# Investigations of Metric Camera Data Quality

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## 1. Introduction

This contribution deals with first results of the usability of Metric Camera imagery of the Spacelab-1 mission. The first part of this paper demonstrates in general the way to derive empiric exposure functions for optimal picture quality.
In the second part the Metric Camera pictures are compared with imagery of different types of sensors, such as scanners and radar-systems.
Summarizing first results of these investigations are

(a) With respect to the exposure function:

- It is possible to derive sufficient information from high altitude photography to estimate an empiric solar angle and diaphragm depending empiric exposure function for space photography.

(b) First results with respect to the benefit of Metric Camera imagery for topographic mapping purposes are:

- Metric Camera imagery is sufficient for topographic mapping purposes in the scale-ranges 1 : 100 000 until 1 : 50 000.
- According to the extremely high resolution and geometric stability Metric Camera imagery meets all requirements of a reference data base for medium scale mapping purposes.

## 2. Empiric exposure function

This investigation is based upon high altitude photography of the Montpellier (France) campaign.
The both for the Spacelab flight selected films

- Kodak Double-X Aerographic film 2405 (black and white) and the
- Kodak Aerochrome Infrared film 2443 (infrared false colour)

were flown in overlapping flights of the same area under extremely different sun angle conditions.

To derive proper empiric exposure data

- the used densitometer has been calibrated,
- the whole grey value range representing areas were chosen within the imageques, densitometric measured and coordinated.
- data correction based upon calibration data and position on the film,
- selection of the lowest density value for the black and white film respective the lowest average value for the densitometer measurements with 3 colour filters for the infrared false colour film,

- Derive gain of exposure by comparison with defined exposure criterias.
- Combined equalization of the single corrected exposure values according to the formular

$$k = a \sqrt{\sin h^b}$$

with
k = diaphragm value
a and b = empiric exposure values
h = sun angle (degrees)

- Chosing of the optimal exposure from the equalization result, e.g. to limit imagemotion it is tried to use 1/1000 sec. exposure time for $5,6 \le k \le 11$ for the black and white film.

For black and white film PAULY (1983) got the following exposure values:

| h | k | t |
|---|---|---|
| 90°-50° | 11/8 | 1/1000 |
| 50°-37° | 8 | 1/1000 |
| 37°-28° | 8/5.6 | 1/1000 |
| 28°-22° | 5.6 | 1/1000 |
| 22°-17° | 8/5.6 | 1/500 |
| 17°-13° | 5.6 | 1/500 |

For the infrared false colour film resulted:

| h | k | t |
|---|---|---|
| 90°-72° | 5.6/8 | 1/1000 |
| 71°-41° | 8 | 1/500 |
| 40°-26° | 5.6/8 | 1/500 |
| 25°-18° | 5.6 | 1/500 |
| 17°-12° | 5.6/8 | 1/250 |
| 11°- 8° | 5.6 | 1/250 |

## 3. First results of a sensor comparison

Up to now map production and map revision is carried out by two alternative data acquisition methods:

1) terrestrial survey
   In view of the relatively slow speed and high costs, the classical surveying method is limited to small areas, which eliminate this method for a worldwide production and revision of medium scale maps.
2) conventional photogrammetry
   For the task of the worldwide map production and revision of large scales conventional photogrammetry using aircraft is the only accep-

table method to obtain maps or orthophotos.
However, the progress of mapping by this method is still too slow with respect to the demands of map production and map revision, even if the faster orthophoto techniques are applied.
This means that the world wide mapping need at the scale 1:50 000 cannot be fulfilled by traditional photogrammetric methods.
In order to meet the mapping needs it will therefore be necessary to explore other remote sensing possiblities from sapce:

