# OPERATIONS CONCEPT AND CHALLENGES FOR 11 DIFFERENT PAYLOADS ON THE TET-1 MINI-SATELLITE

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## ABSTRACT

TET-1 is a satellite intended for verification of new space hardware and scheduled for launch end of this year. The German Space Operations Center is responsible for preparation and operations execution for this satellite. Routine operations are driven by the requirements of 11 payloads, which are significantly different. Operations are split in two different phases, a one year initial routine operations phase and an optional extended operations phase, the focus of the both is different.

An operations concept has been jointly developed by GSOC together with Kayser-Threde. This concept comprises elements like the selected routine operations network, the design of the system for payload operations (NVS) as well as payload data immediate storage and dump concept.

During the planned first year of operations all 11 payloads are operated with the goal of payload verification under space conditions. Routine operations cycles are planned on an orbit by orbit cycle within a spread sheet developed by KTH. All activities for the first year are already planned at the start of the phase. This data is automatically read into the mission operations system of GSOC and adapted for daily satellite operations. A variety of different tools is used for generation and modification of the command sequences, either manually or automatically. These tools are mostly used as heritage from other GSOC missions.

For some payloads special operations requirements apply, like a 180° 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 by a disadvantageous sun incidence angle for the solar generator. All these requirements are taken into account when generating the timeline.

During the possible extension phase only a subset of all payloads is operated and the operations requirements are changed compared to the first year. The driving payload for this phase is an infrared camera assembly, similar to a camera already flown on the BIRD satellite. In this phase mission operations is adapted to the requirements of this camera. Operations are driven by the requirement of short reactions times to camera interesting events like hot spots. Furthermore power and data constraints must be obeyed by the mission operations group.

## 1. MISSION OUTLINE

The Technologie-Erprobungs-Träger TET-1 (technology experiments carrier) is build in the frame of the On-Orbit-Verification (OOV) program of DLR and scheduled for launch end of 2010. With an overall weight of 120 kg it can be classified as a mini satellite. The mission has been initiated by the DLR Space Agency with Kayser Threde as the selected prime contractor and two major subcontractors: the satellite bus is developed by Astro- und Feinwerktechnik, Berlin and the ground segment is provided by DLR GSOC (German Space Operations Center), Oberpfaffenhofen. More details on the overall mission can be found in [1] and especially on the ground segment in [2]. Further presentations are also part of the 4S Symposium 2010.

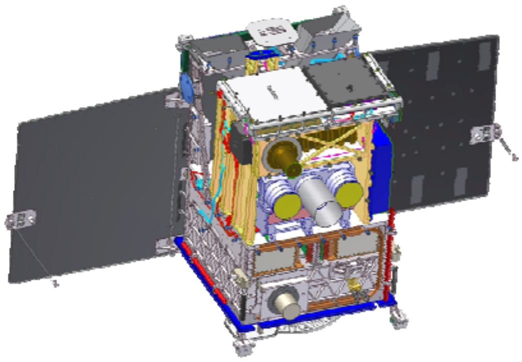

**Fig. 1: TET-1**

## 2. MISSION PHASES

The project is in phase D at the moment. On the ground segment side the spacecraft operations procedures are developed, software is configured, control rooms and trainings are in preparation. After launch, the satellite will be activated and tested during a 2 week long LEOP phase. This is 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.

## 3. EXPERIMENTS ON TET-1

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. 1.

**Tab. 1: 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 |

## 4. PLANNED MISSION OPERATIONS

### 4.1. Bird Operations: The Predecessor Mission

BIRD is a satellite solely build by DLR and launched in 2001. The satellite bus and the ground segment are used as a baseline for TET – 1. BIRD is, in contrast to TET-1, only equipped with one payload, a camera. The ground station network consists only of one station with one planned contact per day (also DLR Neustrelitz ground station has been used during earlier project stages, but due to the age of the satellite the number of contacts per day has been reduced).

Operations are prepared on a weekly basis once the scheduled ground station contacts are fixed for the upcoming week. For every day a back ground command sequence is prepared. The sequence covers all necessary commanding, especially time-tagged activation and deactivation of the transmitters for upcoming contacts. This sequence is generated by a specific Excel sheet with underlying macros in the ODL language. ODL files are read by the multi mission command system and uplinked to the satellite.

