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THE TET-1 SATELLITE BUS – A SMALL HIGH RELIABILLITY BUS FOR CHALLENGING LEO MISSIONS

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The TET satellite bus is designed as a modular and flexible microsatellite for LEO applications, with an altitude between 450 and 850 km and an inclination between 53° and SSO. The satellite bus is available in two different configurations: At first the TET satellite bus for a 120 kg space segment, as used for the TET-1 mission, and second the upgraded and upsized TET-XL satellite bus for a 200 kg space segment. Due to its high quality approach and multiple functional and hardware redundancies these two satellite busses offers a high reliability platform for scientific, in-orbit demonstration and high resolution earth observation missions in the field of micro satellites.

Key Words: Micro satellite, Platform, TET, TET-XL, Earth observation

1. BACKGROUND

The TET satellite bus is designed as a modular and flexible microsatellite for LEO applications, with an altitude between 450 and 850 km and an inclination between 53° and SSO. The typical launch of a satellite based on the TET-1 satellite bus is as a piggyback payload. This results in an actual overall envelope of 670 x 580 x 880 mm and a satellite mass of 120 kg.
The first mission for this satellite bus is the TET-1 mission which will be launched as part of the OOV program on November 2011. Kayser-Threde is the prime contractor for this mission, Astro- und Feinwerktechnik is responsible for the satellite bus and DLR-GSOC for the ground system. The launch is provided by Lavoshkin with an SOYUS/FREGAT launch.
By requests of the community for a bigger payload capacity for the existing TET-1 satellite bus a upgrade study was made in 2010, with the resulting TET-XL satellite bus which includes propulsion system, X-Band downlink and a higher payload mass and volume. But it is still a classical piggyback satellite.

2. THE TET-1 SATELLITE BUS

2.1. The Satellite Bus Concept

The TET satellite bus is designed as a modular, flexible and high reliable microsatellite for Low Earth Orbit (LEO) missions. A typical orbit for this bus has an altitude between 450 and 850 km and an inclination between 53° and SSO.
Considering an overall satellite mass of 120 kg, the TET satellite bus provides a payload mass capacity of 50 kg with an envelope of 460 x 460 x 428 mm³, taking into account a satellite bus mass of 70 kg, including a payload support system.

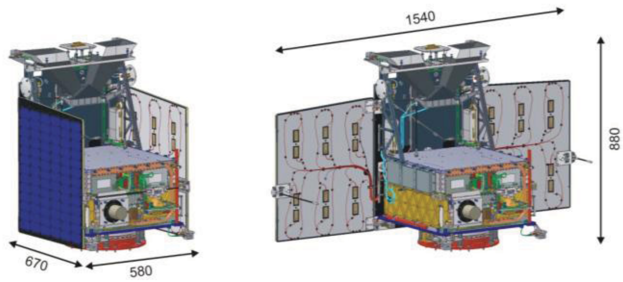

Fig. 1. TET-1 bus and envelope

The TET-1 mission carries 11 (eleven) different payloads. Nine payloads are accommodated in the payload segment (free space is seen in fig. 2). The other two payloads are placed on the middle solar panel and the payload back plane panel (see fig. 3).

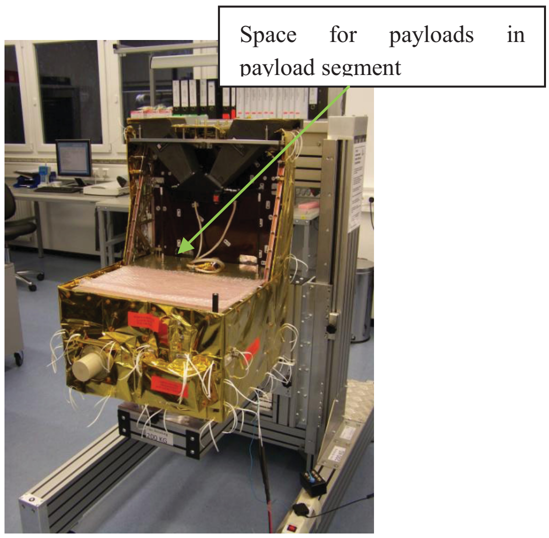

Fig. 2. Payload segment (here shown during MLI fitting)

