# Systematic Image Processing of the Small Satellite Mission BIRD

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## INTRODUCTION

For hot spot events as forest and vegetation fires, volcanic activity or burning oil wells and coal seams dedicated space instrumentation does not exist. Sensors being used now for the observation of these events have some drawbacks because they are not designed for the hot spot investigation. For the near future there are missions planned with a new generation of cooled infrared array sensors. The German BIRD (Bi-spectral Infrared Detection) mission will answer a lot of technological and scientific questions related to the operation of a compact bi-spectral infrared push-broom sensor on board of a micro satellite and related to the detection and investigation of fires from space. The DLR small satellite mission BIRD is dedicated to the remote sensing of hot spot events like vegetation fires, coal seam fires or active volcanoes from space and to the in-orbit verification and demonstration of new micro-satellite technologies. The total mass of the complete spacecraft is 92 kg.

## MISSION OBJECTIVES

The BIRD mission has to answer scientific and technological questions related to the operation of a compact bi-spectral infrared push-broom sensor on board of a micro-satellite and related to micro-satellite technologies for remote sensing missions with optical instruments. Therefore, the BIRD primary mission objectives are:

- test of a new generation of infrared array sensors adapted to Earth remote sensing with an adaptive radiometric dynamic range,
- detection and scientific investigation of High Temperature Events (HTE) such as forest fires, volcanic activities, and coal seam fires,
- Test and demonstration of new small satellite technologies.

Furthermore, BIRD has of secondary mission objectives:

- Test and demonstration of on-board classification by means of a neural networks circuit
- test and demonstration of an experimental ground station.

BIRD shall demonstrate the limits and the advantages of using new developed components, methods, algorithms and technologies basing on a mixed parts and components qualification level.

## THE BIRD SPACECRAFT BUS

The BIRD space segment is a 3-axis stabilized micro satellite without a propulsion system. The satellite consists of a box-shaped main body. The complete main body is covered by MLI with cuttings for the instruments and radiators. Deployable solar arrays and the eject mechanism are mounted on the body. A general view to the BIRD spacecraft and the main components gives fig.1. The payload is mounted on a special platform and takes 1/3 of the body volume and the total mass of the spacecraft. The special designed platform is close connected with the satellite bus to keep the line of sights of the instruments under all circumstances very stable. Due to this design conception the spacecraft bus and the payload platform are easy separable. This allows to modify the BIRD spacecraft easily for other missions with quite different payloads. A basic mission constraint is the launch as a piggy-back or auxiliary payload within a Low Earth Orbit because of the costs. This requires a micro-satellite solution. Some basic features of the BIRD spacecraft bus are

- cubic shape (620 x 620 x 550 $mm^3$) in launch configuration with variable launcher interface
- mass ratio bus : payload = 62kg : 30kg, high peak power of 200W @ 20min, and av. power 60W
- new developed high-performance spacecraft bus computer with integrated latch-up protection and error detection and correction system
- three-axis stabilization of the spacecraft by an attitude control system in state space representation
- S-band communication with high bit rate (2.2 Mbps) and low bit rate
- design life time: 1 year.

BIRD is an experimental satellite. The duty time of the payload is 10 minutes in one orbit. The data of one duty cycle can be stored in the 1Gbit mass memory and will be transmitted during the next pass to a German ground station. Simultaneously data take and down-link are possible, too. Fig. 1 shows the BIRD satellite during the preparation of the final tests in the space simulation chamber.

