NEW SATELLITE DATA WITH HIGH GROUND RESOLUTION FROM THE SPACE COMPLEX MIR AND OTHER PLATFORMS

V. Liebig

Kayser-Threde GmbH, Munich, F.R.G.

ABSTRACT

Since the opening of the USSR different organisations of the CIS have been trying to sell satellite image data in the Western world. This gives the opportunity to receive space images at very low costs compared to Landsat and Spot data. After introducing new Russian organisations which entered the market, the main platforms and camera systems are discussed, focusing on the KFA-1000 and MKF-6MA systems. The KFA-1000 is a metric camera with about 7.5 m ground resolution (from the MIR station). MKF6-MA is a multispectral sensor, developed by ZEISS Jena.

NPO Energia and Kayser-Threde are working together in marketing earth observation data from the MIR space complex.

To keep track of the thousands of photos a database system has been installed. Plots of the available images are produced after every acquisition period.

On customer request special acquisition campaigns are organized for selected areas. The operational flow of a special acquisition mission is shown. Due to the low costs even developing countries could afford to get sets of satellite images from their country.

Keywords: Russian satellite images, space-complex MIR, low cost.

1. INTRODUCTION

The rapid changes in the political system of the former USSR led to an opening of the space industry in the CIS. Cooperations on many fields have been started during the last year. The big space companies in the CIS are looking for western partners and offer their experience and products. In addition former military used systems are starting to open to commercialization.

In 1991 different Russian space companies entered the market for remote sensing products. This paper will describe new photographic products available now on the western market at very low costs.

Since 1987 the All Union Foreign Economic Association Sojuzkarta offered high resolution images from KFA-1000 cameras on board of Kosmos satellites (Ref. 1-3).

Meanwhile organizations behind Sojuzkarta, as the State Center Priroda or NPO Planeta have settled own contracts with companies in the Western world. At the same time a new foreign trade organization, Sovinform Sputnik, has been founded and tries to replace Sojuzkarta. In addition to the products offered by Sojuzkarta, Sovinform Sputnik also tries to market former military systems.

With NPO Energia, the leading space company in the CIS, a new competitor has entered the market in 1991.

Since 1990 NPO Energia is running photogrammetric and multispectral cameras on board of the space station MIR. NPO Energia, with its headquarter in Kaliningrad, is the biggest space company in the CIS. It has constructed space vehicles as SOJUS-TM or BURAN and is responsible for the space complex MIR. Now it is trying to commercialize parts of its activities.

In 1991 Kayser-Threde, Munich, signed a contract with NPO Energia to cooperate in offering the data from the MIR cameras on the market.

2. PHOTOGRAPHIC EARTH OBSERVATION SYSTEMS IN THE CIS

Mainly two different space platforms are used in the CIS for high resolution earth observation cameras:

- Resurs-F spacecrafts
- the MIR Space Complex

The Resurs-F spacecraft is used in two versions for earth observation purposes (fig. 1 and 2): Resurs-F1 and Resurs-F2 (Ref. 4). Technically both spacecrafts are very similar but they are equipped with different instruments (see chapter 3). The orbital altitude is between 250 km and 400 km, the inclination is 83°. Films and cameras return to earth by a reentry capsule using soft landing rockets.

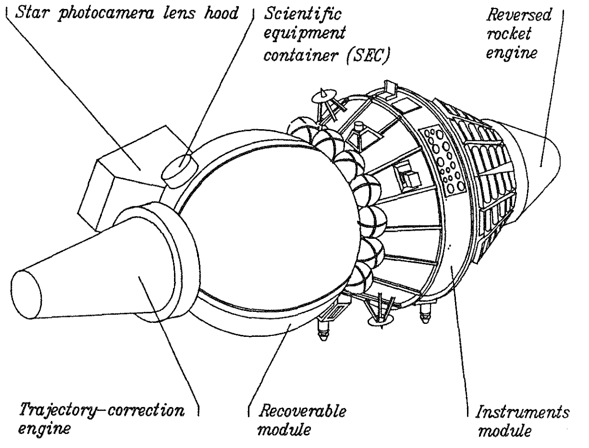


Fig. 1: Resurs-F1 spacecraft (Ref. 4)

Resurs-F1 has a 25 days flight duration, including 7 days of flight without orientation. The whole earth surface can be photographed once, some regions twice during one mission. It is equipped with 2 KFA-1000 and 3 KATE-200 cameras.