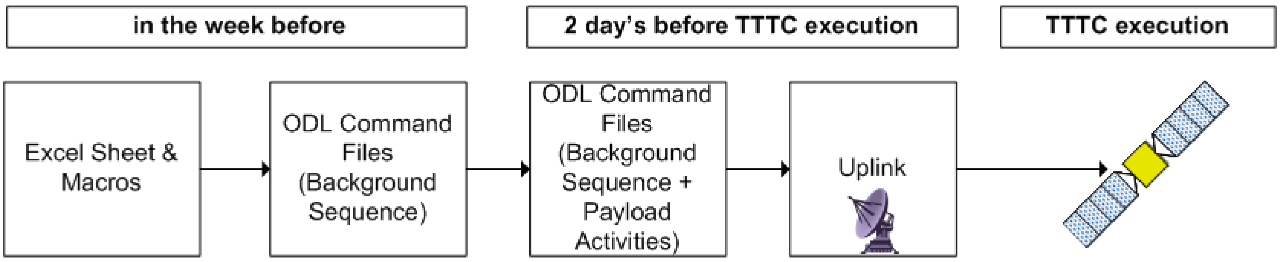


**Fig. 2:** BIRD Operations Flow

Fig. 2 shows the principle operations flow. Payload activities are planned two days before execution, necessary commands are added to the regular background sequence. The background sequence consists of the commands required for transmitter switching, setting of navigation and GPS system and other regular on-board activities which are not related to payload operations. During the contact payload data of the camera is dumped to the ground station. As there is only one payload no differentiation of different payload data sources is necessary.

### 4.2. TET Operations

For routine operations TET relies on a network consisting of two ground stations in Germany, Weilheim (WHM) and Neustrelitz (NST). Fig. 3 shows the used network with routine and LEOP stations. Contacts with NST and WHM are nearly identical with respect to the AOS and LOS times, contacts are therefore only scheduled at one of both stations.

Telecommands 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.

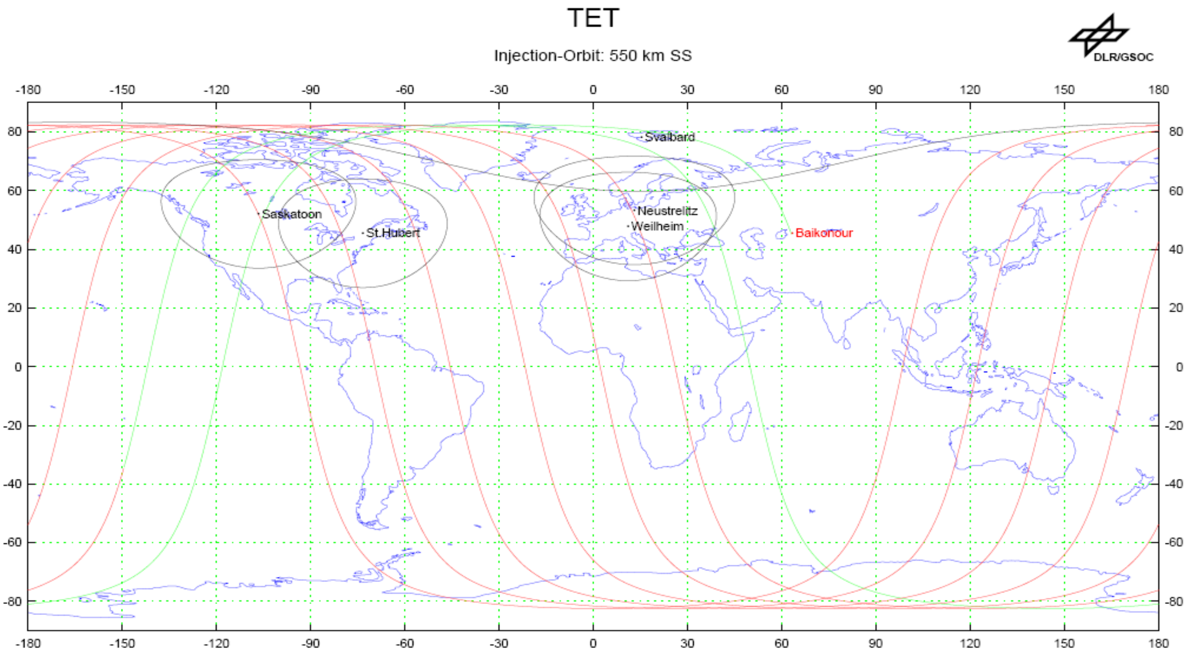


**Fig. 3: TET-1 ground station network (with LEOP stations)**

All payloads are physically assembled on a payload supply system (NVS). This system is connected to the satellite bus via dedicated interfaces and isolates possible errors during payload operations either on the level of payload or on the level of the NVS. The satellite bus remains unaffected by any failures during payload operations. Telecommands for the NVS system and the payloads are only received by the bus and directly forwarded for execution to NVS.

