THE ON-ORBIT VERIFICATION MISSION TET-1
PROJECT STATUS OF THE SMALL SATELLITE MISSION & OUTLOOK FOR A ONE YEAR MISSION OPERATION PHASE

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ABSTRACT

The TET-1 mission is a national program funded by the German Space Agency. The TET-1 Phase C/D started in May 2008, followed by a successful CDR January 2009 and the launch date is scheduled for end 2010. Kayser-Threde is the Prime Contractor for the Phase C/D with its major subcontractors Astro-und Feinwerktechnik for the satellite bus and DLR-GSOC for the ground segment.

The goal of small satellite TET is the support of German industry and research institutes with the On-Orbit Verification (OOV) of new and innovative satellite technologies. For this purpose regular and reliable flight opportunities shall be offered, which can be realized on short notice.

The TET satellite is a micro-satellite of 120 kg mass and the dimensions are 880x670x580 mm^3.
In total, eleven different payloads have been accommodated on TET-1. These include optical experiments such as an infrared camera as well as novel solar cells, batteries, new communication equipment, on-board computers, GNSS receivers and a micro-propulsion system. The flight units had been accepted and are integrated into the payload compartment.

An operations concept has been jointly developed by GSOC and Kayser-Threde. All activities for the first year are already planned at the start of the phase. These data are automatically read into the mission operations system of GSOC and adapted for daily satellite operations. For some payloads special operations requirements apply, like a 90° rotation around nadir axis for thermal and attitude determination reasons. Other payloads require operations at a certain attitude during several orbits challenging the power subsystem. Furthermore power and data constraints must be obeyed by the mission operations group.

TET-1 will be launched as piggy back together with a Russian weather satellite METEOR-2. A subcontract with NPO Lavochkin for the launch segment is in place. The main passenger of this launch will be separated into 820 km SSO. Due to its re-ignition capabilities, the FREGAT upper stage will perform dedicated orbital manoeuvres to inject TET-1 finally into the required 550 km SSO.

TET with its new standardized bus and modular payload supply system shall serve also in future as standardized platform for On-Orbit-Verification purposes. The payload compartment is large enough to accommodate even complex experiments, and the bus performance is powerful enough to provide also challenging mission requirements as demonstrated for the IR payload onboard TET-1.

1. BACKGROUND

The goal of the OOV (On-Orbit-Verification)-Program is to qualify new technological solutions for their application in space projects. It focuses on the in-flight demonstration and verification of highly advanced technologies. The core element of the program is the micro-satellite TET (Technology Experiment Carrier) as a platform for the verification flight.

1.1 The Need for On-Orbit Verification

It is necessary to validate new, unproved techniques and technologies before using them in advanced missions. The OOV-Program fills the gap between a technology which has been qualified on the ground and its application in space. In order to support German industry and research institutes, the German Space Agency provides flight opportunities to qualify in-flight new technological solutions in all areas of spacecraft technology such as power generation and storage, propulsion, guidance, navigation and control.

1.2. Flight Opportunities

Flight opportunities for technology demonstration and verification should ideally be provided on a regular basis, independent, cost efficient and safe. A market survey of German industries' and institutes' technologies has shown that about 75 % of the experiments can be verified using a micro-satellite. The OOV-Program is thus structured into two main parts with respect to the flight opportunities offered. The first comprises the micro-satellites TET with a planned flight every two years. For payloads which do not fit on TET, the DLR Space Agency cooperates with national and international partners in order to provide flight opportunities on other carriers.

2. MISSION OVERVIEW

The whole mission is designed based on the main mission requirements shown in Tab. 1.

Tab. 1. TET main mission requirements

Mission duration: 1 month LEOP incl. Satellite commissioning and 12 months mission operations
Type of Orbit: circular Orbit height: between 450 – 850 km Orbit inclination: 53° to sun-synchronous
Piggy-Back Launch
Reliability requirement: 0.9 (for platform and payload supply system)
Ground stations: Weilheim for TT&C, Neustrelitz for payload data downlink
TET platform should be based on the BIRD satellite (maximum use of the BIRD heritage)
TET-1 satellite mass: 120kg
Total payload mass: 50kg

Derived from the above mentioned requirements and following a detailed mission analysis a mission scenario has been defined as shown in Fig. 1 below. The TET-1 satellite is launched as piggy-back in a LEO orbit. After LEOP and Commissioning the one year mission operation is controlled via the mission control centre in Oberpfaffenhofen. Payload data are stored in the payload data centre in Neustrelitz and retrieved from the Experimenters via secured web access.

The essential conditions for operation of the payload are:
- Electrical power supplied by the satellite bus via the payload supply system to the experiments,
- Thermal power consumption of the payload impacts the overall thermal system,
- Pointing mode of the satellite,
- Data take/rate of the experiment limited by the mass memory.