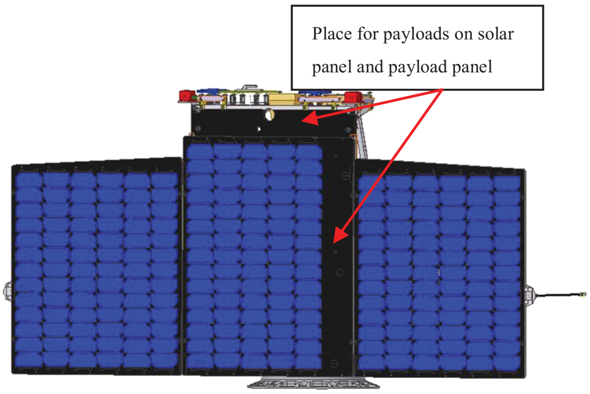

Fig. 3. Place for payloads on solar panel and payload back plane panel

2.2 The TET-1 Payload Support System (PSS)

A critical point in the design of the TET-1 satellite bus was the interface between satellite bus and numerous payloads. To support very different payload types a Payload Support System (PSS) is integrated in the TET bus (see fig.4). The TET-1 PSS – for the TET-1 mission built by the Kayser-Threde company - is adaptable on its variable payload interface side to the interface requirements for: payload data transmission & storage, payload control (using Spacewire, RS422/485, CAN-Bus), and power interface requirements of the payloads.

The use of mission adapted payload support systems will permit to leave the TET satellite bus unchanged for different missions, however it can be adapted in parts, as, for instance, by an X-Band transmitter, if higher data rates are required. (see chapter 5). The Printed Circuit Boards (PCBs) of the Payload Support Systems – as designed for TET-1 – also allow an adaptation for new payload accommodations.

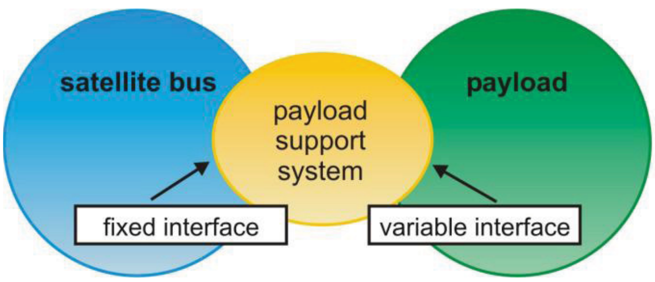

Fig. 4. TET payload – bus- interface philosophy

2.3 The TET Segment Design

The TET satellite bus comprises three segments: the Service Segment, the Electronic Segment and the Payload Segment (fig. 5).

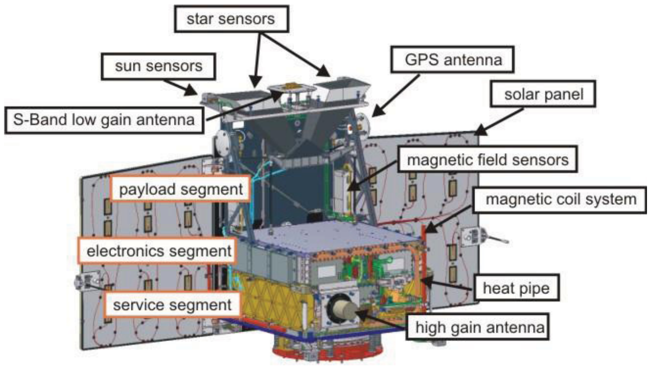

Fig. 5. Segments of TET satellite bus

The Service Segment contains the Power Control Unit (PCU), two redundant Inertial Measurement Units (IMUs), four Reaction Wheels(RWs) and two battery stacks.

In the Electronic Segment (shown in fig. 6) contains the Payload Support System the cold and hot redundant Spacecraft Bus Computer (SBC), the Power Distribution Unit (PDU), data processing boards of the redundant sun sensor system, the redundant GPS receiver and the driver electronic for the redundant magnetic coil system. Additional to that the complete TM/TC hardware is integrated into the Electronic Segment, except the two low gain antennas (for omni-directional communication). The low gain antennas are mounted on: (i) the payload segment (see fig. 5) and (ii) the bottom of the Service Segment (see fig. 10).

2.4. The TET Bus Electronics

All electronic parts of the Electronic Segment are designed as Printed Circuit Boards (PCB)s in Europe Card size (160 x 100 mm²)., max. 15 PCB's for PSS and max. 15 PCB's for satellite bus electronics can be integrated in the Electronic Segment of TET. All PCBs of the segment are connected via two backplanes.