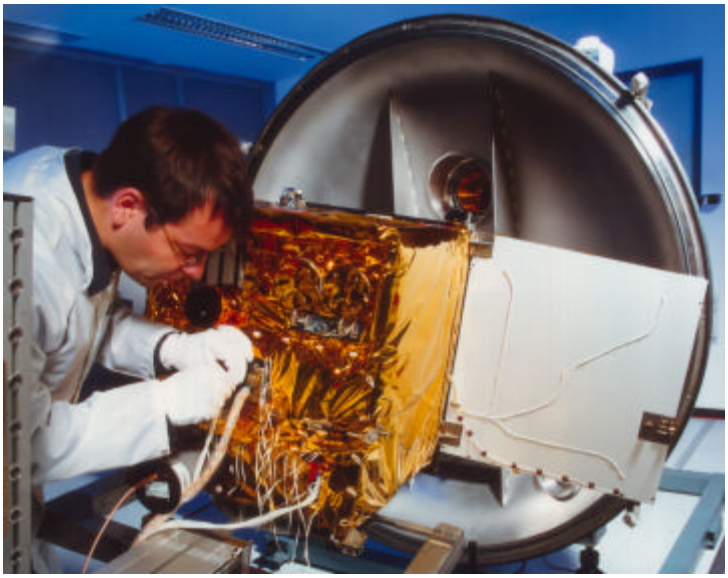

Fig.1: The BIRD spacecraft in front of the space simulation chamber

**LAUNCH AND ORBIT PARAMETERS**

The Indian launcher PSLV-C3 was selected. The BIRD satellite was launched successfully into a sun-synchronous circular low Earth orbit with the launcher PSLV-C3 from Shar/India at 22. Oct. 2001. The average orbit altitude is 568km.

**THE BIRD PAYLOAD**

The payload of BIRD consists of:

- the Infrared Sensor system dedicated for hot spot recognition and investigation,
- the Wide-Angle Opto-electronic Stereo Scanner WAOSS-B for vegetation analysis and fire "false alarm" rejection,
- a payload data handling system to control the instruments and the data storage of a 10 minute's data take,
- an on-board classificator experiment, basing on a neural network chip.

Tab. 1 gives an overview on the characteristics of the BIRD instruments. Because of the high peak power consumption of the BIRD payload it is not possible to assure a continuous observation of Earth, but a data take with a duration of 10 min only in one orbit. The data volume can be dumped down simultaneously or stored in a mass memory (2x1Gbit).

**GROUND SEGMENT**

The general mission architecture is depicted in Figure 2. The BIRD ground segment consists of the

- Mission Control Centre (GSOC) in Oberpfaffenhofen (DLR),
- the prime TT&C ground station for Telemetry, Tracking and Command in Weilheim (DLR),
- the prime data receiving station and processing centre in Neustrelitz (DLR),
- the experimental micro-satellite ground station in Berlin-Adlershof (DLR) and
- the supporting ground station network for the first acquisition phase consisting of Kiruna (DLR) and Fairbanks (Prioranet).
- Cooperation with ground stations in Cordoba (CONAE, Argentina), Taejon (KARI, South Korea) and Villa Franca (ESOC, Spain)

According to the mission architecture the mission operation is to be carried out by the GSOC. The scientific data are received by the ground station in Neustrelitz, which is also responsible for the processing and distribution of these data. The mentioned ground stations are supplemented by the experimental micro-satellite ground station in Berlin-Adlershof. This ground station demonstrates the way

a small/local user at any place of the world can directly obtain the BIRD data. It consists of a small controllable antenna (2.40 m) and of the appropriate facilities for reception and processing of the data. It is adapted to the needs of a local or regional user, who wants to utilise the satellite data without delay.

Table 1: Characteristics of the BIRD Instrumentation

| | **WAOSS-B** | **Infrared Sensor System** |
|---|---|---|
| Spectral bands | VIS: 600-670nmNIR: 840-900nm | MIR: 3.4-4.2µm TIR: 8.5-9.3µm |
| Focal length | 21.65mm | 46.39mm |
| Field of view | 50° | 19° |
| f-number | 2.8 | 2.0 |
| Detector | CCD lines | CdHgTe Arrays |
| Detector cooling | Passive, 20°C | Stirling, 80-100 K |
| Pixel number | 2880 | 2x512 staggered |
| Quantisation | 11bit | 14bit (for each exposure) |
| Sampling step | 185m | 185m |
| Swath width | 533km | 190km |

WAOSS-B Wide Angle Opto-electronic Stereo Scanner
MIR Medium Wave Infrared Sensor
TIR Thermal Infrared Sensor