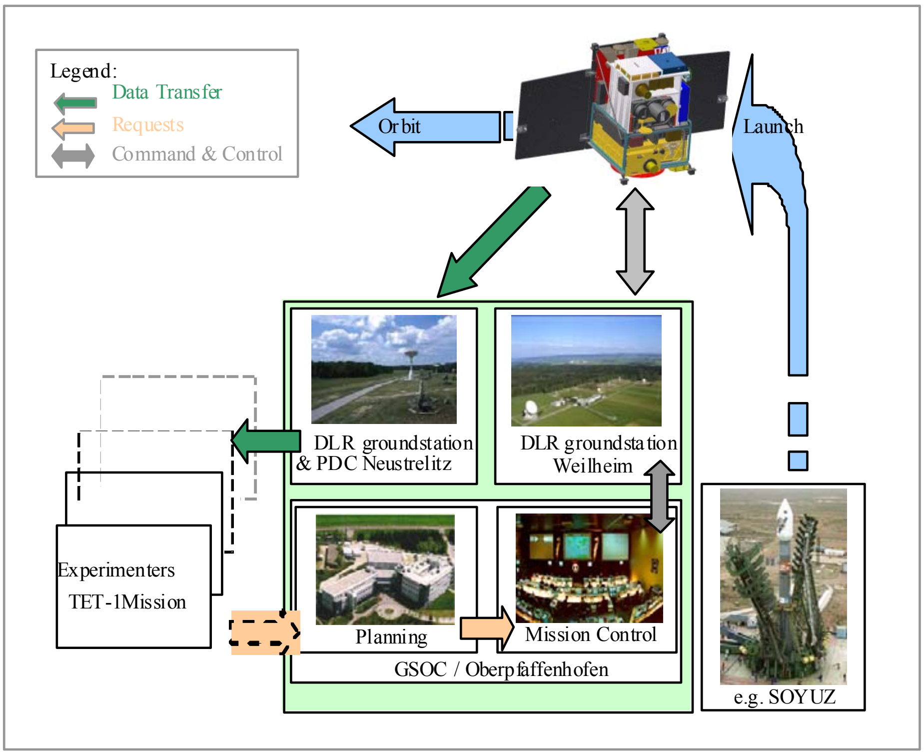


Fig. 1. TET-1 mission scenario

A careful mission planning for the experiments is necessary to be compatible with these conditions. The following principle operational scenarios are foreseen:

- Standard weekly mission scenario: the TET payload is operated according to a schedule that is repeated after one week (approx. 15 orbits with approx. 100 minutes data downlink every day).
- Mission scenario 12: 12 times per year continuous experiments lasting 4 days are performed.
- Mission scenario 2: 2 times per year experiments with direct space-ground link is foreseen lasting 2 days.

The main phases are described in more details:

- LEOP: The Launch and Early Operations Phase will last a few days and has the goal to ensure satellite survival after separation from the launcher. Solar arrays will be deployed; satellite attitude will be stabilized to allow battery charging by the solar arrays and initial housekeeping data will be acquired from the LEOP ground station network. LEOP will end when the satellite is in a stable situation with respect to power, attitude and communications.
- Bus and NVS commissioning: Components which were not activated in LEOP will be activated. All subsystems of the satellite bus and the NVS will be systematically tested.
- Operational mission: The operational mission will last 12 months. Payload commissioning and payload operations will be performed in this phase.
- End of operations (disposal): In this phase the payload will be switched off and passivation measures will be performed for the satellite and the payload.

TET-1 will be launched together with a Russian weather satellite METEOR-2 end of 2010. The main passenger of this launch will be separated into 820 km SSO. Due to its re-ignition capabilities, the FREGAT upper stage will perform dedicated orbital manoeuvres to inject TET-1 finally into the required 550 km SSO as shown in Fig. 2. The designer of the basic payload has chosen the target orbit of the “Meteor-M”#2 S/C with the longitude of ascending node equal to 45.36°. In this context the local time in the “TET-1” S/C orbit node will be 14h 55min. The layout of injection of the “Meteor-M” #2 S/C and “TET-1” S/C is similar to the layout used during the “Meteor-M”#1 S/C launch. By means of the first two ignitions of the Sustainer Propulsion System (SPS) of the “Fregat” VST, the target orbit of the “Meteor-M”#2 S/C will be reached, after the “Meteor-M”#2

S/C separation, by means of following two ignitions of the “Fregat” VST SPS, the target orbit of the “TET-1” S/C will be reached.

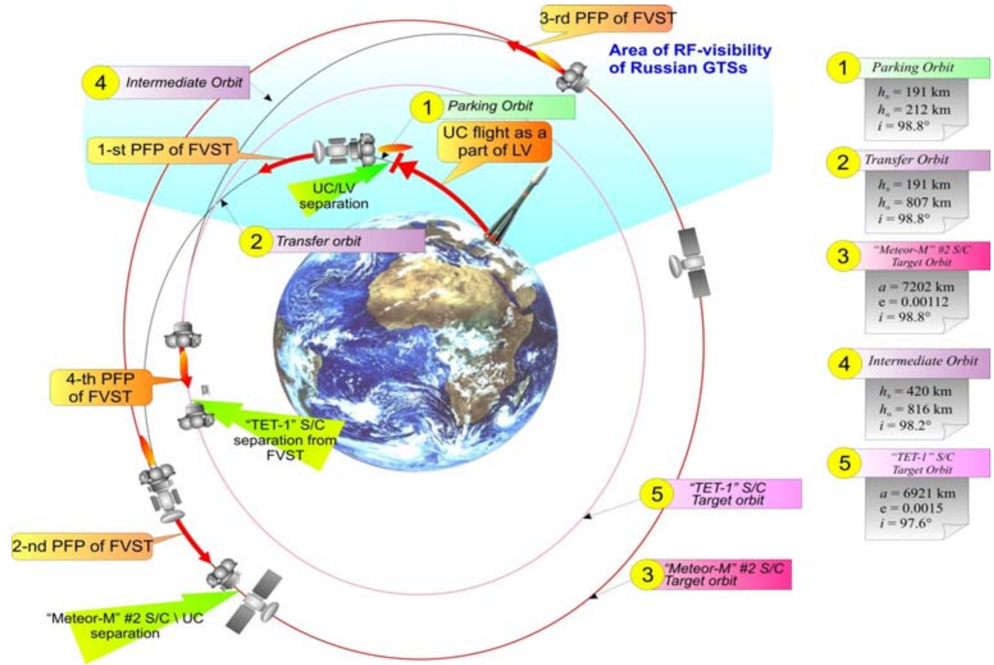
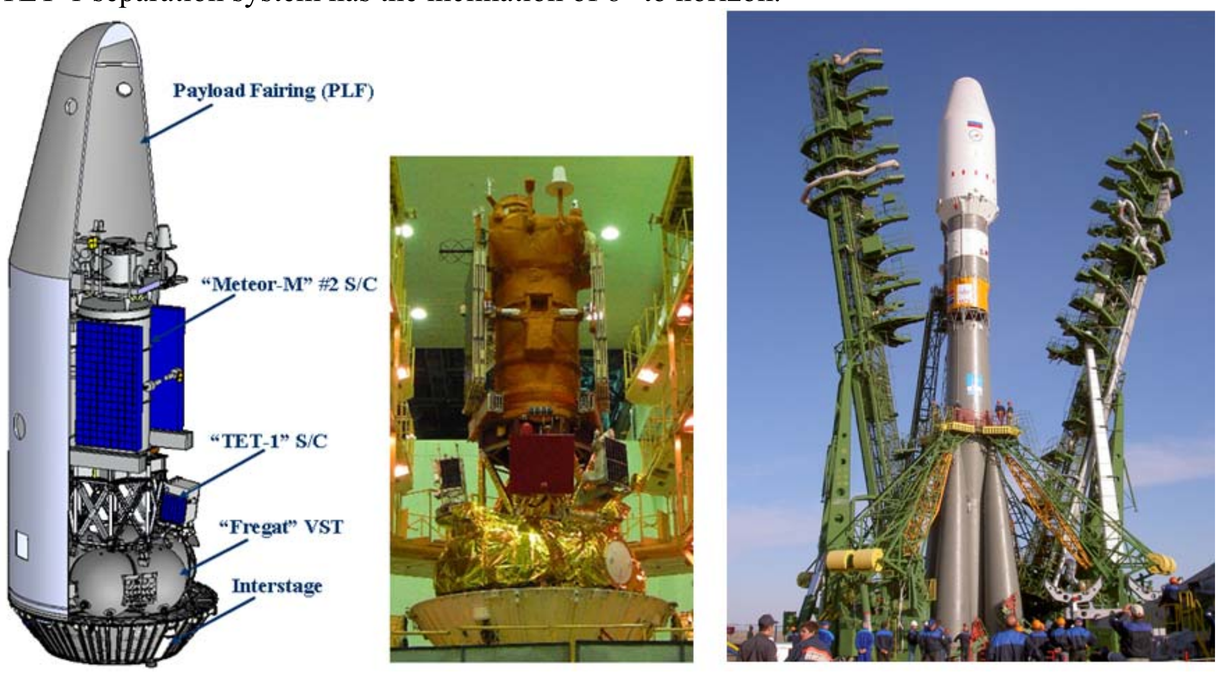