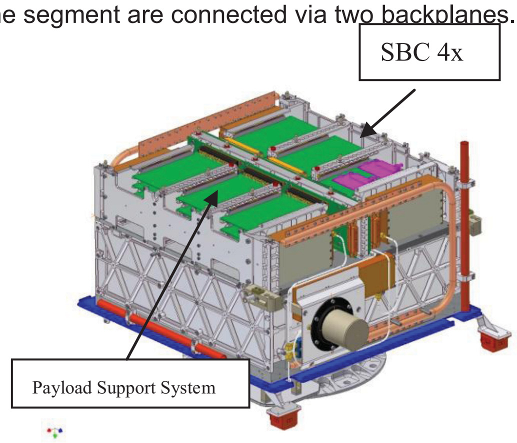

Fig. 6. Top view of Electronic Segment (above the Service Segment)

2.5 The TET Payload Platform

The Payload Segment contains the payload(s) itself, parts of the Attitude and Orientation Control System (AOCS) and one of the low gain antennas. The TET payload platform is the sole mechanical and thermal interface between the payload(s) and satellite bus. The TET payload platform allows an easy and fast integration of the pre-assembled payload(s). Although in the TET-1 mission it was not required, the TET payload platform can be also designed as an optical bench (as it was done by AFW for the BIRD satellite).

2.6 The TET Power System

The power subsystem consists of a Power Control & Distribution Unit PCDU (PCU+PDU), two NiH2 cell battery stacks (with a energy capacity 240 Wh) and a solar generator comprising 3 panels (1 fixed and 2 deployable) with 220W electrical power capacity.

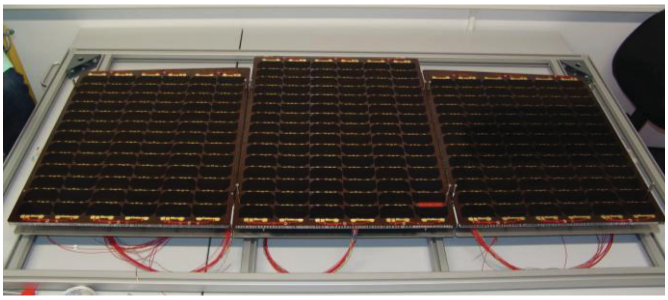

Fig. 7. Top view of solar generator (on the integration frame)

2.7 The Multiple Redundant TET Spacecraft Bus Computer

The TET Spacecraft Bus Computer (SBC) controls all activities of the satellite bus and consists of 4 identical SBC boards (2 in hot, 2 in cold redundancy) and watchdog circuits for failure detection and recovery. One node (the "worker") is controlling the satellite while the second (the "master" node) is supervising the correct operation of the worker node.

2.8 The TET Telemetry and Tele-command (TM/TC) System

The Consultative Committee for Space Data Systems (CCSDS) standard compatible TM/TC system is based on a S-Band transmission system with two hot redundant receivers (with 4 kbit/s uplink data rate) and two cold redundant transmitters with a downlink high bit rate of 2,2 Mbit/s and a low bit rate of 137.5 kbit/s. The two receiver/transmitter pairs can be switched to the omni-directional low gain antenna system or the high gain antenna (see fig. 8).