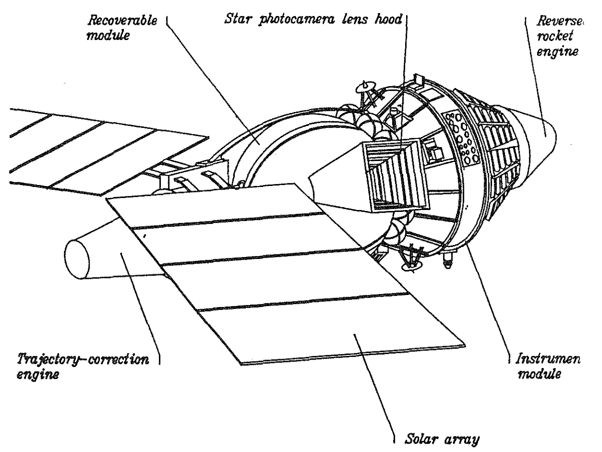


Fig 2: Resurs-F2 spacecraft (Ref. 4)

Resurs-F2 is able to take pictures of the whole earth twice or three times within its 30 days flight duration. on Resurs-F2 a MK-4 multispectral camera is used.

The second platform for space photography besides the capsules is the MIR space station.

At the moment the space complex MIR consists of four modules (see fig. 3):

- the main block
- KWANT
- KWANT-2
- KRISTALL

KWANT-2 and KRISTALL are mounted perpendicular to the main axis of the space station. Early in 1993 a third module, PRIRODA (nature), shall be launched. The main purpose of the PRIRODA mission will be earth observation. A fourth module, SPEKTR, is nearly ready but its launch is under discussion due to the budgetary situation in Russia.

Because of its inclination of 51.6° the MIR station is much better suited for earth observation as other manned systems, e.g. the American space shuttle missions or the planned space station FREEDOM with its 28° inclination.

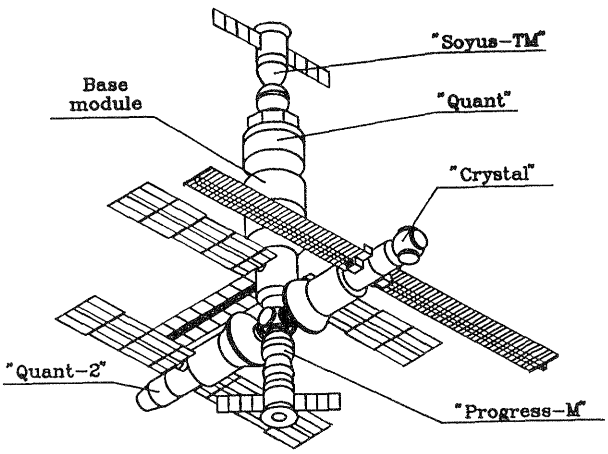


Fig. 3: The space complex MIR (status 1992)

MIR orbits have a repetition rate of two days. The overfligth is about 45 minutes earlier every two days. A certain area is overflown every 2 months at the same time of day.

The orbital parameters of the MIR space complex are shown in table 1:

Inclination:	51.6°
Altitude:	ca. 400 km
Excentricity:	< 0.001
Orbit period:	ca 90 min.

Table 1: Orbit parameters of the MIR station (Ref. 5)

Normally the MIR complex is oriented by the on-board computer in a way, that the large solar panel arrays are always looking toward the sun. Only for data acquisition periods the station is turned in a position that the flight direction is parallel to the forward motion compensation of the cameras. This orientation could be stabilized for approximatly three rotations, which is equivalent to about 270 minutes. After this time the board accumulators need to be charged again by solar power (Ref. 6).

Different earth observing cameras are installed on board of the MIR station. On KWANT-2 a KAP-350 camera and the multispectral MKF-6MA are installed. On KRISTALL two KFA-1000 systems are mounted. In addition two spectrometer (MKS-M2 and Phasa) and some TV cameras are working on the space station. After the launch of the earth observation module PRIRODA a new set of instruments, including the East-German MOS Spectrometer and a Russian SAR, will be used on board of MIR (Ref. 7). In 1994 the German MOMS-02P sensor shall be installed on MIR after its flight on the D2 shuttle mission. A high precission orbit and attitude determination system shall support this camera (Ref. 14 and 15).