Fig. 2. TET-1 orbital maneuvres

3. LAUNCH SEGMENT OVERVIEW

During the preparation and the launch of the “Meteor-M”#2 S/C and the “TET-1” S/C, the launch service provider (NPO Lavochkin) will use the experience, acquired during the “Meteor-M”#1 S/C with a piggyback payload (5 S/C). The launch adapter corresponds to a cylindrical spacer with a flange, which is a mounting site for the S/C separation system. Interface surface of the adapter with the TET-1 separation system has the inclination of 8° to horizon.



Courtesy Lavochkin

Fig. 3. TET-1 launch configuration (left & centre), Soyuz/Fregat on the launch pad (right)

The “Meteor-M”#1 S/C and piggyback payload were launched from Baikonur launch site on September 17th 2009. All spacecraft were successfully injected into the target orbits. According to the contract the TET-1 launch will take place until end of 2010 from Baikonour.

4. SPACE SEGMENT

4.1 Overview

The TET-1 Satellite consists of the Platform and the Payload. The overall mass of the TET Satellite is about 120kg. The Payload including the Payload Supply System and necessary support structures contributes with about 50kg. The Platform weighs about 70kg. Fig. 4 below shows the TET Satellite in the launch configuration. The overall height of the Satellite is less than 880mm with a depth of 670mm and width of approximately 580mm (with deployed solar array it is 1540 mm).

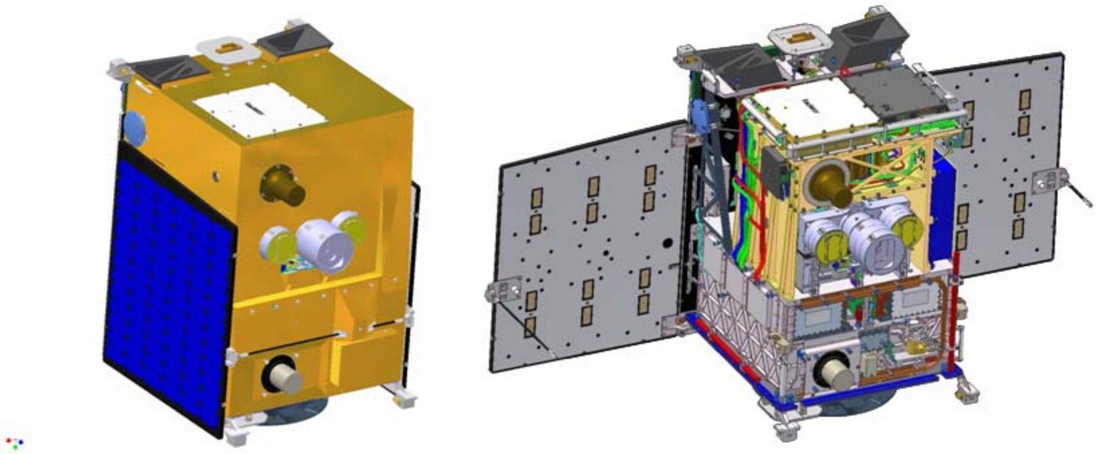


Fig. 4. TET-1 satellite: launch configuration (left), deployed w/o MLI (right)

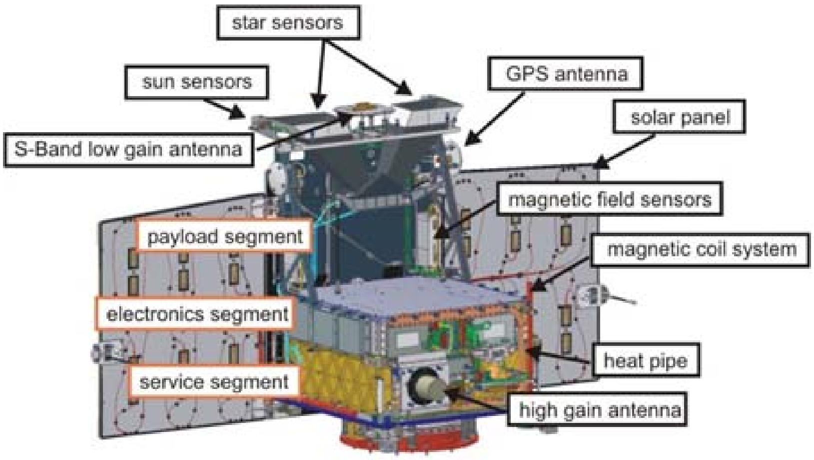
In the deployed configuration and without MLI as shown above, the Payload Segment can be seen more clearly. It is located on top of the Platform main structure with the Payload Base Plate as the mechanical and thermal interface. The TET-1 satellite is based on the heritage of the BIRD satellite bus. The open satellite structure allows for a flexible payload accommodation which has been adapted for size and mass to fulfil the TET-1 needs. Eleven experiments have been selected by DLR for this first TET mission. The experiments are developed by 11 different companies and institutions and comprise newest technology to be demonstrated for usage in space environment. The technical areas cover next generation solar arrays, navigation equipment, batteries, cameras, communication equipment, and satellite propulsion system and computer hardware. The Payload - Bus interface is realized and managed by a modular Payload Supply System developed by Kayser-Threde, allowing to be customized with minimum effort to the experiment needs and thereby reducing the effort for recurring missions.