3) Photogrammetry from Space
Frame cameras have been operated successfully from airplanes for decades. To use them from space platforms is a logical alternative for worldwide mapping of medium scales. To test this method a RMK 30/23 has been used on the Spacelab-1 mission in 1983. Another attempt is to fly the Itek LFC on Space Shuttle in 1984. Further recommendations are contained in the "Atlas Study" /6/.
The advantages of frame cameras for photogrammetry from space are:
   a) extremely high resolution:
   While the first Metric Camera mission from an orbit of 250 km shows a photographic resolution of approximately 20 m on the ground the Atlas proposal includes a design for a capability to obtain a photographic resolution of 5 m on the ground, which roughly corresponds to a pixel size of 2 m on the ground, when Kell-factor is considered.
   In this way cartographic requirements for scale ranges from 1:25 000 to 1:50 000 may be fulfilled.
   b) large area coverage
   For a frame camera with a focal length of c = 30 cm an area of about 192 x 192 km results at an orbital height of 250 km for a format of 23 x 23 cm.
   c) simple conventional evaluation technique
   The photographs may be directly evaluated by an existing technology with available plotting instruments.
   d) high geometrical fidelity
   because of strictly controlled camera calibration with simultaneous imaging in two dimensions.

For these reasons the frame camera experiments for space platforms are suitable to produce

1) fundamental mapping of the earth surface at medium scale ranges (around 1:50 000)
2) global determination of the digital terrain model for the derivation of contour lines
3) global densification and combination of control point networks with the help of bundle aerotriangulation adjustment.

The disadvantages of applying frame cameras from space are the necessity to carry large film rolls into space and to retrieve them.
However, the Space-Shuttle transporter utilized in the Spacelab-mission offers this opportunity. Hasselblad-photography taken during the Skylab mission already demonstrated excellent results for space photographs.
The images of the multispectral frame camera MKF 6 on the space stations Soyuz 22 (from onward) make possible a ground resolution of around 25 m achieved by the socialist countries.

4) Use of scanner and array systems
Space missions with passive scanner systems (line scanner and pushbroom scanner) are characterized as one dimensional line images. The total image becomes integrated by movement of the platform with the scanner.

Advantages:

The scanner can operate as a digital system which need not carry film. The data may be transmitted. Therefore scanner systems are more adaptable to long-life satellites and to multitemporal imaging of cloud-free regions. Multitemporal images provide the possibility of change detection.

The information can easier be separated into different spectral bands. Spectral information may also be significantly extended beyond the visible range. The digital form of the data is well suited for automation.

Linear pushbroom scanners as compared to line scanners with rotating mirrors have the advantage of a perspective imaging capability for the imaged line.

The disadvantages of scanner systems are

1) an expensive and complicated technology of data transmission, data receiving, data storage and data processing;
2) limited geometric resolution
The resolution of a scanner system is limited by the data transmission rate of the satellite system. Thus either an extended coverage or an extended resolution may be aimed for. Ground resolution is dependent on the orbital height. Landsat has sofar been operated at a 15 Mbit/sec data rate, Spot will operate at 64 Mbit/sec. The technical limit for data transmission at still affordable cost is at about 200 Mbit/sec.
The present technical limitation at an orbit of about 300 km can reach a minimal ground pixel size of approximately 8 m (panchromatic) for an image strip width of 80 km. This also corresponds to a minimum integration time limit considering the satellite velocity. This actually corresponds to a photographic ground resolution of about 20 m. Therefore the cartographic application of such a scanner system may be suitable for scale ranges between 1:100 000 and 1:250 000.
The ground pixel size of Landsat 1 and 2 (MSS) imagery is 79 m, which is comparable with a photographic resolution of about 220 m. The positional accuracy of Landsat rectification indicates a result of ± 50-80 m (1 Pixel).
Landsat 3 is additionally equipped with a Return Beam Vidicon TV-camera (RBV) (ground pixel size 40 m, photographic ground resolution of about 110 m); while Vidicons may be suitable for higher geometric resolution, their radiometric resolution is poor.
3) high requirements for the stability of the spatial attitude of the attitude of the sensor and the continuity of forward movement of the platform.

The geometric accuracy of satellite scanner images may be restored to ± 1-2 pixel accuracy.