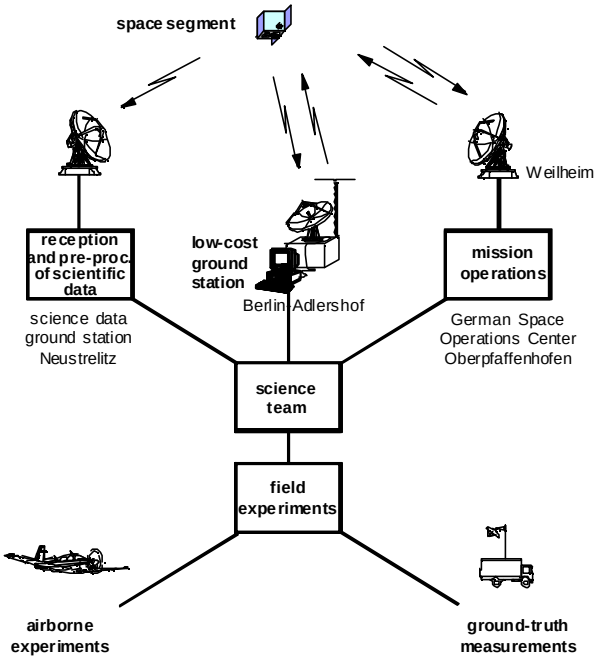


Figure 2: Mission architecture of BIRD

**DATA ACQUISITION**

Data acquisition of BIRD will be directed by the mission objectives. Because of the limited mission operation time 10 minutes in one orbit and 5 orbits per day the data acquisition will be selected and scheduled very carefully by the experiment manager. The co-investigator and the science team members of BIRD will give their requirements to the experiment manager. The experiment manager collects the midterm and short-term requirements for measurement seances by a form sheet. He develops a first proposal for a midterm and short-term observation plan and discusses it in the science team in Berlin-Adlershof. After this evaluation the schedule will be given to the German Space Operation Center for a detailed preparation of a mission operation plan. In the case of conflicts or time critical observations the decisions for measurement seances will be made according to the following order of priorities:

1. Spacecraft and instrument health and safety
2. Research contract obligations
3. Vegetation fires in areas of co-operational partners (ESA members, Argentina, South Korea, India and other)
4. Time critical acquisition related to national security, natural disasters and environmental emergencies
5. Time critical acquisitions to support airborne campaigns and ground truths measurements.

All requests for data acquisitions will be received directly by the BIRD experiment manager. The primary ground station for the BIRD data reception will be located in Neustrelitz. The ground station receives both real time data and recorded data via direct transmission. The primary ground station from mission operations is located in Weilheim and will be controlled by the German Space Operation Center in Oberpfaffenhofen. The BIRD mission is supported by other receiving ground stations in the world (Argentina, South Korea, Ny Alesund). They can apply for BIRD data reception and than they could be taken into account in connection with the mission timeline and scheduling. The received BIRD data should be sent to the BIRD main ground station in Neustrelitz for archiving purposes. The implementation of any other ground station are organized without exchange of funds.

**DATA PROCESSING**

The BIRD data will be processed and archived in the ground station Neustrelitz. They generate data of level 0 and level 1 according to table 2.

Table 2: Level of BIRD data products

| | |
|---|---|
| Level 0 | unprocessed instrument/payload data in combination with spacecraft data, communication frames/headers removed |
| Level 1A | time-organized single sensor raw data with an appendix of<br>- instrument housekeeping data,<br>- radiometric and geometric calibration coefficients,<br>- geo-referencing parameters (ephemeris data),<br>- other ancillary information |
| Level 1B | radiometric and geometric processed level1A data to sensor units (radiometric and geometric calibrated data) |
| Level 2 | interpreted geophysical parameters (hot spot temperatures, hot spot extension, vegetation indices, cloud parameters) |

The primary ground station will send BIRD data of level 1a or 1b to scientific co-investigators according to their request. Data processing beyond level 1 and distribution of these products is in the responsibility of the users and limited to non-commercial purposes.