Tab. 2. TET-1 technical data

TET-1 Technical Data	
Dimensions	: 880 mm x 580 mm x 670 mm (H x W x D) with about 90 liters of payload compartment
Mass	: Bus 70 kg : Payload 50 kg
Number of experiments	: 11
Stabilization	: 3-axes
Pointing accuracy	: 5 arcmin
Payload power consumption	: max 20W continuous (160W peak)
Uplink rate	: 4 kbit/s
Downlink rate	: 2.2 Mbit/s high rate
Orbit	: 550 km, SSO
Mission duration	: one year

4.2 Satellite Bus

The satellite bus technology is based on the technology of the space proven BIRD satellite bus, flown by the DLR in 2001. It was adapted with regards to new available components with regards to a better performance, more payload volume and mass and a much higher reliability of the system (which results in more redundancies and more reliable EEE-parts). With 70 kg satellite bus mass the it is able to provide a payload capacity of 50 kg with an envelope of 460 x 460 x 428 mm (Fig. 5). The satellite bus offers the possibility of fixing a payload panel above the central solar panel. Additional solar cells can also be installed on a special area on the central panel.
Some other basic features of the TET satellite bus are the compact micro satellite structure with high mechanical stability and stiffness and a cubic shape in launch configuration with a dimension of 670 x 580 x 880 mm³ (see Fig. 5). The TET satellite bus relays on a passive thermal control system with radiators, heat pipes, MLI, temperature sensors and contingency heaters.



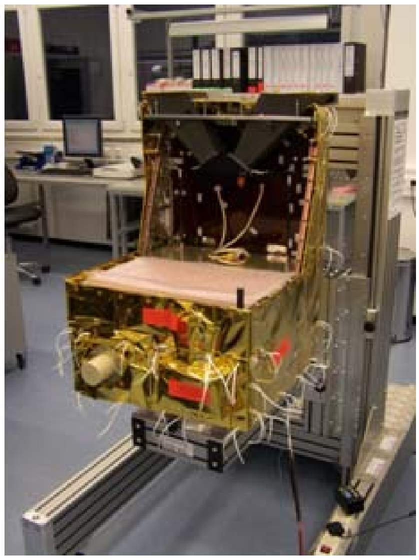


Fig. 5.TET-1 satellite bus: Main segments (left), Flight model w/o solar arrays (right)

The TET satellite bus consists of three compact segments. In the service segment a battery, reaction wheels, the power control and distribution unit and laser gyro are installed. The Satellite Board Computer and the Payload Supply System are located in the electronics segment. The modifiable payload platform is the link between electronics segment and payload segment. Due to the design the sole mechanical and thermal interface between payload and satellite bus is the payload platform, which allows an easy and fast integration of the pre-assembled payload.
The payload segment contains the experiments and also satellite bus components (star sensors, magnetic field sensors) and antennas (low-gain and GPS) (see Fig. 5.). More details about the satellite bus you will find in a separate paper [1].
The power subsystem consists of a PCDU, NiH2 cell battery stacks (with 240 Wh) and a solar generator which has 3 panel (2 deployable) with 220W electrical power. The Spacecraft Bus Computer 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 (worker) is controlling the satellite while the second is supervising the correct operation of the worker node.
The AOCS of the satellite bus consists of two star sensors, two IMUs, two magnetometer, 2 sets of Course Sun sensors, 4 reaction wheels, a redundant magnetic coil systems, 2 GPS systems and an On-board-Navigation-System, which runs as software application on the SBC. The AOCS is a state based systems controlled by an application software in the SBS. More details about the AOCS you will find in paper [2].
The communication system is based on a S-Band system with redundant receivers and transmitters with a 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.

4.3 Payload

4.3.1 Experiments

As mentioned, 11 experiments are accommodated in the TET-1 satellite. A wide range of applications are covered and listed below:

Tab. 3. TET-1 Payloads

Nr.	Experiment	Payload Provider
1	N1 Li Polymer Batterie	ASP Equipment GmbH
2	N2 Flexible Thin-Layer Solar Cells	Solarion GmbH
3	N6 Sensor Bus System	Kayser-Threde GmbH
4	N7 Pico-Satellite Propulsion System	AI-Aerospace Institute
5	N8 Next generation Solar Cells / Azur	AZUR GmbH
6	N9 Next generation Solar Cells / Astrium	EADS Astrium GmbH
7	N15 IR-Camera	DLR-OS
8	N16 Two-Frequency GPS	DLR-RB-RT
9	N17 HW-BOSS	Fraunhofer-Gesellschaft FIRST
10	N18 Keramis-2	IMST GmbH
11	N19 MORE	IDA TU Braunschweig

The experiments are developed by the individual providers according to specific TET standards and are thoroughly acceptance tested at Kayser-Threde before integration in the Payload Segment of the satellite. Fig. 6 e.g. shows the Infrared Camera during acceptance testing.

Fig. 6. Payload N15 (Infrared Camera) during acceptance testing

4.3.2 Payload Segment

The accommodation of the experiments in the Payload Segment is shown in Fig. 7. The accommodation has been driven by the various experiments needs as e.g. viewing directions, unobstructed view angle for antennas, heat dissipation, etc. Thermal analyses, power budget and data handling considerations were performed to establish mission scenarios which are fulfilling the individual operational requirements of the experiments as e.g. number of experiment cycles, durations and timelines which are compliant with the satellite resources.

