indicate areas to be photographed with the Colour Infrared Film.

Numbers show the sequence of camera operations.

►

HUDSON BAY
ALBERTA
SASKATCHEWAN
MANITOBA
ONTARIO
QUEBEC
GULF OF MEXICO
CUBA
JAMAICA
HAITI
MAR DE LAS ANTILLAS
VENEZUELA
PARAGUAY
URUGUAY
31
21
11
29
10
27
19
8
17
6


30
28
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15
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23
14
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2
22
NORWEGIAN SEA
NORTH SEA
UNITED KINGDOM
DANMARK
POLSKA
DDR
BRD
FRANCE
ESPAÑA
MARE MEDITERRANEO
UNION OF SO
ZAPADNAJA SIB
ALGERIE
LIBYA
EGYPT
SAUDI ARABIA
IRAQ
IRAN
SYRIA
MAURITANIE
MALI
NIGER
TCHAD
SUDAN
SENEGAL
GUINEE
COTE D'IVOIRE
GHANA
NIGERIA
CAMEROUN
ETHIOPIA
SOMALIA
KENYA
TANZANIA
ZAIRE
GABON
CONGO
ANGOLA
ZAMBIA
BOTSWANA
SOUTH-WEST AFRICA
MOCAMBIQUE
MADAGASCAR
REP. OF SOUTH AFRICA
RED SEA
PERSIAN GULF
GULF OF ADEN
ARABIAN SEA
GULF OF GUINEA
INDI OCEA
SAHARA
TUNISIE
KARACHI
BOMBAY


SOVIET SOCIALIST REPUBLICS
OHOTSKOE MORE
BERINGOV MORE
Kamčatka
Sahalin
MONGOL ULS
MONGOLIA
SINKIANG
CHUNG KUO
CHOSON
KOREA
NIPPON
JAPAN
Hokkaido
Honshu
Kyushu
Shikoku
TOKYO
SHANGHAI
TAIWAN
(FORMOSA)
HONG KONG
VIETNAM
PILIPINAS
MANILA
Mindanao
MALAYSIA
SINGAPORE
INDONESIA
DJAKARTA
Djawa
BANGLA DESH
CALCUTTA
DELHI
MADRAS
BAY OF BENGAL
SOUTH CHINA SEA
EAST CHINA SEA
CELEBES SEA
ARAFURA SEA
CORAL SEA
PACIFIC OCEAN
INDIAN OCEAN
AUSTRALIA
Western Australia
Northern Territory
South Australia
SYDNEY
Newcastle
Brisbane
Adelaide
MELBOURNE
Auckland
1
12

Evaluation Methods

Optical rectification of images is only possible for aerial photographs covering flat areas. For photography from space earth curvature and varying topography make it necessary to rectify images in a differential manner. The resulting product is an orthophoto which displays the image details of the original photograph in the exact position of a map projection with correct geometry.

An orthophoto can therefore be used as a map substitute which is faster and more economically produced than a conventional line map.

The differential rectification is based upon the knowledge of terrain heights, and coordinates, which can be obtained by various methods, e.g. by the digitalization of existing maps.

For areas without existing maps, terrain data can be gathered from the images by stereoscopic photogrammetric measurements. These terrain model data are used to drive an orthophotoprinter in order to produce differential rectified photos.

The scanning of the photograph by the orthophotoprinter is done systematically in parallel terrain strips, which are continously projected with ranging scale and orientation according to the used instrument and method. The terrain model data are used as inputs for the control of the projection by the orthophotoprinter. The result is an geometric accurate rectified image of the terrain, which has to be completed by graphic information, like superpositioning of grids, contours, text etc. The result is an orthophoto map.

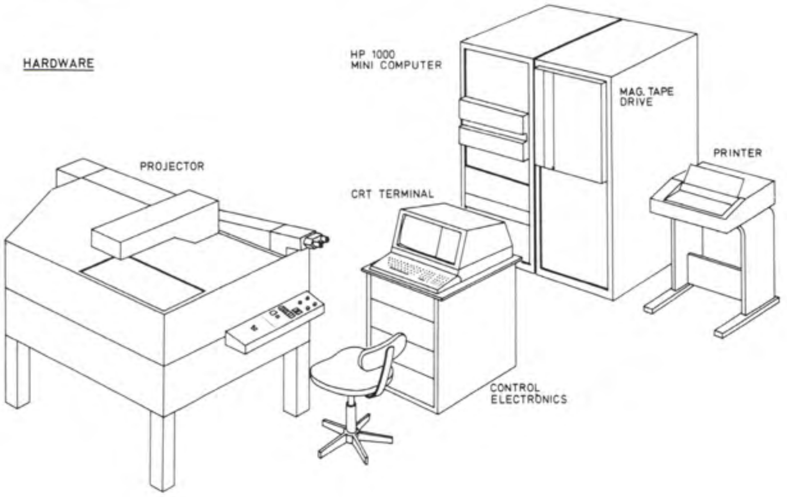
Two overlapping photographs may also be evaluated in conventional photogrammetric stereoplotting devices. Due to earth curvature analytical plotters, (such as the Zeiss Planicomp C-100) are very suitable instruments. They permit to measure corresponding image coordinates of points on the terrain, whose exact geographic position may be calculated by an aerial triangulation block adjustment procedure.