The scheme of the systematic processing of BIRD data is depicted in figure 3. The received satellite data will be removed from communication frames and the raw data are stored into a mass memory at level 0. They are separated in satellite housekeeping data (HK), position data (GPS), attitude data and in payload data from the instruments MIR, TIR and WAOSS and the separated data are archived additionally for fast access to certain data sets. The processing of the instrument data starts with separation of the instrument housekeeping (HK) data followed by the radiometric calibration of the data using calibration files from the ground lab calibration process long before launch. The calibration will be proved and corrected by examination of in-flight calibration files additionally. After the radiometric calibration process the geometric calibration process starts. Optionally it can include the geometric correction of the attitude and position of the spacecraft so the output of this process can be a level 1B data product. This product can be given to the scientific user for thematic data processing and for the generation of value adding data products.

**DATA ARCHIVING AND DISTRIBUTION**

All raw data of BIRD (level 0) will be archived in the DLR ground station Neustrelitz. In most of the cases, data products of level 1 will be also archived in Neustrelitz or in other places of level-1 users.

BIRD level 0 or level 1 data products will be distributed in a timely manner according to the requirements of the co-investigators. An option for data distribution is the FTP data transport via network. Data will be archived on a server and the co-investigator can take the data from this server.

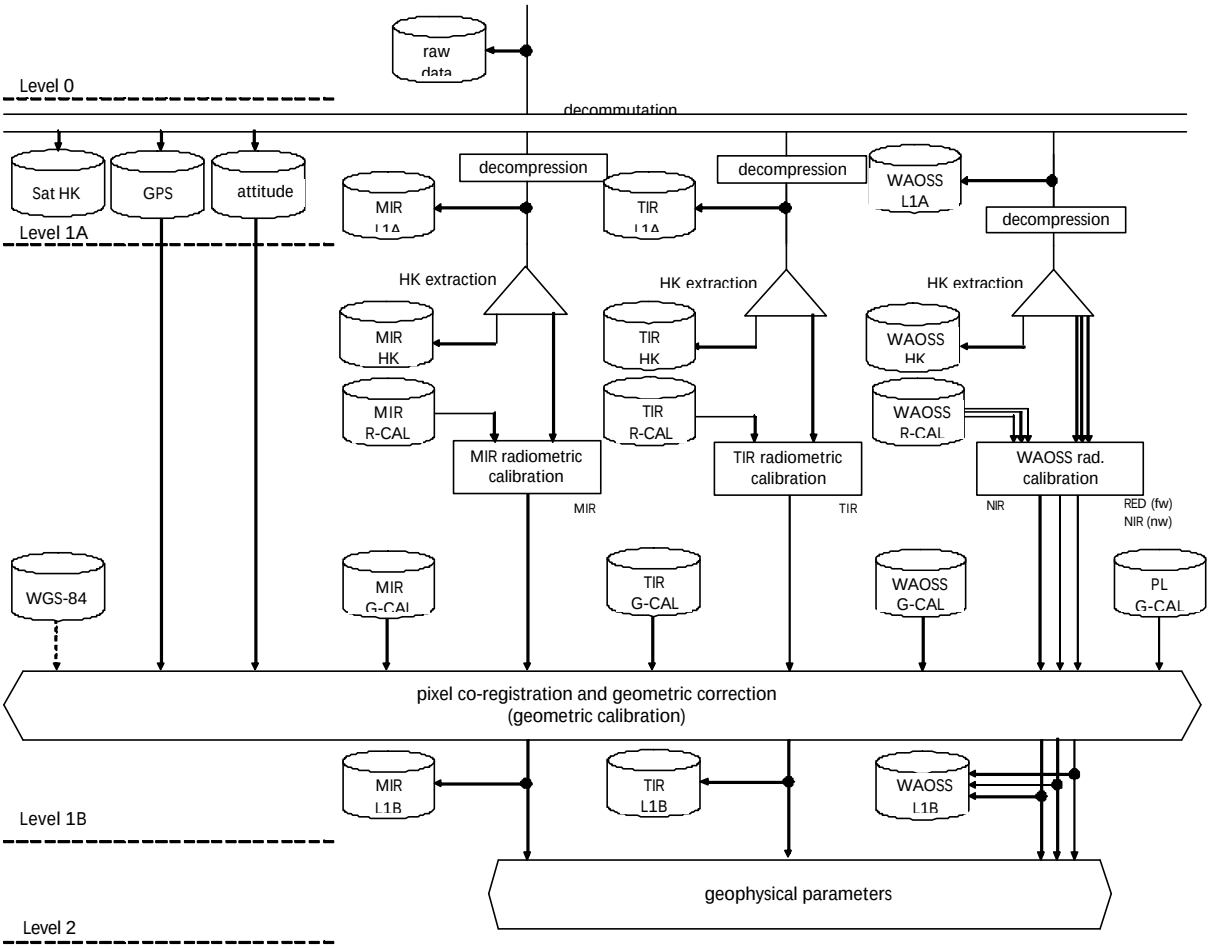


Figure 3: Systematic data processing of BIRD spaceborne data