The solar cell experiments have been accommodated on the sun pointing side of TET-1 next to the Satellite Bus solar arrays.

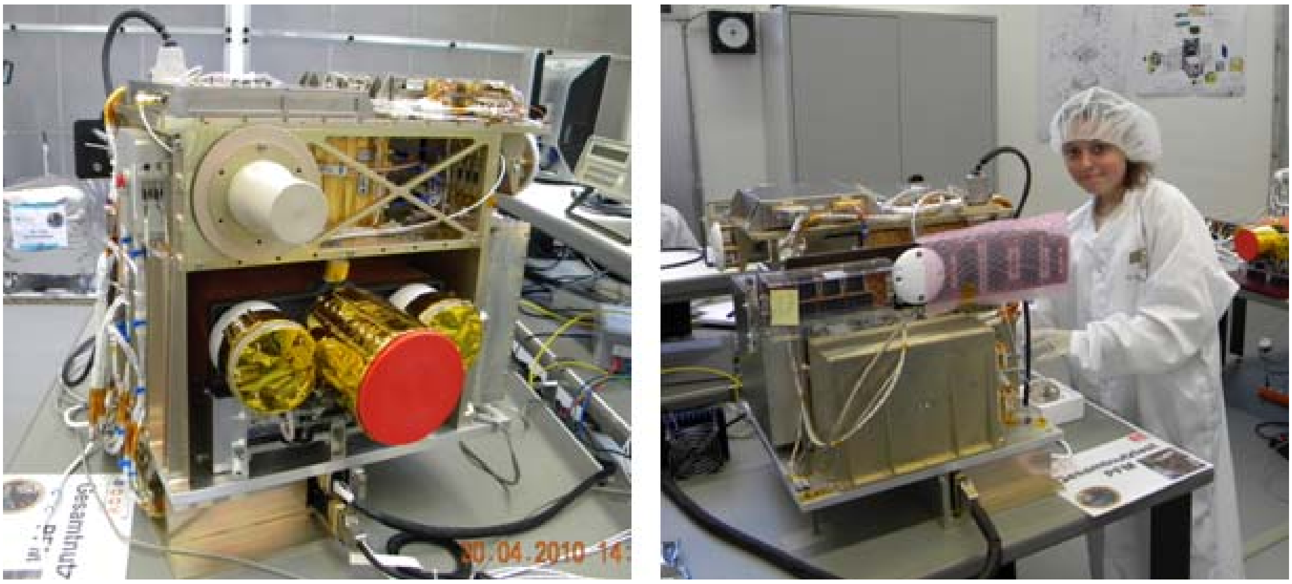


Fig. 7. Integrated payload compartment

The TET-1 Payload configuration data is summarized in Tab. 4.

Tab. 4. Payload configuration data

TET-1 Payload Data	
Dimensions:	428 mm x 460 mm x 460 mm (H x W x D)
Max. Payload Mass:	50 kg incl. mass of Payload Supply System
Power consumption cont.:	0 – 20 W incl. Payload Supply System
Power consumption max.:	160W limited in time and occurrence
Supply Voltage:	18 – 24VDC
Current max.:	8A
TM Data Rate:	2.2 Mbit/s max.
Data Storage:	512 MByte
Heaters:	0 to 15W

4.3.3 Payload Supply System

The Payload Supply System builds the interface between the Satellite Bus and the experiments. The Payload Supply System provides therefore a fixed part that interfaces to the Satellite Bus and a flexible part that can easily be adjusted to the experiments needs.

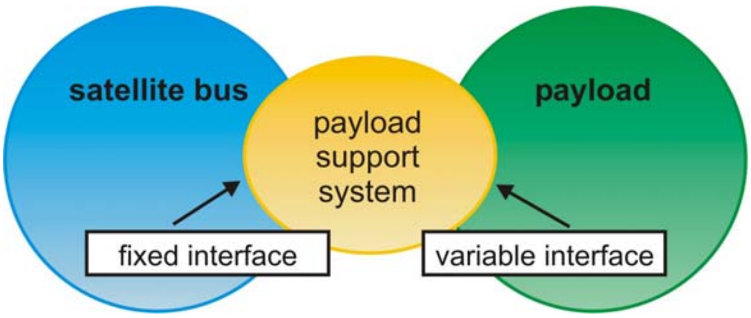


Fig. 8. Payload supply system interface

The chosen concept provides high flexibility for the adaptation to specific payload interface requirements. For future missions adaptations can be realized with reasonable effort.

The Payload Supply System developed by Kayser-Threde (see Fig. 9) is a modular system consisting of a backplane and set of different types of boards in Europe Card size (160 x 100mm²):

- 2 Processor Boards (1 main, 1 cold redundant) used for all Payload Supply System activities, for control of the experiments and for communication with the satellite
- 1 Digital and 1 Analog I/O Boards that provide the electrical interfaces to the experiments The range of interfaces comprises serial communication with RS-422, I^2C and SpaceWire, general purpose digital inputs and outputs, outputs for the distribution of PPS-signals, high precision differential Analog inputs and inputs for temperature sensors of type AD590 or PT1000.
- 5 Power Boards for regulated for unregulated voltages for supply of the experiments and the Payload Supply System itself. All power channels can be switched on/off independently by relays, all channels are protected by latched current limiters and they are equipped with sensor circuits for monitoring voltages and currents. For TET-1 6 regulated and 8 unregulated voltages with up to 8 amperes are provided.