5) Use of active scanner systems (RADAR)
The advantages of RADAR, the possibility of cloud penetrating cannot be compensated by the disadvantages of a restricted general topographic detail detectability, e.g. for buildings. At present radar images from satellite are not even suited for mapping of scales 1:250 000. The resolution of radar signals is determined by the pulse length of the radar system perpendicular to the platform movement and by the (synthe-

tic of real) antenna length in the direction of the platform movement. The returned radar signals may be digitized (or digitized and reconstructed for coherent radars) at arbitrary ground pixel sizes. For Seasat satellite images a pixel size of 25 m is usually chosen. But a detailed comparison of detectability of different objects with relation to reflectance and topography has not yet been completed. However, a preliminary analysis suggests, that certain objects may have a resolution in excess of 5 pixels.
Airborne radar images (GEMS 1000) with a 10 m pulse flown over the test area Phoenix have demonstrated this. Geometric analyses using a dense control point distribution have reached a positional accuracy of ± 20 m standard deviation. For practical image mapping purposes, for example in Columbia, the achieved accuracies have been ± 300 m.

The following sample for a sensorcomparison points out the high quality standard of analog optical imageproducts.

In figure 1 is compared a part of a Metric Camera infrared image of the Hannover region with a Landsat image of the same part. From interpreting the originals derived the evidence for the qualification of Metric Camera imagery for worldwide reference purposes for medium scale mapping.

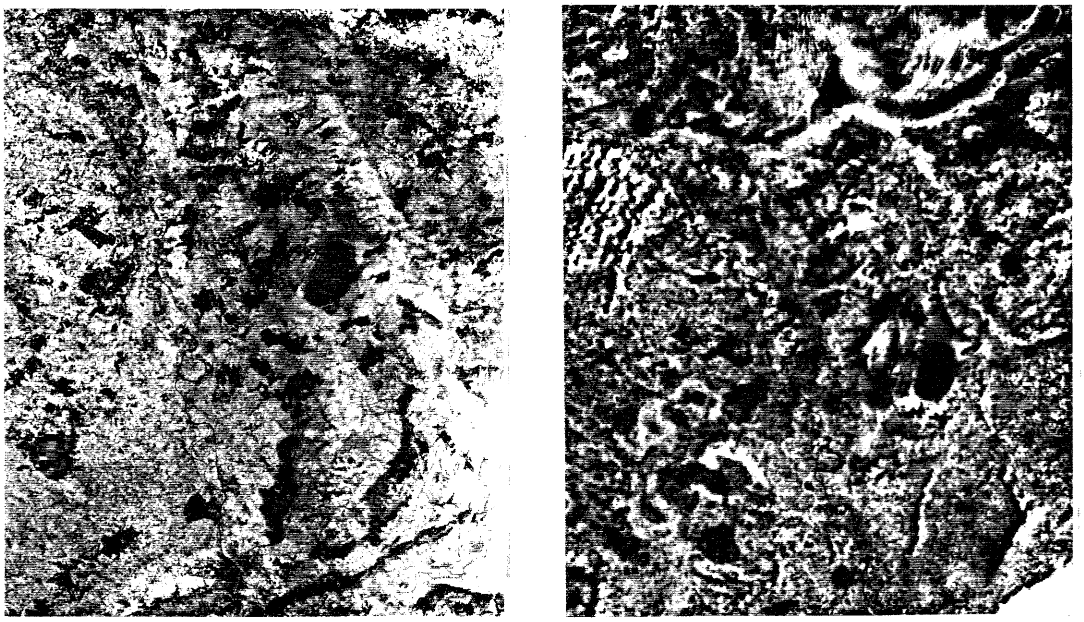

Fig. 1: Part of an IR Metric Camera image of the Hannover region (Federal Republic of Germany)

Comparable part in a Landsat image

In conclusion it can be said that sofar only the photogrammetric frame camera fulfills the requirement of topographic cartography. As far as the capacity of sensor data is concerned, frame camera imagery in color at a resolution of 30 lp/mm has an information content of about $5.7 \times 10^8$ pixels. It is superior to a Landsat scene with $7.4 \times 10^6$ pixels by a factor of 77.

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