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Technology demonstration by the BIRD-mission

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Abstract

Small satellites have to meet a big challenge: to answer high-performance requirements by means of small equipment and especially of small budgets. Out of all aspects the cost aspect is one of the most important driver for small satellite missions. To keep the costs within the low-budget frame (in comparison to big missions) the demonstration of new and not space-qualified technologies for the spacecraft is one key point in fulfilling high-performance mission requirements. Taking this into account the German DLR micro-satellite mission BIRD (Bi-spectral Infra-Red Detection) has to demonstrate a high-performance capability of spacecraft bus by using and testing new technologies basing on a mixed parts and components qualification level. The basic approach for accomplishing high-performance capability for scientific mission objectives under low-budget constraints is characterized by using

- state-of-the-art technologies,
- a mixed strategy in the definition of the quality level of the EEE parts and components,
- a tailored quality management system according to ISO 9000 and ECSS,
- a risk management system,
- extensive redundancy strategies,
- extensive tests especially on system level,
- large designs margins (over-design),
- robust design principles.

The BIRD-mission is dedicated to the remote sensing of hot spot events like vegetation fires, coal seam fires or active volcanoes from space and to the space demonstration of new technologies. For these objectives a lot of new small satellite technologies and a new generation of cooled infrared array sensors suitable for small satellite missions are developed to fulfil the high scientific requirements of the mission. Some basic features of the BIRD spacecraft bus are

- compact micro satellite structure with high mechanical stability and stiffness,
- envelope qualification for several launchers,

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- cubic shape in launch configuration with dimensions of about $620 \times 620 \times 550\,mm^3$ and variable launcher interface,
- mass ratio bus:payload = 62 kg:30 kg,
- high peak power of 200 W at 10–20 min, and average power 60 W,
- advanced thermal control system with radiators, heat pipes, MLI, temperature sensors and contingency heaters,
- 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,
- integrating the payload platform with its structure, thermal and power requirements,
- onboard determination of the spacecraft position and velocity by the onboard navigation system basing on receiving and onboard processing of GPS data,
- S-band communication with high bit rate (2.2 Mbps) and low bit rate.

The total mass of the complete spacecraft is 92 kg. BIRD shall demonstrate the limits and the advantages of using new developed components, methods, algorithms and technologies. The satellite was launched with the Indian PSLV-C3 from Shar on 22nd October 2001 into an Sun-synchronous circular orbit of an altitude of about 568 km.

(The paper describes the new developed technologies like onboard navigation system, the high-performance failure tolerant spacecraft computer, the precision reaction wheels, the star sensor, the attitude control system, the onboard classification experiment and the results and flight experience up to now.)

1. Orbit experience and results of technology experiments

According to the need to decrease the spacecraft costs and keep high-performance characteristics of the spacecraft bus the BIRD satellite demonstrates new developed technologies at moderate costs in space. These are as follows.

1.1. Low-cost star sensor

An autonomous star sensor is necessary for the high-precision attitude information. In the field of micro-satellite technologies there is a need for small and autonomous working star sensors in a low-cost price range. The BIRD star sensor development in close co-operation between Jena–Optronik and DLR shall fill this gap in the market. The sensor has a robust and compact electro-optical design with a total mass of 1.2 kg (Fig. 1). The sensor consists of a CCD matrix camera in combination with an internal star catalogue and an image analysis software for star identification and search. The sensor delivers the attitude information in quaternions. The sensor is calibrated on calibration facilities in the lab and is tested by field experiments on ground looking into the clear night sky. One of the technological objectives in BIRD consists in the test and verification of the star sensor under real space conditions.

First results: First test in orbit showed that both star cameras determine their orientation reliably and with the right sign. They even will remain logged in if the slewing rate reaches up to $0.5^\circ\,s^{-1}$.

1.2. High precision reaction wheel

For BIRD a reaction wheel system with 4 wheels in combination with 2×3 magnetic coils are applied. Up to now, it does not exist a big choice of different types of reaction wheels on the market. Basing on the reaction wheel development of the Technical University of Berlin (Prof. Renner) a new type of high-performance reaction wheel for micro-satellites was developed for BIRD in close co-operation between Astro- und Feinwerktechnik Adlershof GmbH, TU Berlin and DLR (Fig. 2).

These reaction wheels are characterized by

- high-control precision by means of smart control electronics,
- low-level emitted vibrations, due to the advanced mechanical design and the high level of alignments and balancing,