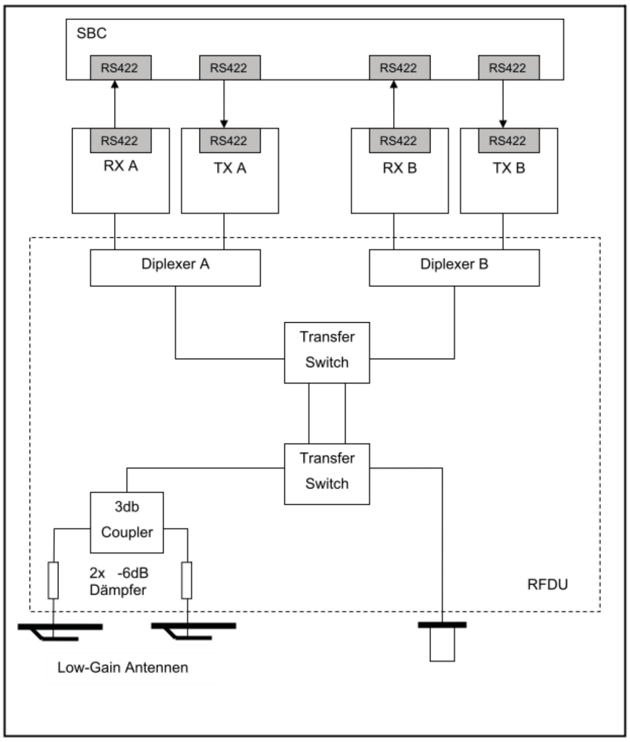

Fig. 8. The TET-1 TM/TC system

2.9 The TET Attitude & Orbit Control System

The AOCS of the satellite bus has multiple functional and hardware redundancies and consists of two star sensors, two IMUs, two magnetometers, 2 sets of course sun sensors, 4 reaction wheels, a redundant magnetic coil systems, 2 GPS receiver systems and an On-board-Navigation-System (based on an so called "orbit propagator" and Two Line Element /TLE/ information), which runs as software application on the SBC. The AOCS algorithm uses a "state estimation" system, and it is controlled in the SBC by autonomous monitoring of the "timings" of all AOCS threads and processes. This is essential for a seamless filtering and processing of AOCS data .

The robustness of the TET AOCS is secured by redundancy of its hardware (H/W) components and a "configuration management system" to handle the redundancy by software (S/W) what provides onboard failure detection and diagnosis. Its robust control loop permits to react against perturbation and component anomaly with sufficient stability margin.

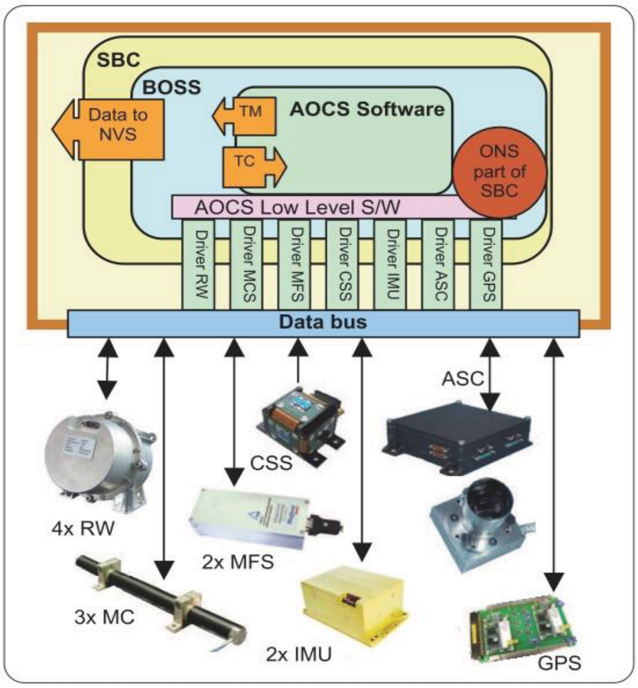

Fig. 9. Software and Hardware (SW/ HW) overview of the TET-1 Attitude and Orientation Control System (AOCS)

2.10 The TET Thermal Control System (TCS)

The TET satellite bus is equipped with a semi-active Thermal Control System (TCS). The Multi-Layer Isolation (MLI) (see fig. 2) isolates the satellite from the space environment, and the TET radiator is the only thermal interface to space. The size of the radiator was defined by a thermal analysis and related tests. The radiator allows the complete radiation of all thermal energy into the free Space during the "hot" phases (when maximum of energy is generated in the satellite, flying in the sun-illuminated part of the orbit), and, on the other hand, it is small enough to prevent an out cooling of the system during "cold" phases (when only minimum of energy is dissipated in the satellite, flying in the Earth shadow). Additional the system is equipped with thermal sensors and heaters on the batteries to prevent a temperature below -10°C. For the payload platform a temperature between -10°C and +30°C is guaranteed.

The payload platform is also connected to the radiator via heat pipes (to avoid that the energy generated in the payloads must be conducted through the satellite structure).

2.11 The TET High Reliability Design

An outstanding feature of the TET satellite bus is the very high reliability of 0.95 over the mission time of 14 month (including LEOP) which is secured by the use of HighRel-EEE-parts, multiple redundancies (in hardware, hot and cold redundancies, and function) and the complete European Cooperation of Space Standardization (ECSS) standard compliant Assembly, Integration, & Verification (AIV) process.