**FIRE DETECTION FROM SPACE**

BIRD performed a lot of hot spot investigation from space. BIRD detected and identified not only vegetation fires at different places in the world but also coal seam fires in China and India, peat fires in Indonesia, Eastern fires in Germany and Austria, hot industrial plants, volcanic activities in Italy (Etna), Mexico and other place in the world. Fig. 4 and 5 show the Australian bush fires at 4 January, 2002, in the area around of Sydney, Australia as an example of the fire data products of BIRD. Fig. 4 shows the image of the medium Infrared (MIR) channel of BIRD. In order to represent a high dynamic range of the images, MIR pixel temperatures below 330 K are coded as grey levels while a color coding is used for higher MIR pixel temperatures (as discussed below, these are only fire pixels).

Fig 5 shows a BIRD image fragment of a part of the scene of January, 4 illustrating the results of fire detection and of equivalent fire temperature retrieval by means of the MIR, TIR and NIR spectral bands of the BIRD payload. Most of the detected hot clusters are located at the border of fire scars and correspond to fire fronts, while only a few small clusters are located inside the fire scars indicating sources of residual burning.

In summer 2003 BIRD was used in the ESA project FUEGOSAT as a semi operational demonstrator. In dedicated campaigns over the Iberian Peninsula should be demonstrated the usage of space technologies for Operational Risk Management Scenarios. Using the ESOC ground station in Villa Franca for a direct downlink of the data it was organized a data transfer and processing scenario (shown in Fig. 6) to submit to the users in Spain the information about fire events in less than 90 min.

**SUMMARY**

BIRD demonstrates the fire detection and evaluation from space by means of a new developed Infrared sensor system successfully. First time the temperature and area extent of vegetation fires are evaluated from space. The ground station demonstrates the advanced conception for a user oriented data reception and processing system without any delay. On board of the satellite a thematic data processing till a high level data product was demonstrated successfully.

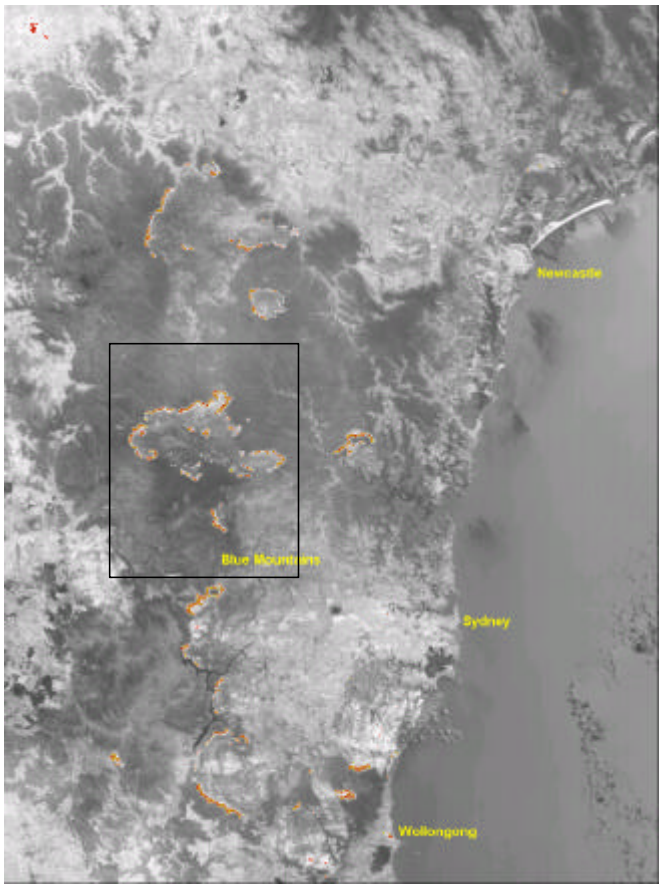


Fig.4: MIR image of the Australian bush fires around Sydney at January 4, 2002, 10:08 local time, fire fronts are color coded

