THE EVALUATION OF SPACELAB 1 - PHOTOGRAMMETRIC CAMERA DATA

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ABSTRACT

A Zeiss RMK 30/23 photogrammetric camera was carried on ESA's Spacelab 1 launched with NASA's Shuttle STS-9.
The mission returned about 1029 high resolution photographs in infrared false color or black and white over Asia, Africa, Europe and the Americas. The images are suitable for topographic and thematic mapping at the scale 1:100 000. A reflight with expected higher resolution is planned on the NASA EOM-1 mission in June 1985.

1. Introduction

The first Spacelab mission was launched on NASA's Space Shuttle flight number 9 from Cape Canaveral in the USA on November 28, 1983. Shuttle landed in Dryden, California on December 7, 1983. This manned mission was jointly conducted by the European Space Agency ESA providing the Spacelab and NASA offering the Shuttle flight. The mission carried 37 major experiments, about half of which were European. Experiment 33 was the Photogrammetric Camera Experiment [1], [2].
It consisted of a Zeiss aerial survey camera RMK 30/23 mounted over the Spacelab window and operated from space at 250 km altitude with two film cassettes loaded with infrared false color film (Kodak 2443) or black and white film (Kodak Double-X). With this material on December 2, 3, 5 and 6 about 550 color infrared and 470 black and white photographs were taken over China, the Middle East, Africa, Europe, North-, Central and South America at an image scale of 1:820 000 in single strips of 190 km width at mostly 60 %, but partly also at 80 % longitudinal overlap.
Several organizations and persons were involved in the tasks of administration, preparation and successful operation of the experiment:
The Minister of Research and Technology of the Federal Republic of Germany provided its funding. On his behalf Dr.A.Langner administered the funds for contracts with ERNO-MBB, Carl Zeiss Oberkochen and Kaiser Threde to supply, modify and integrate the camera for space use into the Spacelab.
The government of the Federal Republic offered the experiment to ESA. ESA officially represented it to NASA by Dr.M.Reynolds. The task of technical monitoring of the contractors and of operating the camera by computer control from the Payload Operations Control Center in Houston, Texas, USA was the responsibility of the Project Engineer M.Schroeder of the DFVLR in Oberpfaffenhofen and his DFVLR/ERNO/University of Hannover team. The scientific objectives were of concern to the author, acting as project scientist and as chairman of the ESA-Metric Camera Working Group with G.Duchossois as Secretary and Dr.I.Dowman, G.Ducher and Prof.G.Togliatti as members. ESA issued a call for experiment proposals and accepted over 100 institutions as experimenters. After these will have received their images for experimentation the material is also available for general worldwide distribution by the DFVLR Oberpfaffenhofen directly or by ESA-Earthnet, Frascati at the nominal cost of reproduction. Several organizations participated in the mission, such as the IGN France and IFAG in film selection [3] and Hansa Luftbild and IGN France in underflights.

2. Mission Objectives

While the NASA-Apollo missions already in 1966 and the NASA Skylab missions in 1973 have yielded interesting and available photography from space, in the Western world digital imaging systems such as Landsat 1 to 5 became to be the principal source of available satellite imagery. Landsat imagery favoured the development of digital image processing systems for multispectral and multitemporal analysis. Landsat MSS with 4 channels, however, suffered from the lack of high spatial resolution at 80 m pixel size. Only recently Landsat 3-RBV took 40 m pixels in one spectral channel; Landsat 4 and 5 - TM brought images with 30 m pixels in 6 channels and an additional low resolution thermal channel; and the MBB-MOMS provided images with 20 m pixels in 2 channels. For these higher resolution channels, in turn, digital processing has become a very big effort.

This photogrammetric camera mission on Spacelab 1 has brought several firsts:

1) It is the first time that a photogrammetric camera of large format (23 x 23) has been in space in a mission available to the public.
2) It is the first time that a calibrated photogrammetric camera has brought back images from space.
3) It is the first time that such space photography is suitable for stereoscopic evaluation in standard photogrammetric instrumentation.

It is therefore possible to use the imagery
a) for the mapping and the map revision of planimetry
b) for the measurement of heights (particularly with those images taken with 80 % overlap)
c) for thematic mapping for different disciplines (geology, land use, hydrology, forestry) with the aid of stereoobserveration.