Based upon such points used for the orientation of stereomodels plotting can proceed in form of conventional photogrammetric line maps. The stereoscopic overlap not only permits to correctly map position information, but also allows to plot elevation data, such as contours.

ZEISS
West Germany

ANALYTICAL ORTHO PROJECTOR ORTHOCOMP Z 2
BASIC SYSTEM COMPONENTS

HARDWARE

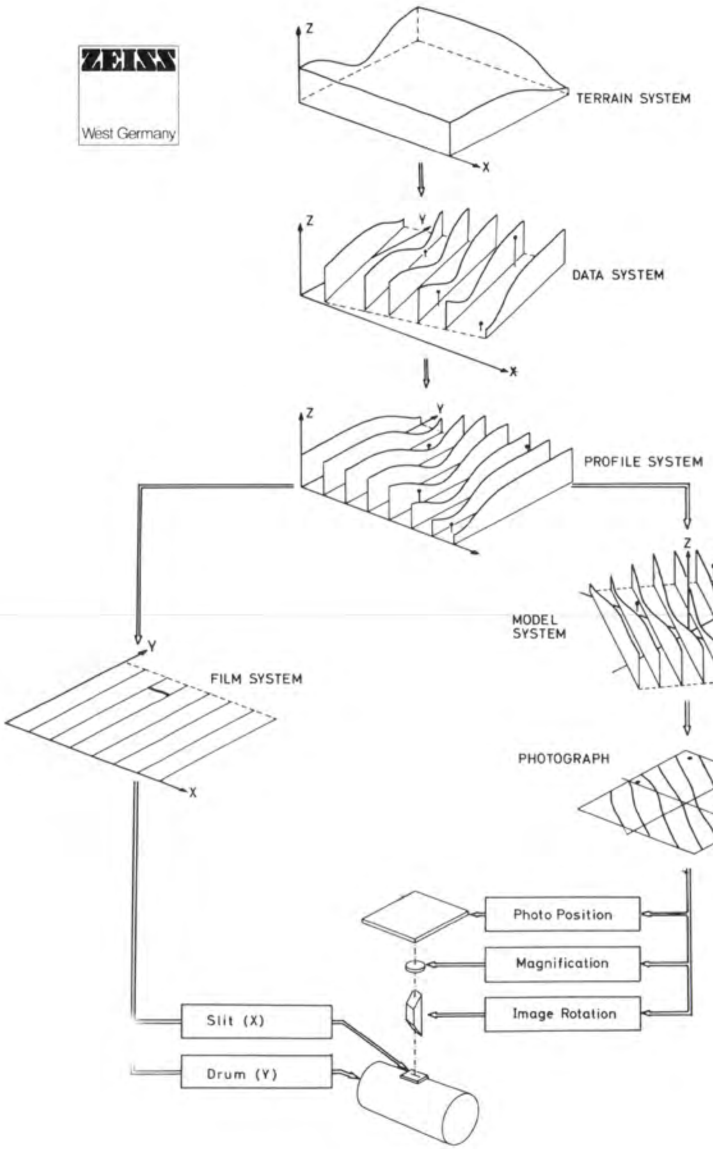


SOFTWARE

PARAMETER	PROGRAM FOR INPUT OF CONTROL POINT DATA, SHEET CORNER COORDINATES, CAMERA DATA, ETC.
ORIENT	PROGRAM FOR MEASUREMENT AND COMPUTATION OF INTERIOR AND ABSOLUTE ORIENTATION
DENSITY	PROGRAM FOR MEASUREMENT AND REGISTRATION OF THE OPTICAL DENSITY AT DIFFERENT LOCATIONS IN THE ACTUAL PHOTOGRAPH
SCAN	PROGRAM FOR EXPOSURE OF THE ORTHOPHOTO
PRINT	PROGRAM FOR EXPOSURE OF ALPHA NUMERIC AND CARTOGRAPHIC SYMBOLS ONTO THE ORTHOPHOTO FILM
LIST	PROGRAM FOR PRINTING A STANDARD RECORD OF THE RECTIFICATION PARAMETERS