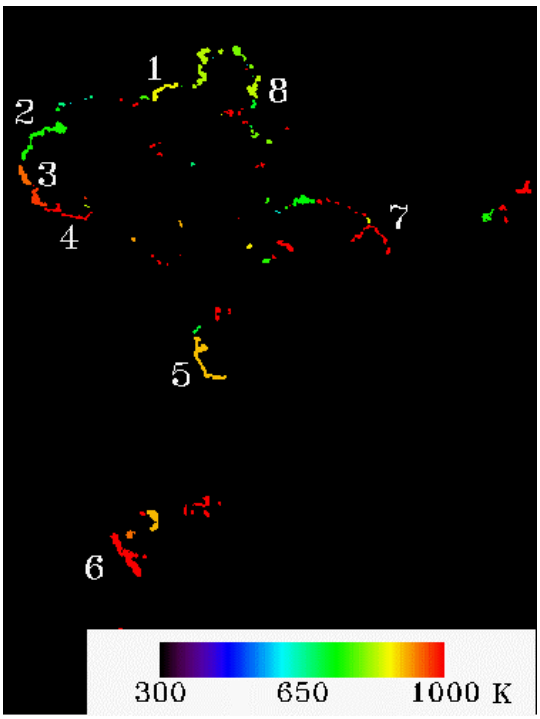


Fig. 5: Detail of the image of fig. 3 with the detailed fire front temperatures evaluated by BIRD
(image size around 60kmx40km)

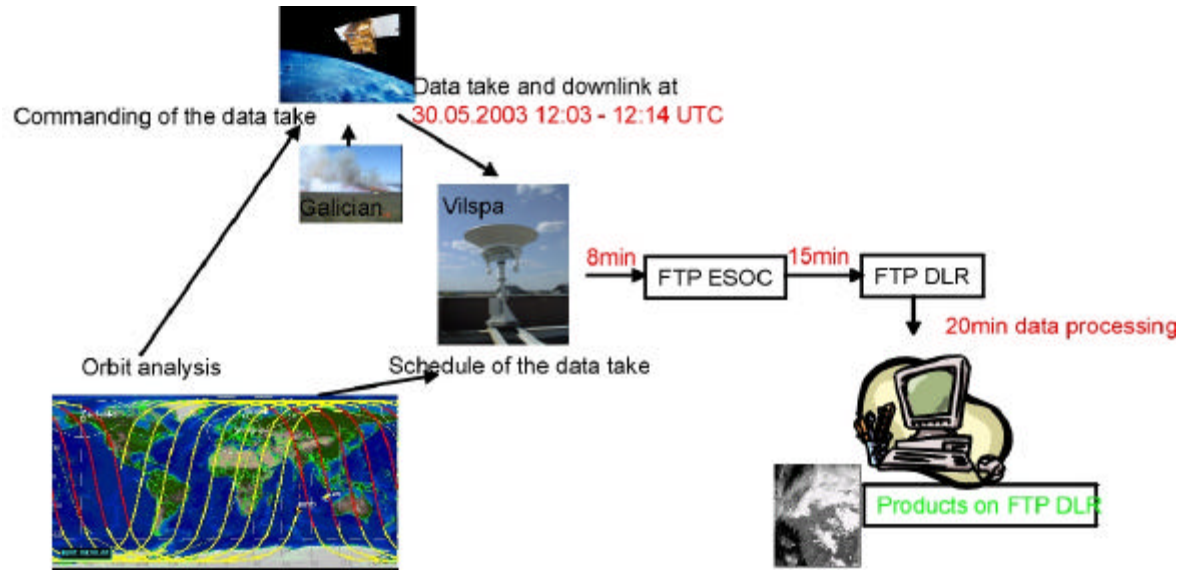


Fig. 6: Demonstration of a semi operational data transfer and processing scenario within the ESA project FUEGOSAT