Topographic and thematic mapping constitutes a necessary prerequisite for planning the environment and for influencing economic development in many fields. Regional and global resource planning requires a 1:100 000 or 1:50 000 map of the land areas of the earth. Recent statistical data [4] show, that in 1980 only the continents of Europe (77 %/91 %) and North America (7 % / 91 %) were sufficiently mapped at the scales 1:100 000/1:50 000. Asia (62 % / 51 %) and Australia (42 % / 42 %) were partly covered by maps. In the developing continents of Africa (17 % / 24 %) and South America (42 % / 27 %) the coverage was totally inadequate with respect to the planning needs. Additionally it must be considered that available maps are sometimes out of date by 20 years.
The present world coverage (42 % / 42 %) has been established during the past 100 years. It is not possible to produce the missing coverage (58 % / 58 %) by conventional techniques within a generation. Present mapping techniques using photogrammetric cameras from aircraft heights of maximally 15 km give excellent mapping results. However, there are too many photos to be evaluated, therefore the mapping process becomes slow; there are administrative and political problems to cross boundaries by aircraft to obtain global information; there are technical problems of not having as many mapping aircrafts as well as local photogrammetric instrumentations and manpower available for the mapping.

On Spacelab 1 within 4 operating hours 11 million km² of the earth's surface were photographed, 70 % of which is suitable for mapping. This amounts to 5 % of the land surface of the earth in a single experimental mission.
In order to fulfill the mapping requirements at scales 1:100 000 or 1:50 000 the images must meet the following criteria:
1) the resolution must be high enough to show object to be depicted on the map. This is about 5 m on maps 1:50 000 and 10 m on maps 1:100 000 (see [5]);
2) the geometry should be reconstituted to ± 10 m for maps 1:50 000 and to ± 20 m for maps 1:100 000;
3) the imagery should permit the determination of 50 m contours.

Automatic satellite imaging systems, including the thematic mapper, sofar do not meet these requirements. They already operate at technical limits which are costly to break. The future French SPOT-program foreseen for 1985 comes closest to the requirements. However, the processing of this imagery may likewise be complex or costly unless existing photogrammetric restitution equipment is used. Such equipment can be used for the evaluation of Spacelab 1 images.

3. Evaluation of Spacelab images

The Spacelab 1-mission was originally scheduled for July 1980. Due to delays in the Shuttle program it was rescheduled for September 1983 and finally postponed until November/December 1983. It was launched with a 57° inclination permitting photography of areas up to 58° northern and southern latitude.
However, the late time of launch in the year, combined with the launch window of 16:00 h GTM at Cape Canaveral brought about, that solar illumination at all photographed areas was never more than 30° at the beginning of the mission and 10° at the end of the mission. This meant, that the foreseen exposures of 1/1000 sec had to be prolonged to 1/500 or 1/250 sec resulting in images motions of up to 14 m or 28 m during the exposures. The low sun angle furthermore reduced the image constrasts.
Because of these unfavourable conditions NASA agreed to refly the mission with the originally scheduled 3 film cassettes on the NASA-Earth Observation Mission 1 (EOM-1) to be launched on June 12, 1985.
In the meantime the stereophotogrammetric evaluation will proceed at those organizations who have been accepted by ESA as official experimenters after the first generation image diapositives of the desired areas are obtained by them in April 1985. These diapositives are produced at the DFVLR, which developed the black and white film only 3 days after the landing of Shuttle in Oberpfaffenhofen and had the color IR film developed at IGN, Creil 4 days after the landing. Subsequently the news media required priorities before a microfiche catalogue of all the images could be produced and before the orders of the over 100 official experimenters could be fulfilled.

At the University of Hannover investigations are under way up to which mapping scale the following techniques may be used:

1) aerial triangulation on the analytical plotter and its bundle adjustment on University of Hannover's BLUH-program
2) line mapping for planimetry and contours on the Zeiss Planicomp C100 analytical plotter
3) DTM generation
   a) by measurement of points in a grid pattern on the Planicomp C100 or
   b) by digitizing of existing of contour maps
   to generate orthophotoprofiles by a computer program such as TASH, available at the University of Hannover
4) orthophoto production on the Zeiss Z2 orthoprinter from the orthophotoprofilse
5) scanning of the photographs on the Optronics P1700 to obtain digital images for further image processing on the Institute's Image Processing System.

In all steps consideration must be made of the orbital height of 250 km which necessitates to convert projection coordinates (Gauß-Krüger or UTM) into geographic coordinates and local three dimensional cartesian coordinates before the usual perspective transformation takes place. This requires changes in the C100 and Z2 software.

The imagery demonstrates, that roads of a width of 10 m are still visible. Points can be determined with an accuracy of about ± 10 m standard deviation in position and height. Due to the unfavourable illumination conditions 1:50 000 orthophoto-mapping is unsharp and shows the photographic grain. Tests have shown, that magnifications to 1:100 000 yield good quality and that 1:100 000 is a suitable mapping scale. It is hoped that the reflight of the camera experiment will permit to map at 1:50 000.