3. CAMERA SYSTEMS

At the moment images of the following Russian camera systems are available in the Western world:

- KFA-1000
- MKF-6MA
- KATE-200
- KAP 350
- MK-4

All of them are analog cameras, i. e. they use conventional film as storage medium, which returns to ground after the mission.

On the Western market only the KFA-1000 images are introduced. In the former German Democratic Republic (GDR) the images of the multispectral ZEISS camera MKF-6MA were widely used. So this paper will concentrate on this two cameras after describing shortly the other camera types.

KAP 350 is a medium size camera with 350 mm lens and a ground resolution of about 40 m. The ground coverage is 200x200 km² (all data are given for an altitude of 400 km, Ref. 6).

KATE-200 consists of three cameras which observe the same surface area in three different spectral bands (510-600 nm, 600-700 nm, 700-850 nm). The focal length is 200 mm and the image size is 180x180 mm². This corresponds to a surface area of 225x225 km². The ground resolution is between 20 m and 30 m (Ref. 4).

MK-4 is also a multispectral camera system with four lenses of 300 mm focus length. Four out of six spectral bands (460-505 nm, 515-565 nm, 580-800 nm, 635-690 nm, 810-860 nm) can be selected for a certain surface area. The image size is 180x180 mm² which is equivalent to 150x150 km² from an altitude of 250 km. The ground resolution from this altitude is 8-12 m for spectrozonal film (Ref. 4).

The East-German made MKF6-MA is mounted in the KWANT-2 module of the MIR space complex. It is a metric multispectral camera with a ground resolution better 25 m (altitude 400 km, Ref. 8-10). The technical data is listed in table 2. The camera consists of the camera body with 6 film cassettes and 6 ZEISS Pinatar 4/125 lenses. The image size is 55x81 mm which is equivalent to 175x260 km² on ground. Each lens and corresponding chamber is optimized to its spectral band. So all 6 images have exactly the same scale. The light is splitted by filters into 6 bands (see table 2).

Focus length:	125 mm
Mean image scale:	1:3.200.000
Mean image size:	175x260 km²
Ground resolution:	20-25 m
Film:	6 x 70 mm b/w
	460-500 nm
	520-560 nm
	580-620 nm
	640-680 nm
	700-740 nm
	780-860 nm
Film capacity:	>1250 images
Forward motion compensation	

Table 2: Technical data of the MKF-6MA cameras (Ref. 8)

The bandwidth of each channel is between 40 and 100 nm (see fig. 4).

The camera is forward motion compensated. The compensation is performed by tilting the whole camera. This system results in a maximum error of 0.8 mrad/s.

All images are taken with 60% coverage in flight direction to enable stereo evaluations.

On KRISTALL two KFA-1000 cameras are mounted. The system of the two cameras is called PRIRODA-5.

The CIS made KFA-1000 cameras are mounted in parallel direction. They are tilted by an angle of 8° against the nadir. So the images of the two cameras show a lateral coverage of 1° (about 7 km on ground) and a doubling of the covered ground area (see fig. 5). Due to that installation and the inclination of

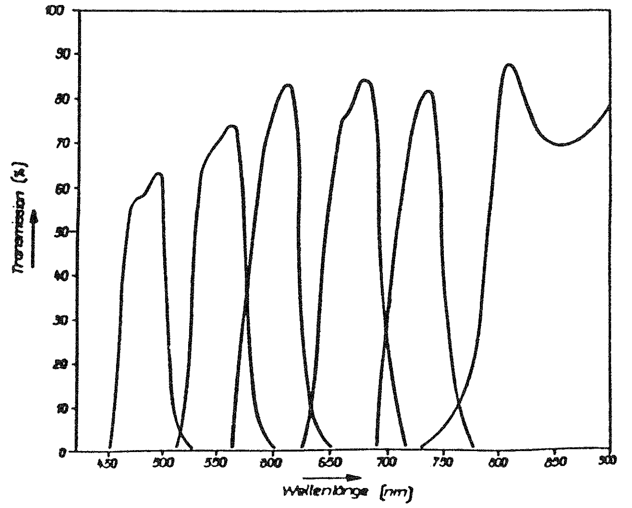


Fig. 4: Spectral Bands of the MKF-6MA Camera (Ref. 8)

51.6° the system can take pictures up to about 52.5° northern or southern latitude, without tilting.