The following table shows the technical data of the TET-1 satellite bus:

Table 1. TET-1 performance data

TET-1 envelope (length x width x height)	(670 x 580 x 880) mm³
Payload envelope	(460 x 460 x 428) mm³
Mass of TET-1 spacecraft bus	approx. 70 kg
Mass of payload	approx. 50 kg
type of stabilisation	3-axis stabilisation
accuracy of alignment	2 arcmin
Pointing knowledge	10 arcsec
jitter	1 arcmin/s
alignment of payloads or solar arrays	sun, earth, nadir, zenith, in flight direction and space
power consumption (payload and payload handling system)	20 to 80 W (depending on radiator design)
peak power consumption (payload and payload handling system)	160 W per 20 min (5 times per day)
nominal operational voltage	20 V DC (min. 18 V; max. 24 V)
maximal current	8 A
data transfer rate (Uplink)	4 kbit/s
data transfer rate (Downlink)	2,2 Mbit/s
Reliability (14 month mission)	0,95 (0,92 required)
Max. mission lifetime	3 to 5 years

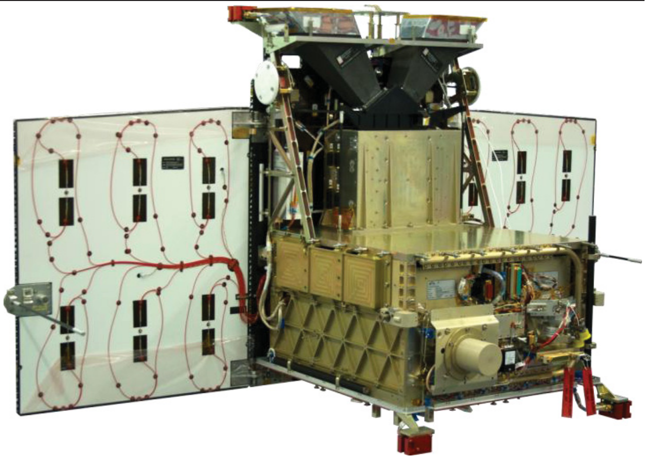

Fig. 10. TET-1 Satellite bus, without payload (except N1 battery experiment) and without MLI

2.12 On-Going and Future Projects

Although we are waiting for the launch and the first flight results of the satellite, the TET-satellite bus is used for different projects and studies by Astro- und Feinwerktechnik Adlershof GmbH and Kayser-Threde.

Since begin of this year the DLR Optical-Sensor Systems and Astro- und Feinwerktechnik are integrating the BIROS satellite, the successor mission of the famous BIRD satellite. BIROS is using the TET-1 satellite bus and a Fire detection payload from DLR OS. After the ending of the TET-1 primary missions after 14 month it is planned that the TET-1 satellite and the BIROS satellite will form the FIREBIRD fire monitoring constellation (see fig.11).

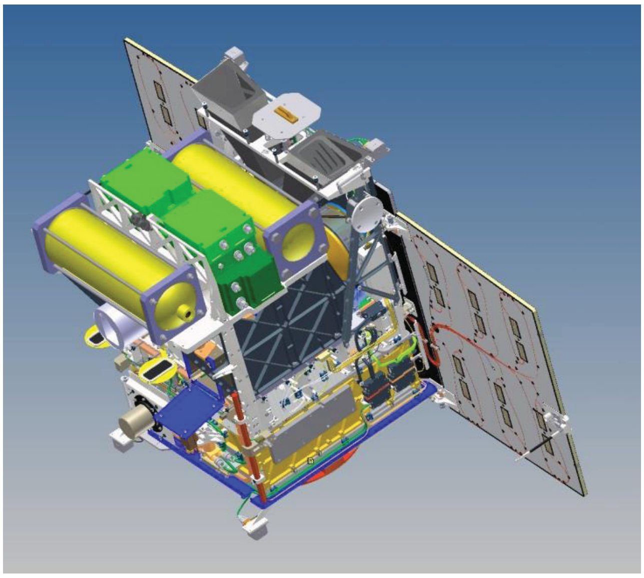

Fig. 11. The BIROS Satellite

Another project based on the TET satellite bus is the pre phase A study for the PARIS mission of ESA, made by Kayser-Threde, together with CASA Espacio (see fig. 12).