### 4.2.1. First Year of Operation

For the first year of 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 telecommands 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.

During the first year 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 KTH from the payload owners. To generate a valid operations concept also the satellite bus capabilities must be collected and analysed. All information together is stored in an Excel sheet, containing all payload activities for the first year of operation.

***Long Term Operations Preparation***

This sheet defines one complete year of operations with different operations profiles on a daily basis. As certain profiles are repeated the number of different profiles in the sheet is 8. Within these profiles a defined subset of the different payloads is operated. For each payload different modes of operation are defined, for a payload N1 this may be the simple modes: N1A (activation), N1M (measure) and N1D (deactivation). The number of different modes depend on the type of payload and the associated operations activities. With each state, power consumption and a data rate for generating science data is associated. Power consumption and data generation is checked in order not to exceed satellite capabilities. Modes of all active payloads are listed on a minute by minute base for each satellite orbit in each of the different profiles.

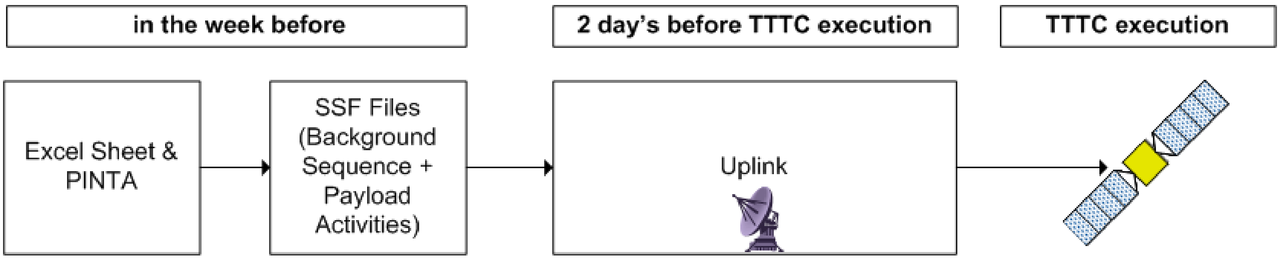


**Fig. 4: TET Operations Flow**

The principle operations flow for TET (see Fig. 4) is similar to the simple BIRD concept (see Fig. 2) with the difference that all nominal payload activities are defined together with the background sequence generation. Main difference is the generation of the command sequences.