The technical data of the KFA-1000 camera are listed in table 3:

Focus length:	1000 mm
Mean image scale:	1:400.000
Mean image size:	120x120 km²
Ground resolution:	ca. 7.5 m
Film:	SN 10 Spectrozonal
	560...680 nm
	680...810 nm
Film capacity:	1500 images
Forward motion compensation	

Table 3: Technical data of the KFA-1000 cameras

Both cameras are forward motion compensated. Normally all images are taken with 60% coverage in flight direction to get stereo data.

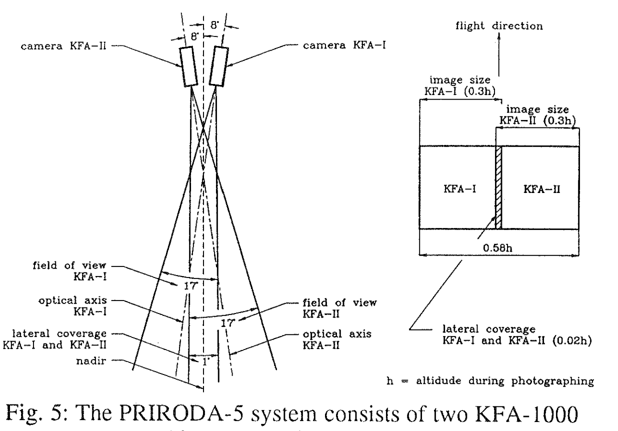


Fig. 5: The PRIRODA-5 system consists of two KFA-1000 cameras mounted in parallel direction

After processing of the films the image number, the camera number, the focus length and a BCD time and date code can be found on every negative (see fig. 6). The resolution of the time code is 2 seconds. All negatives carry image marks to allow photogrammetric processing of the data.

The films for all MIR cameras are transported by SOJUS-TM or PROGRESS spacecrafts into the orbit and latest three month later back to ground. A longer use of the film would degrade it due to the radiation in the MIR orbit.

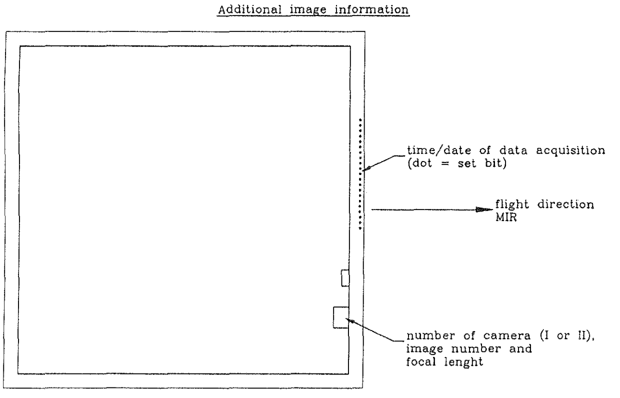


Fig. 6: On every negative the number of the camera, the image number, the focus length and a date/time code can be found.

4. IMAGE DATABASE SYSTEM

To keep track of thousands of images from the MIR station, NPO Energia and Kayser-Threde worked together to establish a database system in which every scene can be found (Ref. 16).

Shortly after each campaign the orbit data of the space station are calculated. This data together with the time of the image acquisition is used to calculate corner coordinates of each image. After the development of the films the image numbers are added. Then all data are played into the database.

A comparison of the calculated coordinates with the coordinates taken out of the images shows an error of less than 10% of the image size (see fig. 7).

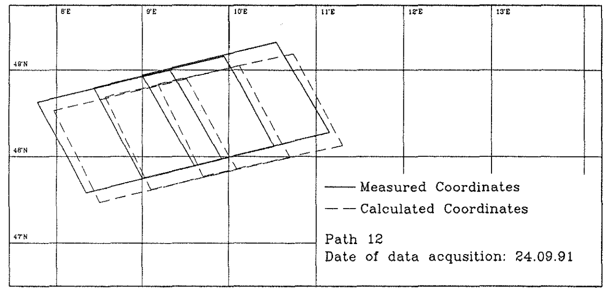


Fig. 7: Comparison of calculated and measured image coordinates.

The database coordinates can be transfered into a graphic package which overlays the image coordinates to vectorized maps (see fig. 8) The plots are regularly distributed to customers and agents.