Instrumentation for orthophoto production

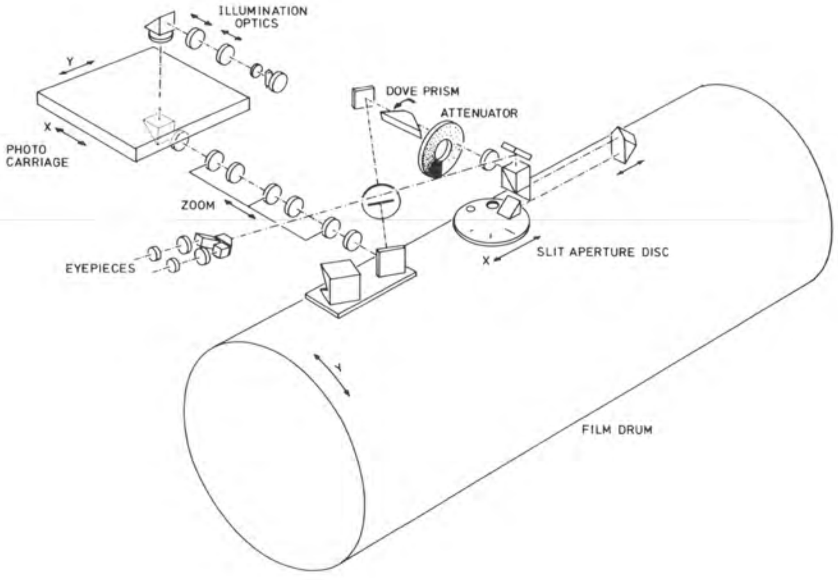
West Germany



Principle of orthophoto production

West Germany

ANALYTICAL ORTHO PROJECTOR ORTHOCOMP Z 2
OPTICAL SYSTEM



Optical system of the orthophotoprinter

Data Distribution

After a call for experiment proposals over 100 experimenters were selected by ESA for data evaluation.

To these experimenters images pertaining to their experiments and additional mission data will be distributed free of charge some weeks after the mission through the ESA-Earthnet-System.

After this the data will then be available for unrestricted distribution. They will be purchasable from DFVLR at an affordable price. The products to be sold will be first generation copies of the original images. An image catalogue will be issued by ESA after the mission.

For data requests after the mission please contact:

EARTHNET Programme Office User Services
ESRIN
Via Galileo Galilei
00044 Frascati, Italy
Phone: (06) 94 40 11

or

DFVLR-Hauptabteilung Angewandte Datentechnik
8031 Weßling
W-Germany
Phone: (0 81 53) 28 (1) - 6 50

For further information please contact:

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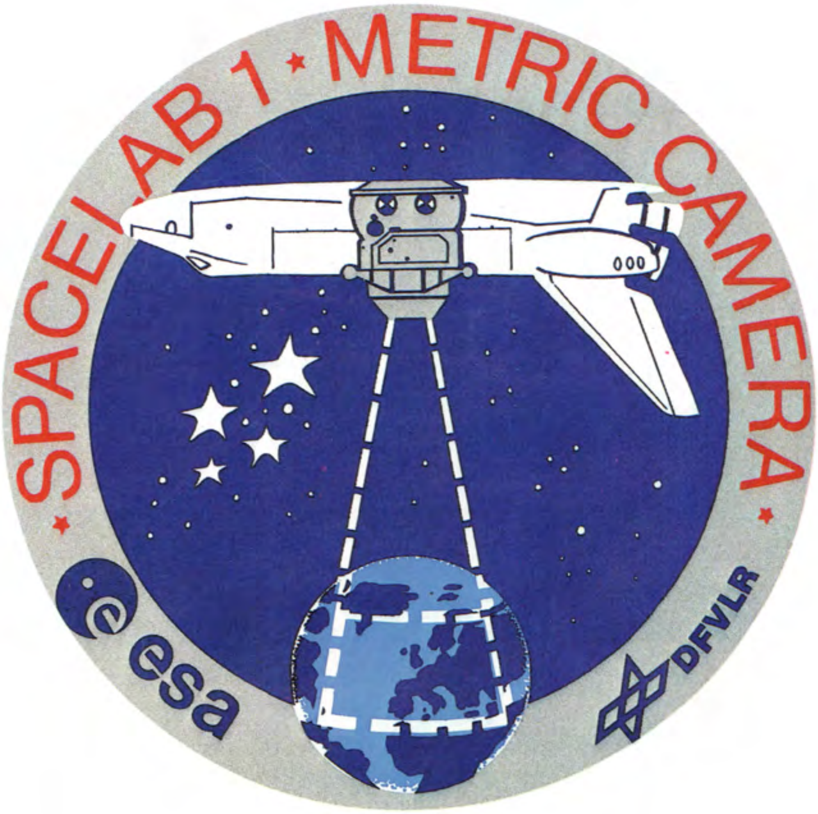
2, Avenue National
94160 Saint Mandé
Phone 3 74 - 12 - 15



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