University of Stuttgart
Institute of Space Systems

Flying Laptop
Academic Small Satellite Flying Laptop

The Flying Laptop is the first satellite of the Institute of Space Systems (IRS) at the University of Stuttgart. It was developed and built primarily by Ph.D. and undergraduate students. The Flying Laptop project is part of the Stuttgart Small Satellite Program, which was initiated by Prof. Hans-Peter Röser.

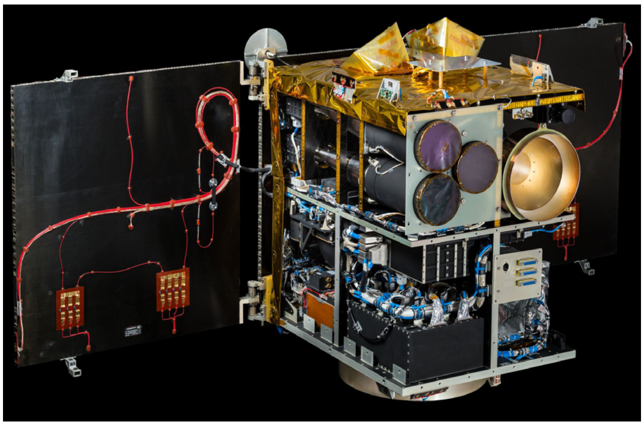

Fig. 1: Small Satellite Flying Laptop.

MISSION OBJECTIVES

Education: The development of the Flying Laptop has been conducted by students in the frame of Ph.D., diploma, master, bachelor, and study theses, and internships. The project is used to improve teaching quality by providing hands-on project experience. More than 120 student theses and 21 Ph.D. theses have been prepared during the development of the Flying Laptop.

Installation of Infrastructure: As part of the development of the Flying Laptop, all relevant infrastructure was installed at the IRS that is required for the design, building, verification, and operation of small satellites.

In-Orbit Verification: The Flying Laptop satellite uses new technologies, which are partly developed by the IRS, other research institutions, or industry partners. Their functionality and performance will be verified during operation under space conditions.

Earth Observation and Space Weather: The Flying Laptop satellite will carry out multi-spectral Earth observation. It shall detect Near Earth Objects and identify ship traffic.

DEVELOPMENT APPROACH

The Flying Laptop is designed to be single point failure tolerant. This is applicable throughout the main satellite bus and partially applicable for the payload system.

Experts from industry are involved to review the design on a regular basis. ECSS guidelines and standards are used for the selection of materials and parts and applied for the environmental qualification of equipment and the system wherever possible.

As an alternative solution, commercial off–the–shelf components with space heritage are used if available. Components from space industry are preferred for all system critical equipment.

The functional verification on the equipment and system levels is based on the working processes of industry.

The Flying Laptop is designed to comply with CCSDS and ECSS communication standards. Therefore, the compatibility to ground stations supporting the commercial S-band frequencies is given.

Furthermore, the satellite also fulfills the European code of conduct for space debris mitigation.

FLYING LAPTOP PAYLOADS

The main payload is the so-called Multi-Spectral Imaging Camera System (MICS), which consists of three separate cameras, using filters for green, red, and near-infrared.

The satellite also carries the so-called Panoramic Camera, which has a wider field of view for large scale observations and public outreach. This system is based on a commercial off–the–shelf product.

The satellite will also monitor international ship traffic by receiving Automatic Identification System signals and combine this data with the MICS pictures.

For the search for Near Earth Objects, the satellite uses its Star Sensors.

Furthermore, a reconfigurable FPGA architecture is implemented as the Payload On-Board Computer.

In addition, the satellite features three GPS sensors, which shall allow for a precise determination of the position and attitude of the satellite.

The payload data is transmitted to the ground station using a ham radio S–Band downlink system featuring a custom designed directional antenna.