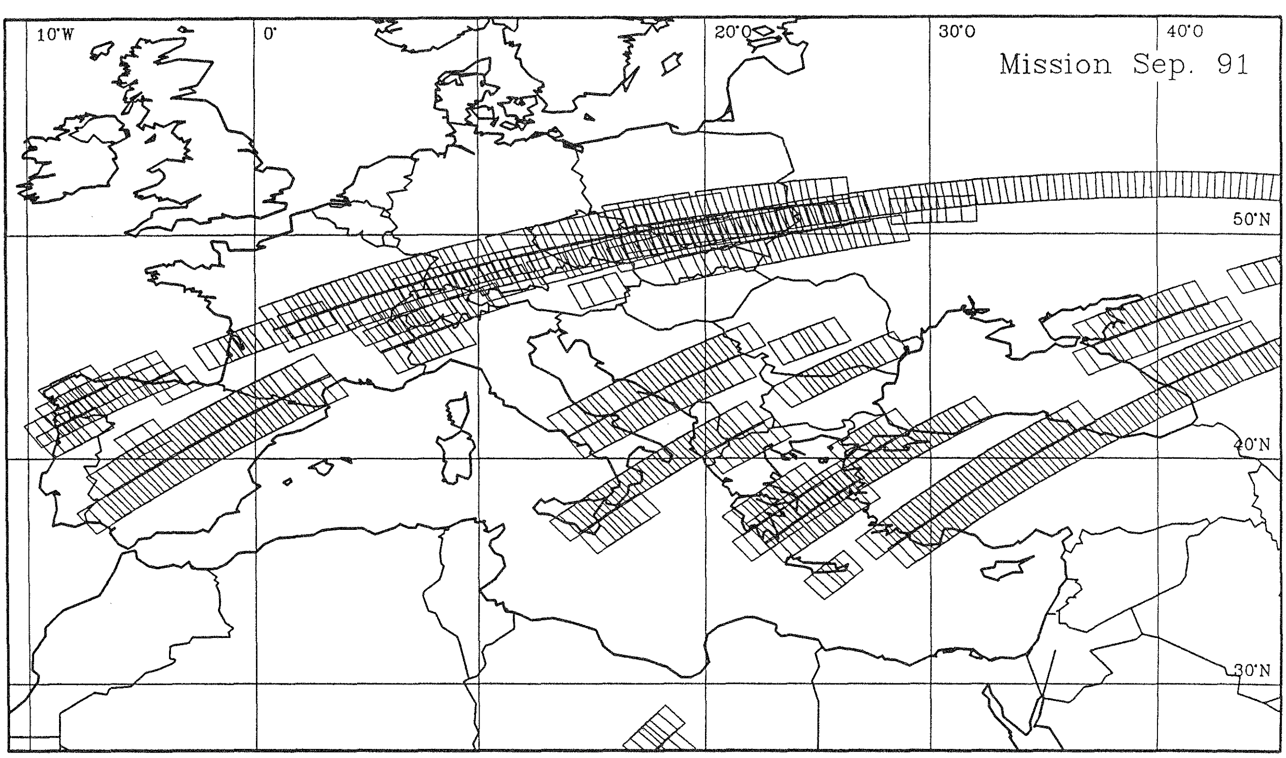
On request of a customer cloud figures for an interesting scene will be delivered by a mail box system installed between Munich and Moskow.

5. SPECIAL ACQUISITION CAMPAIGNS

Image acquisition on request of a customer is called Special Acquistion. If a customer needs actual data of a certain area not included in the archive it is possible to organize a Special Acquisition campaign.

In 1991 three campaigns were organized. Two of them were successfully finished (one in Germany, one in Southern Europe), one could not be fulfilled due to permanent cloud cover.

Fig. 8: Acquisition period September 91 over Europe.



The first step of a special acquisition campaign is the determination of the customer requirements, e.g. location, prefered daytime and month, sun elevation etc. After that the orbit planning is performed and possible data acquisition dates are identified. In preparation of the campaign 3-day weather forecasts are organized and sent to Moskow during the possible mission period. Based on this information a decision is made to try the acquisition or not. After having taken the photos the films are sent to ground with the next spacecraft (SOJUS or PROGRESS return capsule).

On ground the films are processed and the negatives are selected. After transport to Munich the copies are prepared and delivered to the customer.

As the MIR complex has not a sunsynchronous orbit it is possible to take photos from a certain area at different day-times (see chapter 2).