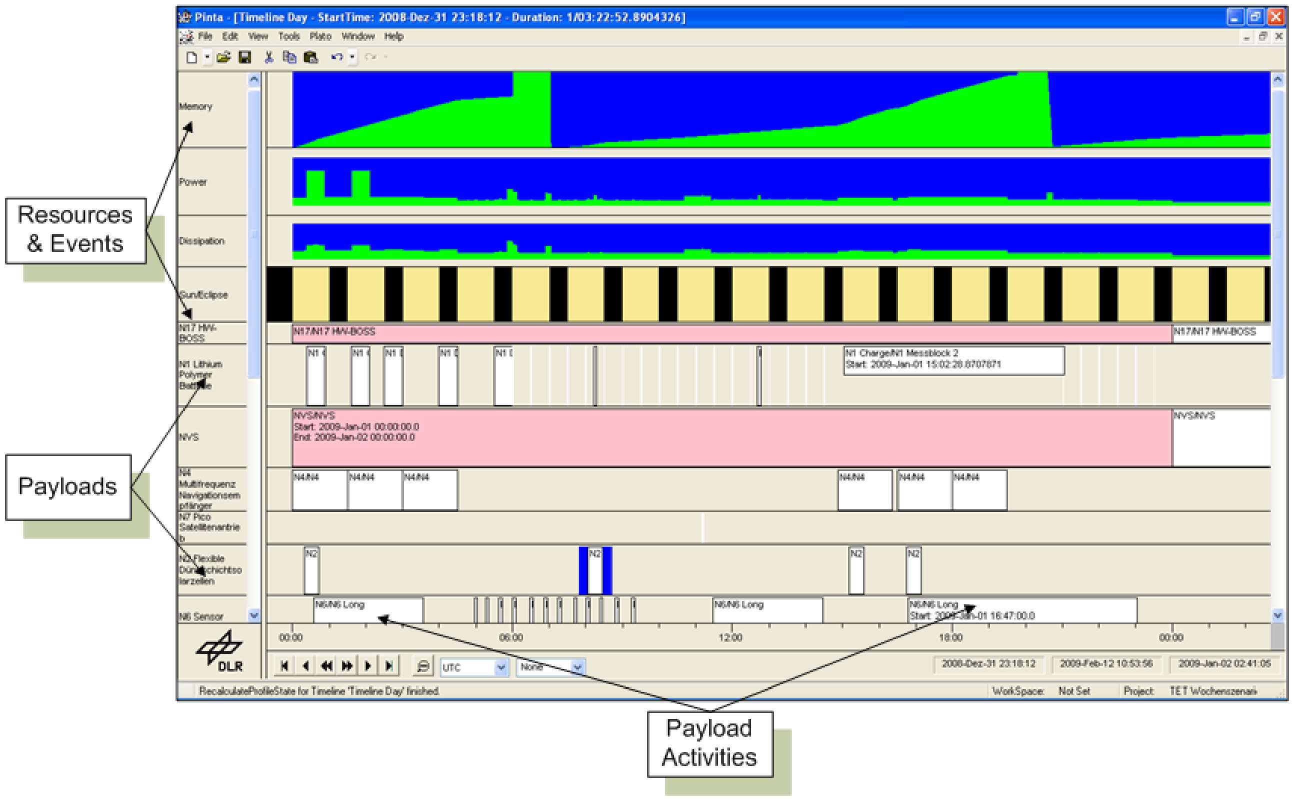


**Fig. 5: PINTA tool used for daily operations**

### *Short Term Operations Preparation*

In the control center we use a tool named PINTA (Program for INteractive Timeline Analysis, see Fig. 5) for generation of commands for daily operations, processing the following information:

**- Prepared operations scenarios data**

Information of the prepared operations scenarios (the Excel provided by KTH) are read by an specific macro and translated into a csv-file which can be imported to PINTA. This prevents manual import of all activities for one complete year of operations.

**- GSOC scheduling office information for scheduled ground station contacts**

All ground station contacts for GSOC mission are schedule by one scheduling office. Stations are either dedicatedly requested or are scheduled based on a general rule. For TET we use the general rule to request 4 contacts per day with one uplink preferably over WHM station.

**- Information of the GSOC flight dynamics system for orbital events**

Flight dynamics provides different orbit related information required for daily operations, as elevations above selected grounds stations (e.g. 5° or 10° contact times), position information as well as orbital eclipse times.

**- Procedures from the MOIS database**

As described above each payload has a number and different possible modes of operation. For each mode procedures are defined to command this mode. Payload operations are defined in the prepared operations scenarios as certain defined states of the payload, the MOIS procedures allow switching in between the different states (telecommands are also imported together with the procedures, but not mentioned additionally in the figure).

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. This may be bus activities which are not routine but necessary for operations as for example reading of extended telemetry.

***Operations Execution***

Based on the weekly timeline a fraction of one complete day of operations is exported. This export is converted into a SCOS compatible ssf – file, containing all required time tagged TC. During ground station contact, this sequence will be uploaded together with necessary real time commands and stored for later time tagged execution.