As part of the technology demonstration, an Optical Infrared Link System shall demonstrate high speed data downlink capabilities using an optical terminal which was developed by DLR.

SATELLITE SYSTEM

The structure of the Flying Laptop is designed as a hybrid structure consisting of integral aluminium parts and carbon fibre reinforced sandwich structure, specifically for stable alignment of the optical payloads.

The Thermal Control System consists of temperature sensors and heaters inside the satellite as well as Multi-Layer Insulation and radiators on the outside.

A de-orbit mechanism developed by the Tohoku University is stowed within the launch separation system until its deployment at the end of the satellite mission. The square sail provides a surface of 2.5×2.5m², increasing the atmospheric drag.

The communication system uses omnidirectional antennas to receive telecommands (TC) and transmit telemetry (TM) in commercial S-Band. The TM/TC packages are encoded in standard protocols according to the Consultative Committee for Space Data Systems (CCSDS). The ground segment uses ESA standard SCOS-2000 software to operate the satellite.

The Flying Laptop is three-axis stabilised with a total pointing error during one pass of less than 150 arcsec and a pointing knowledge of better than 7 arcsec. To achieve these values, state of the art star trackers, magnetometers and fibre optical gyros as well as GPS receivers are used for measurement; reaction wheels and magnet torquers are used as actuators. The Flying Laptop is not equipped with any means of propulsion or orbit control.

The satellite is powered by three solar panels equipped with triple junction solar cells. The Power Control and Distribution Unit provides an unregulated bus voltage of 19-25 V, collects housekeeping data and is able to process high priority commands.

A battery built of off-the-shelf Lithium-Iron-Phosphate cells accumulates the electrical power.

The On-Board Computer is implemented redundantly and consists of a core board with a state of the art LEON3FT processor, an I/O-Board which serves as a communication interface to all other systems and a CCSDS-Board to encode and decode CCSDS standard protocol data packets.

The On-Board Software is an in-house development programmed in C++. The modular, object-orientated software is compliant to International Satellite Communication Standards.

SIMULATION ENVIRONMENT

For the verification of the Onboard Software, careful testing of the flight procedures and the training of the operator team, a model-based simulator was setup at the IRS. This hybrid test bench is commanded via the On–Board Computer in the loop and allows for the simulation of the space environment. This also allowed cost effective testing of the Attitude Control System and will ease the analyses of failure cases during operation.

LAUNCH

The Flying Laptop satellite will be launched as a secondary payload with a Soyuz 2.1 launch vehicle from Baikonur. The launch window in Q1 2017 is defined by the Russian main passenger Kanopus-VI-K.

SATELLITE OPERATION

The LEOP-Phase will take up to 5 days, from the separation of the launcher until a first stable state of the satellite is achieved with all vital subsystems working and deployed solar panels.

For the following 2 months, all remaining components including redundancies and payloads are switched on and checked for their basic functionality.

After the Commissioning Phase, the nominal operation starts with the execution of the in-orbit verification of new technologies and with the scientific earth observation. The satellite is operated via the control centre and ground station at the IRS.

At the end of nominal operation, which is planned for 2+ years, the de–orbit mechanism unfolds a sail. The increased drag ensures that the Flying Laptop will be slowed down and burns up in the atmosphere.

FLYING LAPTOP TEAM

The FLP-team consists of Ph.D. students under the guidance of Prof. Sabine Klinkner. The team is supported by a number of students and the institute's electrical and mechanical workshops. Furthermore, industrial consultants supported the project with their expertise.

Fig. 2: Flying Laptop-team in 2015.

KEY CHARACTERISTICS

Dimensions	60×70×87 cm³
Mass	~110 kg
Attitude Control	3-axis stabilized Inertial, nadir & target pointing
Orbit	Sun-synchronous 600 km, LTAN 11:30am
Lifetime	>2 years
TM/TC	S-band
Data Downlink	S-band (ham radio)
Power Max.	270W
Launch	Q2 2017

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