6. COST COMPARISONS

There are mainly two reasons for using Russian space images:

- High ground resolution of KFA-1000 data
- Low prices

Table 3 compares the prices of the Landsat and Spot Images with prices for the Russian KFA-1000 and MKF-6MA images

sensor	cost per image (US$)	ground resolution	ground area (km^2)	area per image (km^2)	cost $ /km^2
Landsat MSS[1]	1000	79	170x185	31450	0.03
Landsat TM[1]	4400	30	170x185	31450	0.14
Spot-XS[1]	ca. 2100	20	60x60	3600	0.58
Spot-Pan[1]	ca. 2650	10	60x60	3600	0.74
KFA-1000[2]	ca. 1150	7.5	120x120	14400	0.08
MKF-6MA[2]	ca. 880	20	175x260	45500	0.02
MK-4[3]	ca. 1200	10	150x150	22500	0.05

Table 4: Cost comparison of different sensors
1) Ref. 11,12
2) all values for the MIR platform (400 km altitude)
3) Ref. 4

The comparison shows that all Russian products are one magnitude cheaper (costs per area) as comparable Western images. Even if the multispectral products cannot replace TM or Spot-XS data at all applications due to their limited spectral bandwidth, they could be interesting where photographic infrared is sufficient as vegetation monitoring or similar applications (Ref. 13).

The KFA-1000 images however show ground resolutions, no other satellite based system can offer at the moment. This resolution is delivered at costs much cheaper then the Western sensors can offer.

7. CONCLUSIONS

With the availability of Russian space images many projects seems to be possible that could not be realized up to now due to the cost situation.

The PRIRODA-5 system onboard of the space complex MIR offers a satellite data system for many applications. The ground resolution is about 25 % better then that of e.g. SPOT PAN and the costs for a scene are lower compared to the Western systems.

The MKF-6MA is a good choice for all who need cheep multispectral data without thermal infrared bands.

The use of Russian satellite images could help to realize low budget projects in the Western world or in development countries and it supports the Russian economy at the same time.

8. REFERENCES

1. Almer A., Buchroithner F. & Raggam J., Digital Mapping with High Resolution Sojuz KFA-1000 Images, EARSEL, 1990.

2. Strathmann F.-W., Untersuchungen zum Anwendungspotential hochauflösender KFA-1000-Satellitenphotos in der Regionalplanung, 47. Deutscher Geographentag, Saarbrücken, 1989.

3. Siebert A. Strathmann F.-W., Kosmos-KFA-1000 Ein hochauflösender Sensor zur Dokumentation von Raum- und Umweltveränderungen, Die Geowissenschaften, 8. Jahrgang 1990.

4. Kazakova A. E., Kozlov V. D., Earth and Ecological Spacecraft, International Space Year Conference, Munich, 1992.

5. NASA Orbital Prediction Bulletin, Goddard Space Flight Center, 1992.

6. Personal information by NPO ENERGIA, 1991.

7. IRE, Complex for Remote Sensing of the Earth "PRIRODA" ("Nature"), Scientific Program, Moscow , 1991

8. Multispektralkamera MKF-6M, Werkprospekt.

9. Wolter D., Die Multispektrale Kosmische Fotoapparatur MKF 6MA - eine Weiterentwicklung für die sowjetische Raumfahrt, Jeanaer Rundschau 3/89.

10. Marek K.-H., Zur Nutzung der Metrischen Multispektralphotographie bei der Umwelt- und Ressurcenerkundung, Jenaer Rundschau 4/87.

11. Konecny G., Review of the Latest Technology in Satellite Mapping, Interim Report of the Intercommission Working Group I/IV on International Mapping and Remote Sensing Satellite Systems of the ISPRS, Hannover, 1990.

12. EOSAT Product ordering information.

13. Sabins Jr. F. F., Remote Sensing Principles and Interpretation, Freeman and Company, New York, 1986.

14. Zilger J., Nutzungskonzept für die präoperationelle Mission des modularen optoelektronischen Stereo-Scanners MOMS-02 auf dem Modul PRIRODA der sowjetischen Raumstation MIR (MOMS-02P), DARA Studie, Nov. 1991.

15. Kayser-Threde GmbH, MOMS-NAV A Navigation Package for Orbit and Attitude Determination of MOMS-02P, Study, 1991.

16. Liebig V., High Resolution Stereo Images from the Space Station MIR, ISY-Conference, Munich, May 1992.