First results of MOMS-02 data and future geoscientific applications

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ABSTRACT

The Modular Opto-electronic Multi-spectral Stereo Scanner MOMS-02 experimental data acquired during the German Spacelab D2 mission will be used for a broad range of geoscientific objectives. The simultaneous acquisition of high spatial resolution, multispectral and stereo scenic data enables a real combination of thematic and topographic information, thus considerably improving the verification and interpretation of dynamic changes of the Earth's surface by means of remote sensing.

This paper gives a first assessment of the MOMS-02/D2 mission, the data quality and an overview on the planned methodological and application-oriented investigations for various test sites. On the basis of a few examples the possibilities of this system for future thematic applications are shown.

1. INTRODUCTION

MOMS-02 is the technological continuation of MOMS-01, which was the first instrument in space using the "push broom scan" principle. It was successfully flown aboard the Space Shuttle missions STS-7 and STS-11/41-B in 1983 and 1984 (Bodechtel *et al.*, 1985). MOMS-02 was launched aboard the Second German Spacelab Mission D2 on Space Shuttle flight STS-55 and aquired data between April 26 and May 6 1993.

The thematic geoscientific goals of the mission are focused on the combination of topographic and spectral information, which will be derived from the simultaneously acquired multispectral, multi-resolution and stereoscopic data (Ackermann *et al.*, 1989; Bodechtel & Jutz, 1990). To meet these goals, 3 panchromatic and 4 spectral bands were defined in the visible (VIS) and near infrared (NIR) range of the electromagnetic spectrum. Width and centre wavelength of these bands are optimised for the detection of the spectral response of vegetation and for the discrimination of Fe-bearing rock and soil surfaces due to significant absorptions in the VIS/NIR spectral range (Kaufmann *et al.*, 1989).

2. TECHNICAL PARAMETERS

The technical features of the MOMS-02 camera are oriented toward the requirements of today's photogrammetric and thematic applications. Characteristic features of the sensor design include

- three-linear stereo imagery
- along-track stereo imagery
- high resolution imagery
- multispectral imaging
- combination of stereo – and multispectral imaging

Figure 1 shows the total MOMS-02 imaging geometry, and the resulting ground track. The swath width for the high resolution channel can be as much as 37 km, depending on the recording mode, and 78 km for the other channels.

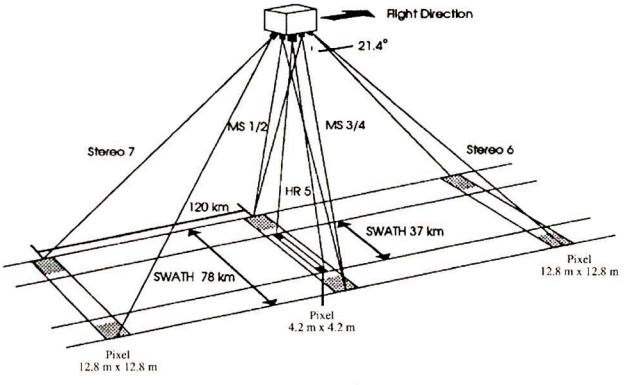

Figure 1 - MOMS-02 imaging geometry.

These values are relative to a nominal orbit altitude of 296 km. Because of the viewing angle of 21.4° of the two off-nadir stereo channels, the image swath on the earth's surface for these channels is seperated from the swath of the nadir channels by about 120 km.

Figure 2 gives a schematic representation of the MOMS-02 optical concept. In order to fulfil the different user requirements a modular concept was selected. The system consists of five lenses, three were designed for stereoscopic applications, wheras the other two enable the acqisition of multispectral data sets.The central lens, with a focal length of 660 mm, forms the core of the camera system. This camera acquires the high resolution imagery with a ground pixel size of 4.2 m x 4.2 m. In combination with the central high resolution lens, there are two other stereo lenses, each with a focal length of 237.2 mm. Because of their tilt angle of +21.4° and -21.4°, respectively, relative to the direction of flight, threefold stereoscopic imagery is enabled. The focal length of these lenses was selected as a way to obtain a 1:3 ratio for the ground pixel size of the high resolution and the tilted stereo channels. In addition, two other lenses, each with a focal length of 220 mm, enable the multispectral imaging of a total of four channels.

