

Project description

The Micro-Satellite *Flying Laptop*

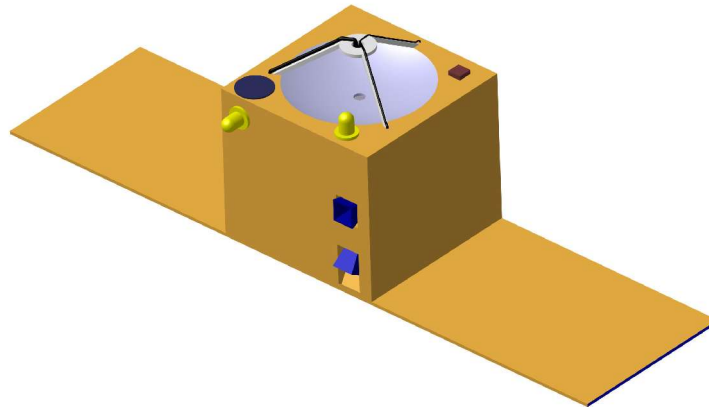


Figure 1: *Flying Laptop*

Stuttgart Small Satellite Program

Through technical minimization, micro-satellites are currently of increasing interest. Their possibilities as well as their scope of missions is growing steadily. Today, payloads with a mass of just a few kilograms are able to perform measurements that would have been unthinkable a few years ago. Another advantage is the fast and cheap development of micro-satellites, which makes them a suitable platform for technology evaluation. Hence, they provide the ideal opportunity to test new systems in space within a short timeframe and low budget.

Within the Stuttgart Small Satellite Program the Institute of Space Systems at the University of Stuttgart will develop and build several small satellites. The existing ground station is currently being upgraded and extended to allow satellite communication in different frequency bands (UHF, VHF, L-band, S-band and Ka-band). Direct access and control of the satellites is ensured by operating all equipment in-house. Furthermore, a satellite integration room is being set up at the laboratory section. After the completion of several testing models, the following three small satellites will form the core of the program:

- Flying Laptop: Earth Observation & Technology Demonstration
- Cermit / Desire: Re-entry Vehicle & Technology Demonstration
- BW1: Lunar Mission

The *Flying Laptop* will be the first satellite to be launched at the end of 2006. This project is described below.

The *Flying Laptop*

The project is at an early stage of development. Many of the currently listed facts will become more accurate as time progresses, and updates will follow.

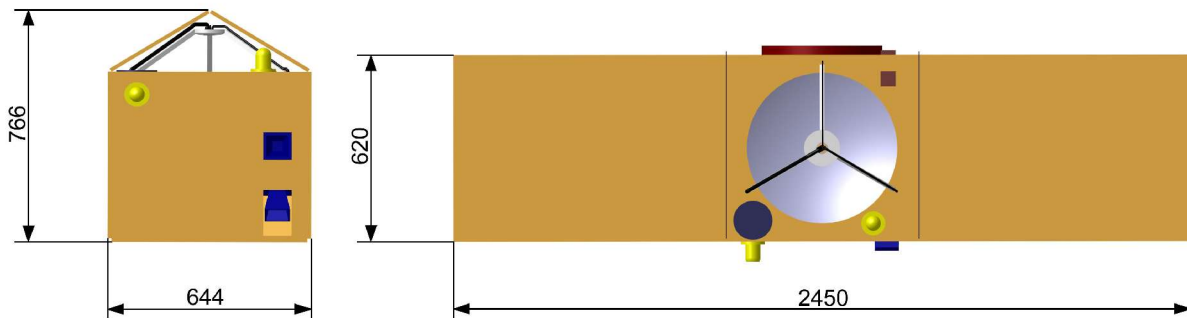


Figure 2: Dimensions of the *Flying Laptop*

The *Flying Laptop* is a micro-satellite with a mass below 100 kg and a size of 55 cm x 62 cm x 62 cm. Power is generated by three solar panels, two of which are deployable. The satellite is 3-axis stabilized by momentum wheels which are desaturated by magnetic torquers. Earth observation and technology demonstration are the two main objectives of the mission:

- VIS/NIR camera Ground Sample Distance (GSD) = 25 m
- TIR camera GSD = 50 m
- VHF, UHF, S-band, Ka-band
- FPGA (Field Programmable Gate Array) on-board computer

The FPGA on-board computer allows the satellite to operate in a so-called *Rent-A-Sat* mode. The satellite will be offered to interested companies as a software testing platform to verify their algorithms or firmware under real space conditions. Because of the reconfigurable computer architecture a simple reset will regain full control of the satellite within milliseconds in case of emergency.

A target-pointing or spotlight mode is necessary in order to achieve the planned scientific measurements. In this operation mode the satellite is pointed at the same specific Earth target during the entire orbit pass. The necessary pointing stability of 10 arcseconds is a big challenge for the attitude control system of the *Flying Laptop*. This accuracy will be achieved by momentum wheels and magnetic torquers.

Scientific Research

With its cameras and the Ka-band antenna – also proposed to be used as radar transmitter - the *Flying Laptop* will contribute to research in the field of Earth observation through remote sensing. Topics of special interest include:

- Measurement of the Bi-directional Reflectance Distribution Function (BRDF) in the visible spectrum as well as the Temperature Directional Distribution
- Precipitation measurement

- Atmospheric attenuation in the Ka-band frequency range
- Trace gas detection using the Ka-band
- Multi-spectral Earth observation

BRDF Measurement:

The BRDF (Bi-directional Reflectance Distribution Function) plays a decisive role in the analysis of spaceborne remote sensing data. The BRDF describes the distribution of reflected light from a body under various insolation and observation angles. Depending on the direction of the sun (insolation angle) and the position of the observer (observation angle) the light reflection from the target is different. An example of the different colors of grass is shown in Figure 3. In the target pointing mode this function is measured in different spectral bands (visible, near infrared and thermal infrared). The cameras continuously take images of the same ground segment during a flyover or pass. A homogeneous ground segment is important for the measurement, therefore, deserts or large forest areas are ideal candidates.