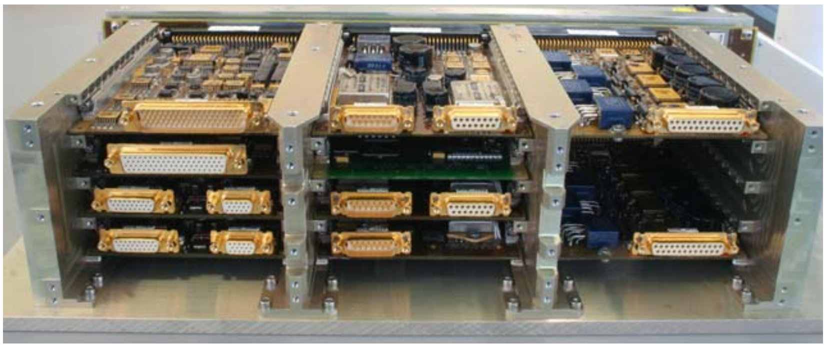


Fig. 9. Testing of the payload supply system in a test rack

The Payload Supply System is accommodated in the Electronic Segment of the Satellite Bus next to the Satellite Bus Controller. The Electronic Segment provides space for 12 boards in 3 stacks as shown in Fig. 9. Thus it was possible to integrate one of the experiments, the N17 board within the Payload Supply System. The block diagram Fig. 10 shows the Payload Supply System with the various interfaces.

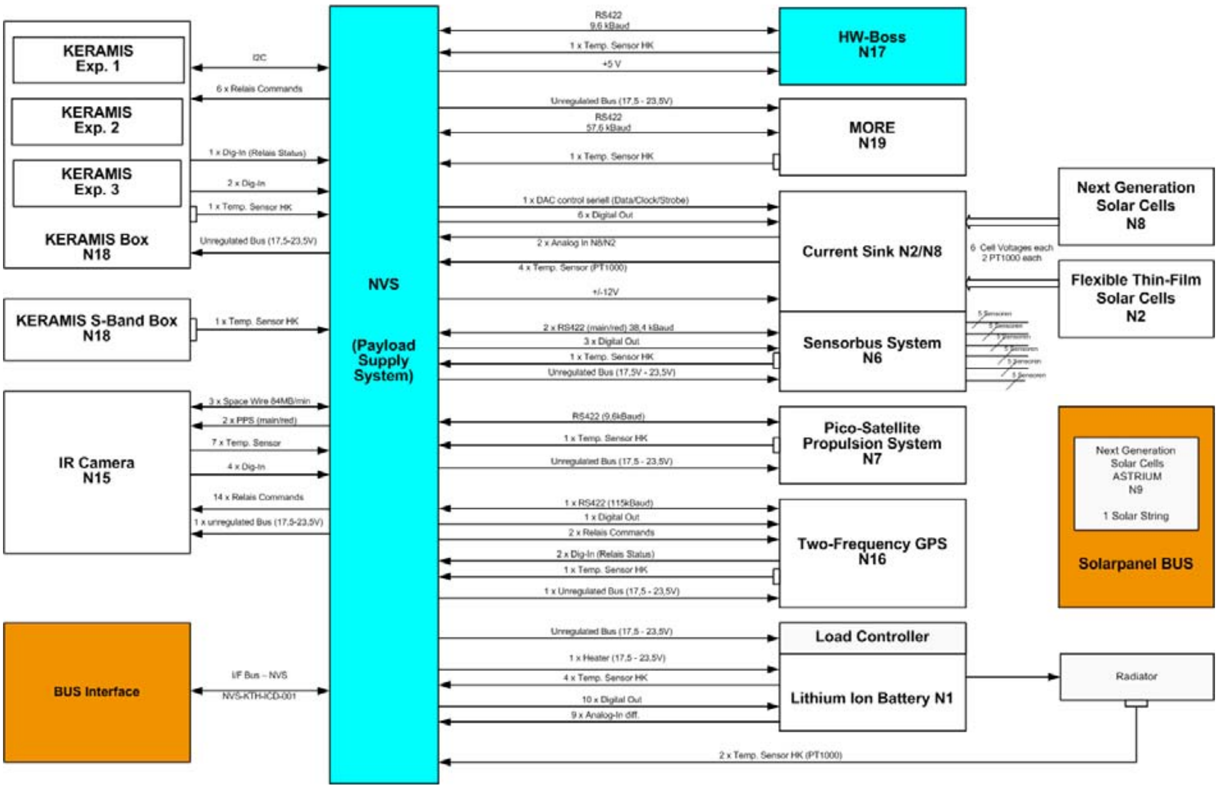


Fig. 10. External interfaces of the Payload Supply System

5. GROUND SEGMENT OVERVIEW

Ground Segment project management, integration, and test and training as well as all LEOP activities, routine mission operation and satellite control for TET-1 will be performed at the German Space Operations Center (GSOC) [3].
Interfaces are established to external partners such as the launch-provider (data-exchange) and to the Canadian Space Agency (CSA) as provider of additional ground-station for LEOP-support. This is done on a co-operative basis (no exchange of funds), as DLR-GSOC supports Canadian missions with its resources. DLR-owned S-Band ground stations in Weilheim (WHM), Neustrelitz (NST) provide the necessary access to the satellite in all mission phases. Svalbard/Norway, St. Hubert/Canada and Saskatoon will support the LEOP phase.
A so called Payload Data Center (PDC) will be provided at the location of the data reception station in Neustrelitz. The main tasks are acquisition, extraction, processing (formatting to a generic ASCII format) archiving and provision of payload data. The 11 users with their experiments onboard TET-1 retrieve (download) their data via a secure FTP interface.
The core element of the ground segment – the so-called Mission Data System (MDS) – is already fully operational and available and just needs to be configured for TET. The only exception being the Mission Information Base (MIB) which is specific for each project as it contains the definitions of TM and TC. Fig. 11 gives an impression of the TET-1 Ground-Station Coverage and Orbit Tracks