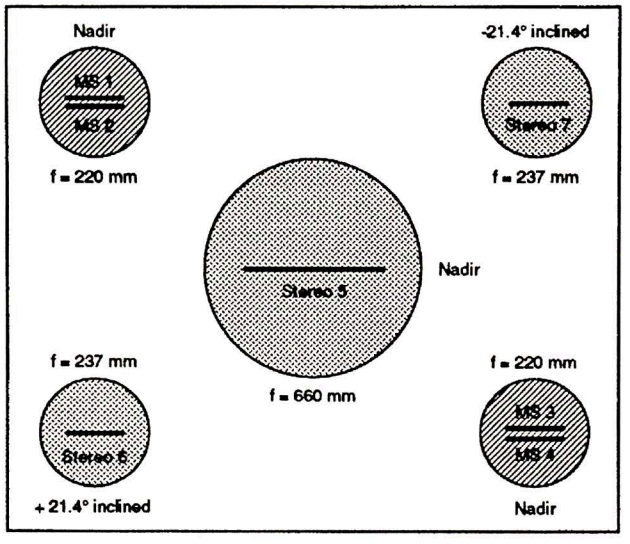

Figure 2 - MOMS-02 optical concept.

MOMS-02 is designed for spectral data acquisition in the VIS and NIR range (four channels) and for along-track stereo recording using a panchromatic channel for one nadir and two off-nadir looking modules. A ground pixel size of 12.8 m x 12.8 m for the spectral channels is a sound compromise between a high spectral resolution and a sufficient signal-to-noise ratio. In additon, the IFOV of the spectral bands and the tilted modules is an integer multiple of that of the panchromatic nadir module, which significantly simplifies the merging of simultaneously recorded data. Figure 3 shows the position and width of the spectral bands of MOMS-02.

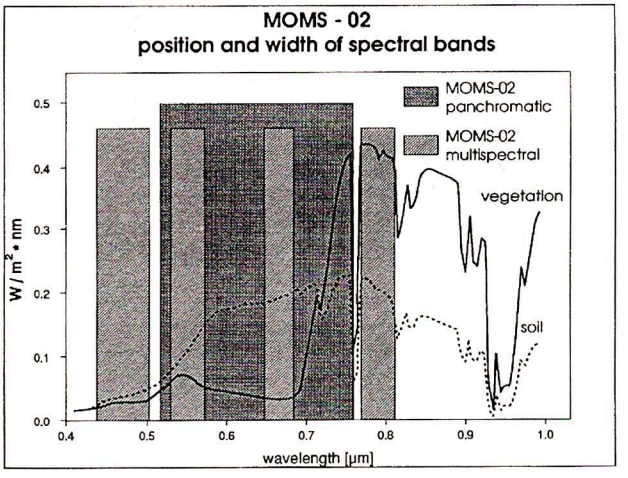

Figure 3 - Overview of the MOMS-02 spectral and panchromatic bands.

Table 1 summarizes the most important performance parameters of the MOMS-02 camera where all geometric data are related to a nominal flight altitude of 296 km.

Table 1 - MOMS-02 characteristics

Channel	Mode	Orientation	Band Width	Ground Pixel	Swath Width
1	M/S	Nadir	449 - 511 nm	12.8 m x 12.8 m	78/43 km
2	M/S	Nadir	532 - 576 nm	12.8 m x 12.8 m	78/43 km
3	M/S	Nadir	645 - 677 nm	12.8 m x 12.8 m	78/43 km
4	M/S	Nadir	772 - 815 nm	12.8 m x 12.8 m	78/43 km
5	HR	Nadir	512 - 765 nm	4.2 m x 4.2 m	37/27 km
6	Stereo	+21.4°	524 - 763 nm	12.8 m x 12.8 m	78/43 km
7	Stereo	-21.4°	524 - 763 nm	12.8 m x 12.8 m	78/43 km

3. DATA ACQUISITION

The data takes during the D2 mission are considered very successful. The sensor was controlled and operated from the German Space Operation Centre (GSOC) at Oberpfaffenhofen upon the requests of the scientific user team, set-up by the principal investigators and the project management. According to the mission profile given in table 2, 48 data takes were performed during 5.5 hrs recording time including calibration runs before and after imaging (net time of imaging 4.5 h). Thus an overall coverage of approximately 8 mio km² was achieved and a cloud free coverage of 2.8 mio km² is realised.