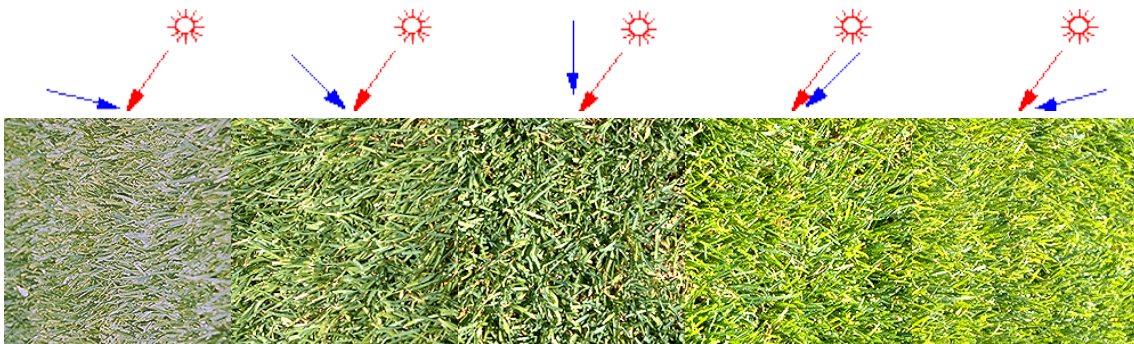


Figure 3: Bi-directional reflectance effect of grass. (Source:<http://www.geo.unizh.ch/rsl/research/>)

Precipitation Measurement:

A network of rain gauges and precipitation radars are utilized in meteorology for precipitation measurements. However, our knowledge on precipitation is still inadequate, especially over sea and in the mountains. Remote sensing of precipitation is widely used to obtain increased spatial and temporal accuracy. With remote sensors the precipitation cannot be directly measured. Experiments have shown that the differential radio signal attenuation in a horizontal path through rain in two different frequency ranges is linearly dependent on the rain rate. We will test this relationship for vertical propagation. The acquisition of the data will be performed in the target pointing mode using a Ka-band and a Ku-band signal.

Ka-band attenuation and trace gas detection:

Because thorough data of the band gaps in continental Europe for the upcoming use of the Ka-band in the communication sector does not exist, the Ka-band antenna with its large bandwidth will be used for detection of atmospheric attenuation within this frequency range.

In particular we will test to retrieve the total content of a few atmospheric trace gases which exhibit absorption lines in the Ka-band.

Multispectral Earth observation:

The two on-board cameras will record sequences of multi-spectral Earth images. The Ka-band antenna with its high power signal of 70 W will also be used as radar transmitter. The reflected signal will be captured with the help of measurement

towers on the ground, not at the satellite. These measurements offer the capability to address local scientific questions in this area.

Technology Evaluation

With regard to the planned moon mission the *Flying Laptop* will evaluate new technologies which are an absolute necessity for this kind of mission, including the Ka-band communication and the new FPGA on-board computer system.

The Ka-band frequency range is necessary to allow self-controlled communication for the planned lunar mission. Compared to a required dish size of 30 m for communication in a lower frequency range, it is obvious that an installation of such a dish at the roof of the university building is not possible. By using higher frequency communication in the Ka-band, however, a dish with 3 m diameter is sufficient. The installation of a Ka-band dish on the roof is in preparation.

The 50 cm mirror of the *Flying Laptop* works as a dual system. On one hand, it is the antenna reflector for the Ka-band communication; on the other hand, it is the primary mirror for the optical system of the thermal infrared camera. The two wavelengths are separated with the help of a beam splitter. By combining these two complex systems a compact design is achieved which can be flown on a micro-satellite. Another point of interest is the implementation of a Traveling Wave Tube (TWT) amplifier for telecommunication. The use of a TWT operated at 90 W is an unique feature of this micro-satellite.

Comparing the performance of current spaceborne computer systems with commercial PCs, one recognizes that the evaluation of space qualified systems is difficult and therefore the performance is unsatisfying. Today's computers used in space are years behind commercial technology. This shows the need for new systems where FPGA play a crucial role. With a software-to-hardware compiler it is now possible to directly generate the logical configuration of the FPGA gates from a C-like high level language without producing machine code for a processor. Using an on-board computer architecture with several simultaneous reciprocal checks on the FPGAs, one obtains a safe system that even exceeds the performance of current PCs through its ability of parallel processing. Another important advantage of FPGAs is the fact that the gates are reconfigurable within milliseconds. This great flexibility of the on-board computer system will be used to operate the *Flying Laptop* in a *Rent-A-Sat* mode. Interested companies can rent the satellite as a platform for software evaluation in space. It is also possible to configure the system for customer preferences, i.e. the characteristics of a certain processor could be simulated through the hardware.

Co-operation partners

- DLR
- EADS Astrium
- Fraunhofer Institut
- Opto-System-Technik
- STZ Raumfahrt
- TU Berlin
- TU Braunschweig



O.S.T.