The potential of shuttle photography for mapping is demonstrated by the fact, that the Spacelab 1 mission alone offers the possibility to compile 3500 map sheets (50 x 50 cm) at 1:100 000 or 14 000 map sheets (50 x 50 cm) at the scale 1:50 000, if this mapping is accepted in quality.
A repeated use of photogrammetric cameras on subsequent shuttle missions can therefore gradually acquire a global cartographic image archive, from which maps can be made quickly for development projects in the world.

References

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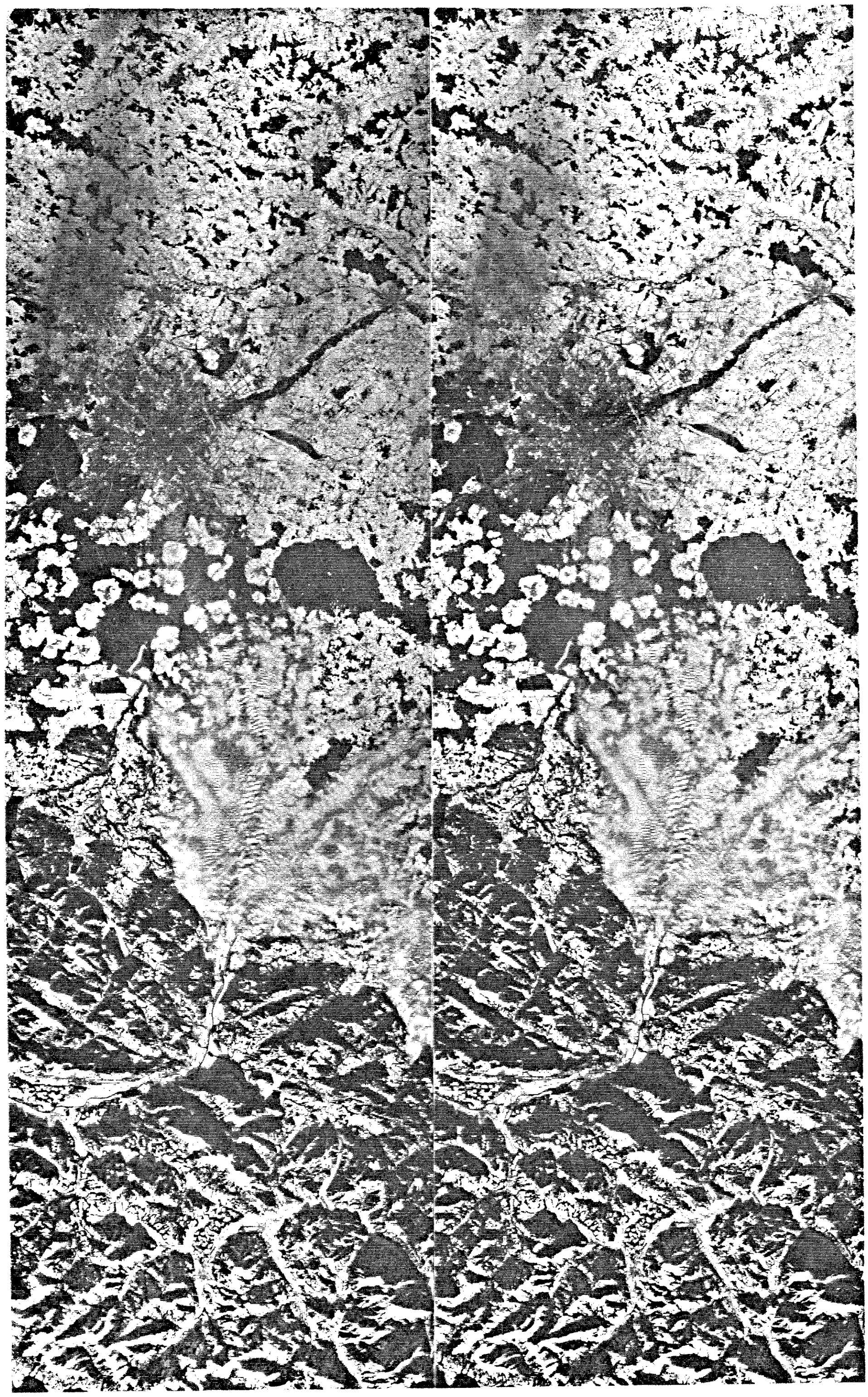

SPACELAB 01

PHOTOGRAMMETRIC CAMERA

EXPERIMENT, DEC 5, 1983;

IMAGE SCALE 1 : 820 000

STEREOPAIR

MUNICH, F. R.GERMANY AND BAVARIAN ALPS