4. THEMATIC OBJECTIVES

The MOMS-02 data are expected to allow the improved interpretation and verification of natural phenomena and man made changes. The main investigations are focused on the fields of land-cover, geomorphology, ecology and urban planning. The 4 narrow multispectral bands in combination with the high spatial resolution enable an enhanced detection of relevant surface parameters, e.g. small scale textures of the earth's surface. Stereo data sets in high spatial resolution allow the derivation of high quality digital terrain models with an accuracy of up to 3 meters. The combination of simultaneously acquired stereo and mul-

Table 2 - Performance of the MOMS-02 system and D-2 mission profile.

7 CHANNELS WITH 6000 ELEMENTS/DETECTOR ARRAY			
spectral range		spatial resolution	
Multispectral bands (MS)			
channel 1	440 – 505 nm	12.8 m	
channel 2	530 – 575 nm	12.8 m	
channel 3	645 – 680 nm	12.8 m	
channel 4	770 – 810 nm	12.8 m	
***Panchromatic bands** (**H**igh **R**esolution + **S**tereo)*			
three-line scanning for in-track stereo coverage			
channel 5	520 – 760 nm	4.2 m	nadir-looking (HR)
channel 6	520 – 760 nm	12.8 m	+ 21.4° tilted (ST)
channel 7	520 – 760 nm	12.8 m	– 21.4° tilted (ST)
RADIOMETRIC RESOLUTION		8 bit selectable from 12	
on-board data compression		8 to 6 bit (only for full stereo)	
7 DIFFERENT OPERATION MODES			
stereo/spectral channel combinations:			
mode 1	channel 5, 6, 7	(HR + ST, all stereo)	
mode 2	channel 1 – 4	(MS, all multispectral)	
mode 3	channel 3, 4, 6, 7	(2 MS / 2 ST)	
mode 4	channel 1, 3, 4, 6	(3 MS / 1 ST)	
mode 5	channel 1, 3, 4, 7	(3 MS / 1 ST)	
mode 6	channel 2, 3, 4, 5	(3 MS / HR)	
mode 7	channel 1, 3, 4, 5	(3 MS / HR)	
SWATH WIDTH		37 km or 78 km, mode dependent	
RECORDING		DDR-100 HDT recorder max. storage cap. 5.5 h max. data rate 100 Mbit/s coverage ca. 10 Mio.km²	
SPACE PLATFORM		German Spacelab D2 Mission	
MISSION DURATION		April 26 to May 6 1993	
ORBIT INCLINATION		28.5°	
ORBIT MEAN ALTITUDE		296 km	

tispectral data sets provide topographic and thematic information for environmental assessment and monitoring.

The major test areas of the thematic-geoscientific group of investigators and their principal research topics are:

- Egypt, Eastern Desert and Saudi Arabia: rock and soil spectral signatures, lithologic mapping, mineral exploration
- Ethiopia: vegetation spectral signatures, vegetation changes, land-use, pedology
- Zimbabwe: vegetation mapping, stratigraphic mapping, mineral exploration, regional planning
- Australia: stratigraphic and tectonic mapping, mineral exploration
- China: land use, natural risk assessment
- Chile and Mexico: coastal environment, natural risks, geological mapping
- Phillipines: rainforest studies

The availability of simultaneously acquired stereoscopic and multispectral information requires new ways of image processing and data extraction. The data extraction through optimised image enhancement and classification plus the quantitatively determinable third dimension enables the derivation of a variety of new data layers from one single system. These layers will be compiled in a Geo-Information-System with intelligent concepts for the combination of the extracted information.

The stereo capabilities combined with multispectral data will considerably improve the detectability of surface phenomena such as tectonic features and stratigraphic layers. The comparison of images taken under different observation angles allows to investigate the directional effects of surface texture on the spectral response and to assess the transparency and depths of coastal waters.

Simultaneously acquired multiresolution data will provide unique possibilities to study surface textures and mixed pixels for understanding the physical and geometric properties of the scanned objects. For vegetation studies and landuse purposes an improvement of classification accuracy is expected, especially in natural forest areas, biotop detection and monitoring regions with agroforestry as well as in urban zones.

In addition MOMS-02 narrow band multispectral data will lead to an improved differentiation of spectral signatures of minerals, rocks, soils and vegetation. Different vegetation targets show significant reflectance differences, dependent on wavelength, irradiation conditions and look direction and angle (Deering & Eck, 1987). This indicates that MOMS-02 modes III-V, combining multispectral bands with off-nadir stereo channels, will provide specific object dependent signal differences, which might be used to improve the differentiation of various vegetation communities.