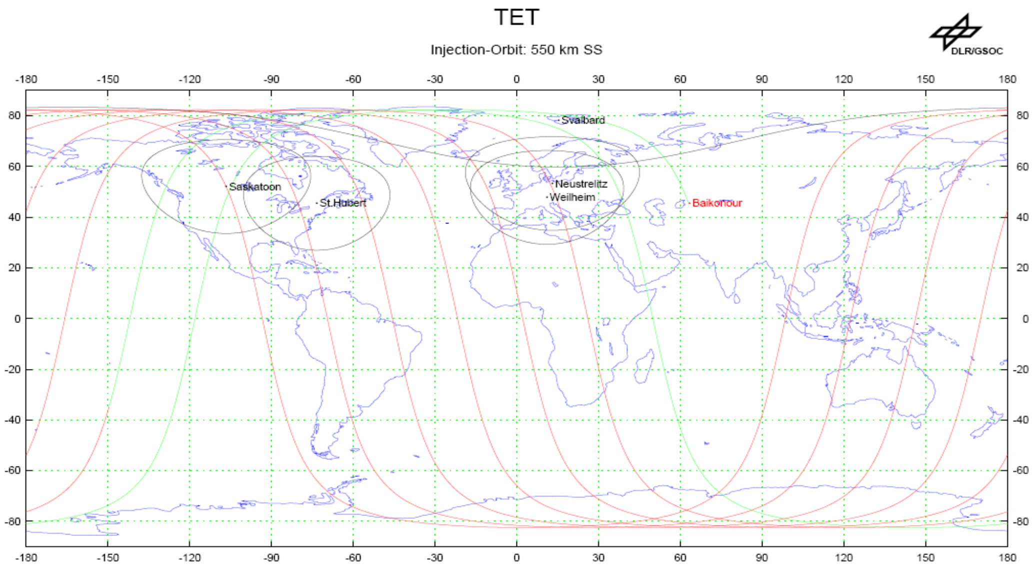


Fig. 11. TET-1 ground station network (with LEOP stations)

6. MISSION OPERATIONS

For the TET-1 mission the ground-segment will basically provide the execution of all necessary activities for a sound operation of the space segment and a continuous survey (Monitoring & Control) of functionality and integrity of all project elements. DLR-GSOC will perform this for all mission phases after launch for both the space segment and the ground segment.
After launch, the satellite will be activated and tested during a 2 weeks LEOP phase. It will be followed by a 2 week phase for bus commissioning activities. After that, the operation phase starts with a short initial payload commissioning and subsequent transition to routine operations.
The routine operations network is based on WHM and NST ground stations with 4 scheduled contacts per day, 1 contact over WHM and another 3 over NST. The WHM contact is the contact also used for uploading of TCs while the 3 other contacts are used for payload data dump and telemetry only. If required, stations can be used interchangeable - increasing reliability of the ground segment.
TCs are uplinked with 4 kbps in S-band. Telemetry data is received either solely with 137.5 kbps or together with payload data at 2.2 Mbps, both also in S-band. Both types of data (TM and payload

data) are received by both stations and are exchanged transparent to operations. Payload data received at WHM is transferred automatically to NST where it is processed and delivered to the payload owner. Payload data and telemetry are transferred in parallel but are separated by different virtual channels (VC) during high rate downlink.
A number of different experiments for in orbit verification are carried by TET. Each experiment sets its own requirements for operations execution, as listed in Tab. 5.

Tab. 5. Different types of experiments on TET-1

Experiment Types	Specific Operations Requirement
Experimental battery	High energy consumption during battery loading
Different types of solar cells	Sun pointing
Memory cells	Nothing specific
Pico satellite propulsion system	Specific attitude in order to avoid satellite bus contamination
Radio transmission experiment	No regular TM/TC transmission possible during experiment
Experimental GPS receivers	Operations with good GPS satellite view which requires an attitude different from sun pointing
Infrared camera	Nadir pointing, high power consumption and high data generation during operations, satellite rotation about nadir axis by 180° for star camera operations
Sensor and software experiments	Operations as long as possible. Not specific other requirements

All 11 payloads are operated by GSOC according to their respective requirements – which may be e.g. number of activation cycles, hours of operation or certain attitudes. Requirements have been collected by Kayser-Threde from the payload owners. To generate a valid operations concept also the satellite bus capabilities have been collected and analyzed. All information together is stored in an Excel sheet, containing all payload and bus activities.

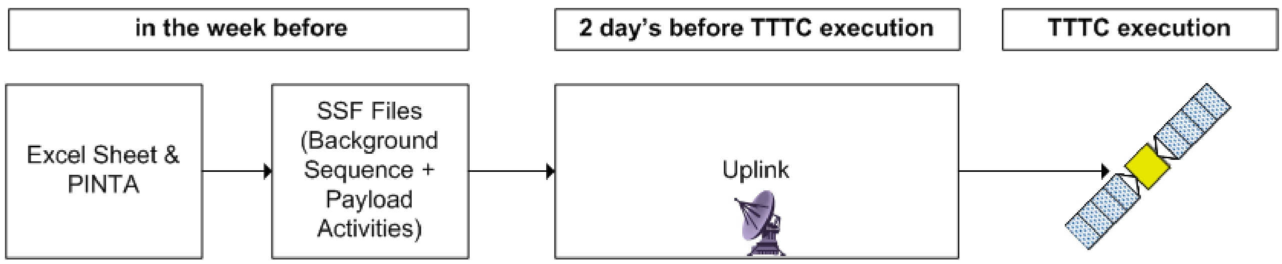


Fig. 12. TET operations flow

In the control center a tool named PINTA (Program for INteractive Timeline Analysis) is used for generation of commands for daily operations, processing the following information:
- Prepared operations scenarios data
- GSOC scheduling office information for scheduled ground station contacts
- Information of the GSOC flight dynamics system for orbital events
- Procedures from the MOIS database

Operations are scheduled on a weekly basis, joining daily routine activities like transmitter activation and deactivation as well as payload activities into one timeline. If required, additional activities are planned. For some payloads (e.g. camera or GPS) attitude modes different from sun pointing are commanded. The return to sun pointing must be assured by mission operations. This is checked in the timeline and also integrated into the payload operations procedures. For security reasons the satellite also checks its vital parameters, once exceeded a safe mode will be triggered with included return to sun pointing.

7. SERVICES AND PRODUCTS

All users with experiments onboard TET-1 will be provided two payload data sets with different formats on ftp-server. The Payload Data Centre (PDC) processes the received payload data during and immediately after data reception, which is planned 4 times a day. The products (instrument source packets in raw binary form and as ASCII text file) will be made available at the ftp server 15 min after finishing data reception, secured by protected and selective access. The format of both payload data products for all 11 users is identical, while contents differ of course. The user additionally receives all auxiliary data (required for calibration purposes or additional processing) provided by the control centre via the same interface. All data is stored on a permanent archive and a function for later retrieval is provided.