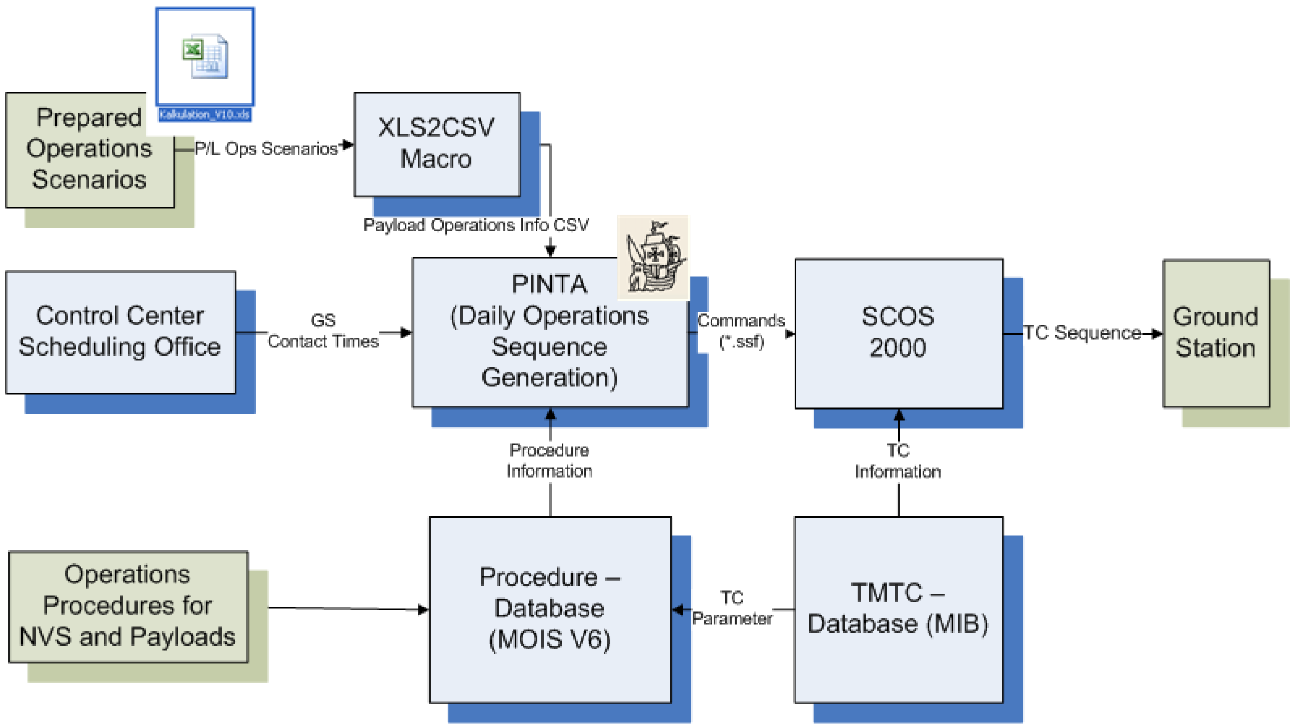


**Fig. 6: Generation of commands for TET with PINTA**

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 checked in the timeline and also integrated into the payload operations procedures. For security reasons the satellite also checks it's vital parameters, once exceeded a safe mode will be triggered with included return to sun pointing.

#### 4.2.2. Extension of Operations

It is expected that the satellite will be significantly longer operational than the first planned year. Operations during an extended mission phases are not yet defined but the focus is placed on operations for the N15 infrared camera. Some other experiments may also be operated but only on request of the payload owner and if the payloads still operational.

During the first year the infrared camera is only operated according to the predefined operations plan. As a result the satellite changes its attitude to nadir pointing and scans are made but now targeted acquisitions are planned as this would conflict with operations of all the other different payloads. This problem is minimized during extended mission operations; priority is placed on the camera. Interesting targets are fires on earth which requires planning on relatively short notice. Also an extension of the routine ground station network may be necessary to dump all acquired images.

## 5. CONCLUSION

TET is a German technology mission for on orbit verification of new space hard- and software.
Launch is scheduled for end of 2010 with an initial operations phase of one year. The mission has been initiated by the DLR Space Agency with Kayser-Threde, AFW and DLR GSOC responsible for space segment and ground segment.

Operations are split into a nominal phase of one year followed by a possible mission extension. For the first year a two-staged operations preparation approach has been selected: Payload operations for the complete first year are prepared as different operations profiles (8 different profiles). This information is imported to the GSOC PINTA tool on a weekly basis for operations and exported as time tagged TC sequence on a daily basis for uplink. All 11 satellite payloads are operated according to their requirements. For some payloads specific attitude modes are required, return to sun-pointing mode is checked by PINTA during operations preparation and partly already incorporated into payload operations procedures.

During a possible extension phase the focus is on operations of a selected sub-set of the payloads. Emphasis is placed on the infrared camera assembly. Short responsive times to camera operation requests are necessary, while utilizing the ground segment as much as possible for dump of camera images.

## 6. REFERENCES

[1] Föckersperger S., et al. *TET-1 A German Microsatellite For On-Orbit-Verification*, In Proc. 'The 4S Symposium - Small Satellites Systems and Services', ESA-ESTEC, Noordwijk, The Netherlands, 26–30 May 2008 (ESA SP-660, August 2008)

[2] Mühlbauer P., et al. *Mission Operation, Ground Segment And Services For The German TET-1 Microsatellite (Technology Experiments Carrier)*, In Proc. 'The 4S Symposium - Small Satellites Systems and Services', ESA-ESTEC, Noordwijk, The Netherlands, 26–30 May 2008 (ESA SP-660, August 2008)