Furthermore, the suitability of MOMS-02 for atmospheric research (scattering, thickness of layers), hydrologic-ecological and coastal studies (transparency, water depth, suspended matter), the detection and classification of instable slopes (areas endangered by land-slides), the mapping of watersheds and drainage area in karst regions, and the modelling of water flow shall be investigated.

5. FIRST RESULTS OF MOMS-02 DATA

One of the first MOMS-02 data sets processed, covers an arid area around the city of Buraydah (Northern Saudi-Arabia). The data take was flown successfully in mode 6 and consists of 3 multispectral bands: 4 (red range), 3 (green range), 2 (blue range) and of the high spatial resolution panchromatic band 5. By merging the high resolution panchromatic band into the false colour composite using the IHS-method (HAYDN et. al, 1982) it is possible to increase data interpretability and evaluation enormously.

Figure 4 is an image of MOMS-02 data which shows clearly the smallscale features and textures in a very high spatial resolution (4.2 m) in combination with its characteristic spectral features. Bright greyvalues in the circular irrigated areas indicate active vegetation, whereas the dark greyvalues are related to dry vegetation in combination with soils. The airport located in the upper part of the figure demonstrates the capabilities of the high spatial resolution of this image, e.g. on the runway there are white markers detectable, and even very small buildings can be separated from more homogeneous areas at the airport. In the area around the city of Anaiza, located in the lower part of the image, even minor roads and small houses are visible, thus enhancing the contrast between the old villages and the modern and still expanding urban infrastructure.

Data products like this will be used in the near future for a wide range of applications. The monitoring of landuse as well as planning and surveying of urban settlements in developing countries are important tasks. The variety of