Tab. 6. TET-1 data products

Data Products	Content	Type	Availability	Remark
Auxiliary Data	- Ops-planning and as flown	tbd	Not restricted	
	- Orbit	tbd	Not restricted	
	- Attitude	tbd	Not restricted	
	- Bus-HK-data (including NVS)	ASCII	Not restricted	
	- Logs	ASCII	Not restricted	various
Payload Data	Raw Instrument Source Packets (ISP)	Binary	User Specific (pass-word protected access)	Generic format, but specific content for each user
	Converted File	ASCII	User Specific (pass-word protected access)	One generic format for all users, contents specific.

8. PROJECT STATUS

Right after the 4S Symposium in Rhodes May 2008 the TET project started in Phase C. The system CDR was concluded January 2009. Phase D and especially the manufacturing phase started after successful STM tests in April 2009 (Fig. 13).

Fig. 13. Structure / Thermal model of the mini satellite TET-1

Until the end of 2009 the engineering model (see Fig. 14 & Fig. 15) was tested and the flight model was built. Acceptance of the 11 experiments (payloads) took place between October 2009 and April 2010.

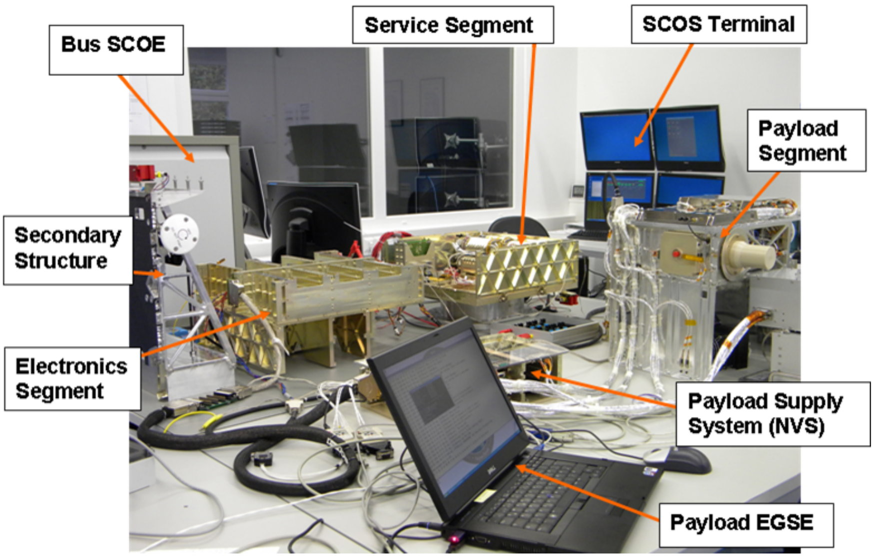


Fig. 14. System & software tests of engineering model (EM)

Fig. 15. EM AOCS (left) on AOCS test bed (right)

Presently the AIV process of the Protoflight model of platform and the payload compartment is in progress. The functional verification of the platform and the payload will be completed until end of May 2010. After platform acceptance final satellite integration, system testing and the environmental verification is planned for the next three months at Kayser-Threde in Munich.

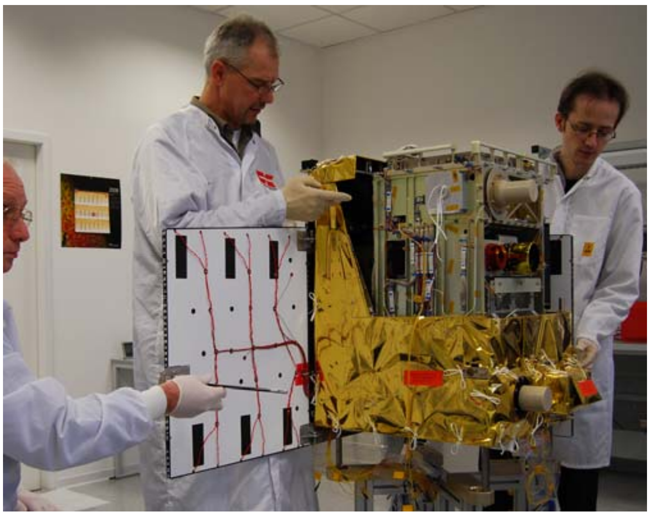


Fig. 16. Final satellite integration (Picture shows STM)

The Final Acceptance Review for the complete TET-1 satellite is planned September 2010. The transport to Moscow followed by the launch campaign is scheduled for November this year.

9. SUMMARY & OUTLOOK

The goal of the TET programme is the support of German industry and research institutes with the on-orbit verification of new and innovative satellite technologies. For this purpose regular and reliable flight opportunities shall be offered, which can be realized on short notice.

With Phase C/D Kick-off in May 2008 and the launch date end of 2010 not only the satellite had to be ready within two and a half years, but also the ground segment and the launch segment. Presently the project is in its final stage (Satellite integration & test) and the launch of the first satellite, TET-1, is scheduled for end of 2010.

The TET satellite is a micro-satellite of 120 kg mass and the dimensions are 880x670x580 mm^3.
In total, eleven different payloads have been accommodated on TET-1. These include optical experiments such as an infrared camera as well as novel solar cells, batteries, on-board computers, GPS receivers and a Pico-Satellite propulsion system. After the LEOP and commissioning phase, the one year mission operation will start beginning of next year. Payload data will be transmitted to the TET ground station and provided to the experimenters via the Payload Data Center.

Finally, TET with its new standardized bus and modular payload supply system shall serve also in future as standardized platform for on-orbit-verification purposes. The payload compartment is large enough to accommodate even complex experiments, and the bus performance is powerful enough to provide also challenging mission requirements as demonstrated for the IR-payload onboard TET-1.

With the TET concept Kayser-Threde is able to enlarge its possibilities to offer flight opportunities for in-orbit demonstration missions, small earth observation missions and commercial micro-satellite missions.

10. ACKNOWLEDGEMENT

The TET-1 phase C/D will be carried out under contract to DLR (no. 50 RV 0801) with funds from the German Ministry for Economics and Technology (Bundesministerium für Wirtschaft und Technologie). The authors like to thank especially NPO Lavochkin for their kind contributions to this paper and also all TET team members.

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