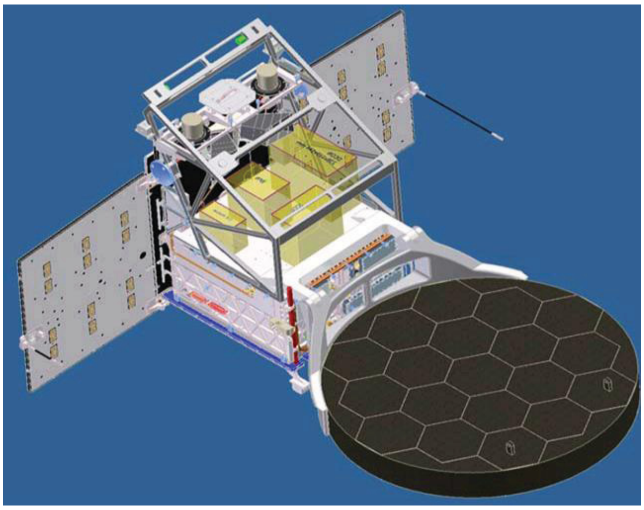

Fig. 12. The PARIS Satellite (photo courtesy Kayser-Threde)

The phase B for the next OOV satellite of the DLR, TET-2, will start in quarter 3 2011.

3. THE TET-XL SATELLITE BUS

During the last two years there was a request from the community to a bigger payload capacity around 60 to 80 kg. Because this request Astro- und Feinwerktechnik Adlershof GmbH and Kayser-Threde has made an update analysis, which results in the TET-XL satellite bus design.

It is based on the TET-1 satellite bus, including the technology and components, but is equipped with bigger payload compartment to support payloads of 70 to 80 kg. Of course this results in a bigger envelope of the satellite itself.

More payload results in higher power demand which results in a bigger solar generator (5 instead of 3 panels) and bigger battery capacity. The higher data rate is respected by a bigger on-board data storage capacity and the integration of an X- Band payload data downlink for typical 150 to 400 MBit/s data downlink. If required a Ka-Band transmitter with up to 1.2 GBit/s can be installed instead.

Additional it is equipped with an ADN green propellant propulsion system (with typical 60 m/s dV capacity) for orbital maintenance and de-orbiting.

The following table shows the technical data of the TET-XL satellite bus:

Table 2. TET-XL performance data

TET-XL envelope (length x width x height)	(800 x 800 x 845) mm³
Payload envelope	(600 x 620 x 460) mm³
Mass of TET-XL spacecraft bus	approx. 120 kg
Mass of payload	70 to 80 kg
type of stabilisation	3-axis stabilisation
accuracy of alignment	2 arcmin
Pointing knowledge	10 arcsec
jitter	< 12 arcsec/sec
Satellite orbit position knowledge	< 10 m
Satellite velocity knowledge	<0.1 m/s
alignment of payloads or solar arrays	sun, earth, nadir, zenith, in flight direction and space
power consumption (payload and payload handling system)	Up to 150 W
peak power consumption (payload and payload handling system)	> 400 W
TC data transfer rate (Uplink)	4 kbit/s
TM data transfer rate (Downlink)	2,2 Mbit/s
Payload data downlink	155 or 400 MBit/s (X-Band) or 1.2 GBit/s (Ka-Band)
Design mission lifetime	3 to 7 years

As one of the first projects the TET-XL platform design was used by OHB and Kayser-Threde for the SMRS (Space based Maritime Reconnaissance and Surveillance) Phase A study for ESA (see fig. 13).

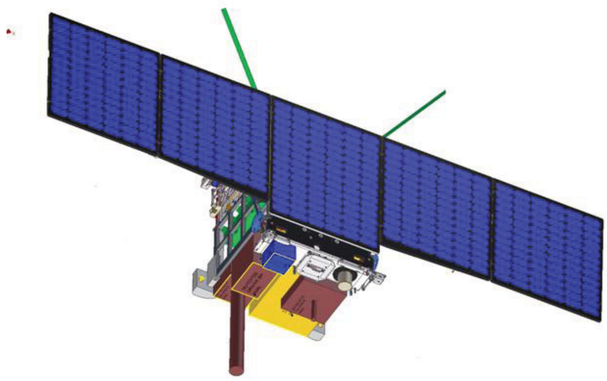

Fig. 13. The SMRS Satellite (photo courtesy OHB)

4. Funding

The R&D project for the TET-1 satellite bus, on which this report is based, is implemented on behalf of the Federal Ministry of Economics and Technology under Ref.Nr. 50RV0801. The R&D project for the TET-XL satellite bus is implemented on behalf of the Federal Ministry of Economics and Technology under Ref.Nr. 50RV1001.

5. References

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