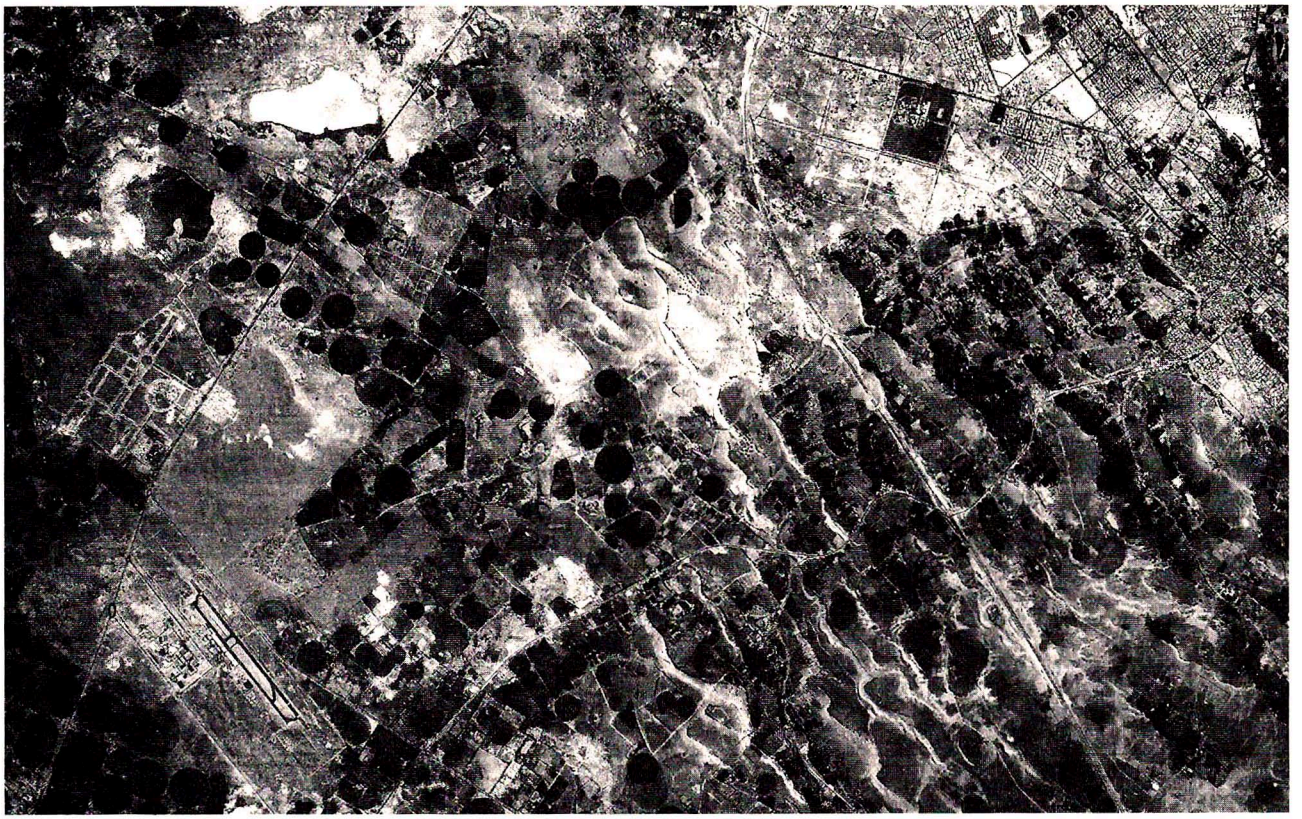

Figure 4 - Image of the MOMS-02 data of Buraydah, Northern Saudi-Arabia. IHS-Merge of MOMS-02 bands 4,3,2 with the panchromatic band 5, spatial resolution is 4.2 meters.

different types of products that will be derived from MOMS-02 data in the future comprises digital terrain models, high resolution panchromatic and multispectral images.

Figure 5 shows an example of a multispectral MOMS-02 image acquired in Mode 2. The datatake consists of 4 multispectral bands (see Table 2). Three bands were used for this false colour composite: 4 (infrared range), 3 (red range), 1 (blue range). It demonstrates the potential of the MOMS-02 narrow multispectral bands to detect minor changes in geochemistry (e.g., $Fe^{2}+/Fe^{3}+$ contents).

The processed image shows an area located in the Northwestern part of Australia near the city of Halls Creek, unveiling manifold geological features. The geologic setting is charcterized by precambrian sediments and volcanics, with greyvalues ranging from grey to dark, which underwent metamorphism and were folded intensively as a part of the Halls Creek Mobile Zone. Granitic intrusions that belong to the Halls Creek Province, an area of mining and prospection activities, are represented by light greyvalues. The high spatial resolution of this image enables mapping of thin layers of metasediments as well as detection of small-scale tectonic structures.

Figure 6 shows an example of a multispectral MOMS-02 image acquired in Mode 3 over the Gulf of California. The datatake consists of 2 multispectral bands and 2 tilted panchromatic stereo-bands (see Table 2), the spatial resolution is 12.8 m. Only the 2 multispectral bands were used for this colour composite: 4 (infrared range), 3 (red range), Ratio 4/3 (blue range).

The image shows a part of the mexican coast of the Gulf of California near the city of Culiacan. At the centre of the image the city Culiacán near the steep raising Sierra Madre Occidental is presented in light colours. The coastal region is dominated by agriculture, which can be recognized by the typical land use pattern in grey to dark values. Interesting are also the foreshore mangrove forests and swamps and their filigran structures of water courses and vegetated areas. Within the coastal hinterland and along the Sierra several water reservoirs were arranged for irrigation. These water reservoirs often lead to inundations seriously affecting agriculture and infrastructure.

For this area a future thematic application based on MOMS-02 data will be the development of a hydrological model using a DTM derived from the stereo data of mode 3. Such a hydrological model is well suited for the eva-

Figure 5 - Image of the MOMS-02 data of Halls Creek, Australia. B & W Image of MOMS-02 bands 4,3,1, spatial resolution is 12.8 meters.

luation of areas potentially endangered by inundations and can serve as a base for prevention and planning activities.

6. CONCLUSIONS AND PREVIEW OF THE FUTURE MOMS-02 PROGRAMME

The technical design of the MOMS-02 instrument is based on up to date sensor, optic and electronic technologies resulting in narrow spectral bands at reasonable SNR values. The position of the multispectral bands were determined with respect to the optimisation of vegetation and pedological/geological feature extraction. Results from simulated data and first assesments of transmitted raw data lead to the conclusion that considerable improvements can be expected through improved spatial and spectral resolution combined with stereo capabilities as compared to existing operational sensors.

The along-track stereo acquisition capability of the MOMS-02 sensor allows the evaluation of DEM's from data registered under the same irradiation conditions. This will be useful not only for photogrammetric purposes, but also for the interpretation of spectral response in regions with orographically developed topography.

After the successful experimental mission on Spacelab D2, MOMS-02 will be deployed on the Russian space platform MIR in the framework of the environmental earth observation module PRIRODA, covering the Earth within the latitudes ±51.6°. This mission offers the opportunity of multisensor data registration with a repetition rate of 2 to 7 days and is considered an indispensable step to prepare

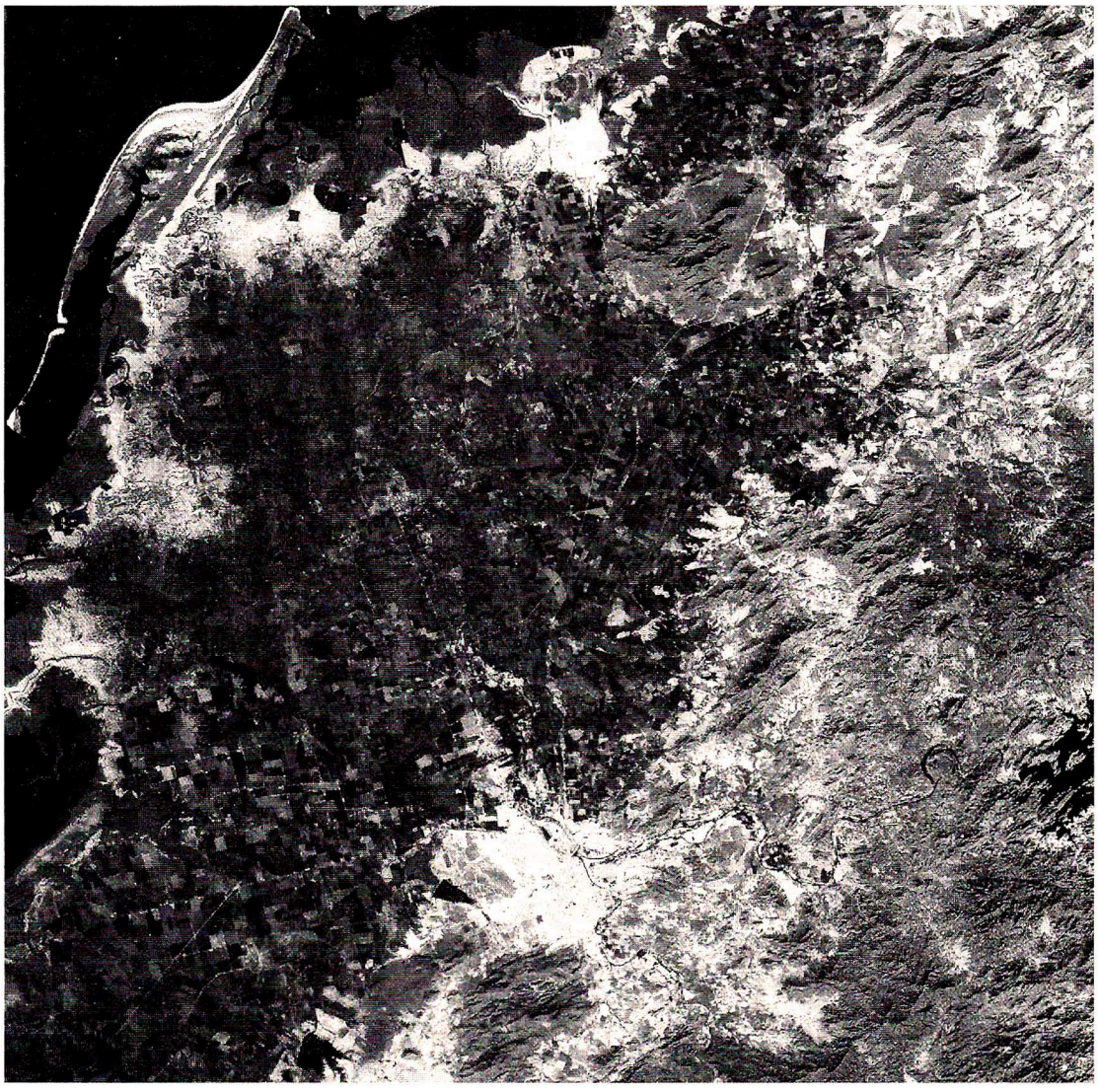

Figure 6 - Image of the MOMS-02 data of Culiacán, Mexico, B & W image of MOMS-02 bands 4,3, and a combination of ratios 4/3, spatial resolution is 12.8 meters.

high spatial, spectral and temporal resolution environmental monitoring at continental to global scales with Polar Platform missions being scheduled for the late 90th.

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