PEGASUS – An Austrian Nanosatellite for QB50

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Abstract

The QB50 project is an international project with the goal of sending up to 50 Nanosatellites, a.k.a. CubeSat, into the Thermosphere. The thermosphere is a region of Earth's atmosphere at an altitude between 80 and 600 km. Albeit high up, it still determines our local and global weather. Recent scientific results seem also to inidcate that the processes occuring in the thermosphere are instrumental in understanding global warming. In spite of its importance the thermosphere is largely uncharted territory. Each of the 50 nanosatellites will be equipped with one of three possible scientific instruments: (i) a set of Langmuir probes, (ii) atomic oxygen measurement device, (iii) ion/neutral mass spectrometer. All satellites will be launched together and released in a string-of-pearls fashion. The QB50 mission offers measurement possibilities with an unprecedented spatial resolution and accuracy. The Austrian satellite PEGASUS will be one of those 50 nanosatellites. It is developed by an Austrian consortium consisting largely of students who work together with various experts from industry and research.

PEGASUS Mission

PEGASUS, together with the other 49 satellites, will be launched into a Low Earth Orbit (LEO). The sunsynchronous orbit with an inclination of ~98° and an altitude of ~400 km allows the satellites to monitor the polar regions inparticular.

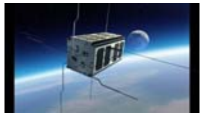

Fig. 1: Articistic depiction of PEGASUS in orbit

The primary mission goal of PEGASUS is a scientific one, namely to monitor over a period of up to nine months, the prevailing conditions in the thermosphere. For this PEGASUS will be equipped with so-called Langmuir probes in order to measure essential properties of the plasma in the Thermosphere such as the electron temperature and –density.

PEGASUS Team

In order to realize the PEGASUS project, the team formed consists of several different groups providing various expertises and various capacities (testing etc.). Under the leadership of the University of Applied Sciences (FHWN) and its research corporation FOTEC, the Spaceteam of the Technical University, the Austrian Space Forum (ÖWF) and the University Vienna are working together to develop PEGASUS.

PEGASUS Design

In order to ensure PEGASUS capability to fulfil its mission, PEGASUS requires almost the same types of subsystems as one would find on large-scale satellites. This includes an attitude control system, an on-board computer, telecommunication devices, an electrical power system allowing to harvest the solar power and a thermal control system – to name only some. In addition to the above, PEGASUS will also feature a propulsion system which would be the first time such a system is used on a nanosatellite.

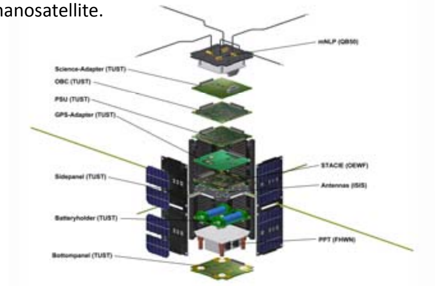

Fig. 2: Explosion drawing of PEGASUS

Structure

Although it is lightweight, the satellite structure must sustain the extreme vibration, shock (up to 2000 g) and noise environment (exceeding 140 dB) of a launch. In order to ensure that the structure can endure such loads, Finite Element Methods (FEM) were used during the design process of the structure.

Furthermore PEGASUS structural elements have dual use insofar as the parts of the structure contain magnetorquers which will be used to control the alignment of the satellite in orbit.

Thermal control

The thermal environment and the resulting thermal loads in a LEO orbit are as challenging as the mechanical loads.

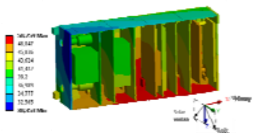

Fig. 3: Temperature distribution (hot case)

In the PEGASUS orbit one can expect surface temperatures between -60°C up to 120°C. Internal temperature will vary somewhat lower with -20°C up to 40°C. Beside the cyclical thermal loads resulting from this (up to 16 times per 24 hours), the internal electronics of PEGASUS have to be protected using MLI and heaters for particular sensitive elements such as the batteries.

On-board computer (OBS)

The PEGASUS OBC features a 32bit ARM microprocessor which can run with up to 120MHz. Furthermore it provides two redundant 1Gbit flash memories and the data can be downloaded via two redundant interfaces with the TT&C. The processor stores its program code inside its flash memory. A copy is also stored on a separate magnetic memory.

Fig. 4: Engineering models of the OBC and EPS

A radiation tolerant microprocessor is used as watchdog and programming controller. For safety reasons, the OBC is supplied via two redundant power lines with automatic switch over and latch-up protection.

Electrical Power System (EPS)

The Electrical Power Supply (EPS) unit harvests energy from the sun via photovoltaic cells. It features eight separate Maximum Power Point Tracker (MPPT). Utilizing converters with an efficiency of more than 95% more than 4A of continuous current at either 3.3V and 5V can be produced. The control and data collection of the EPS is handled by a central microcontroller which is supplemented by two redundant communication and backup controller which can maintain basic functionality even if the main controller fails.

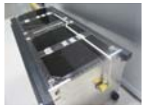

Fig. 5: Solar cells and Langmuir probes

Attitude Determination and Control System (ADCS)

The Attitude Determination and Control Subsystem uses embedded sensors (photodiodes , 3-axis magnetometers) and actuators (multiple magnetorquers) and a propulsion module (Pulsed Plasma Thruster - PPT) enabling rotation around x- and y-axis and translation heading towards +z. Furthermore a GPS receiver is utilized for accurate position determination and to synchronize the real-time clock. In addition a 3-axis gyroscope is being utilized for better rotation measurement.

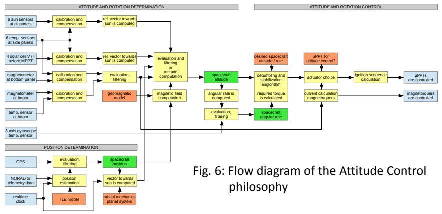

Fig. 6: Flow diagram of the Attitude Control philosophy

Telecommunication & Tracking System (TT&C)

STACIE-Δ (Space Telemetry And Command Interface) The Telemetry, Tracking and Control System (TT&C) of PEGASUS operates in the 70cm amateur radio band.

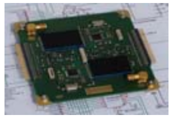

Fig. 4: Engineering model of the TT&C

It features two redundant transceivers with corresponding controllers on one board. Both transceivers can be powered and controlled independently.

A very unique feature is the possibility to remotely change the transmission frequencies from the ground station.

Propulsion System (PPT)

PEGASUS will feature a unique propulsion system, a so-called Pulsed Plasma Thruster (PPT). The propulsion system will provide a Δv of 3.4 m/s which, under optimum conditions, can extend the duration of the mission several months beyond the planed one. No nanosatellite has managed to fly such a system before.

Fig. 8: A PPT firing

Software development

The main tasks of the on-board software are the control of the satellite and the scientific payload, as well as the handling of science data and housekeeping. The software keeps a timeline, i.e. it processes time-tagged command batches which are uploaded from ground, but also has a high degree of autonomy. As the COTS hardware is not radiation resistant, the software concept is built around fail-safe measures.

The internal interfaces are also sensitive to unwanted external signals. Thus data acquisition and quality assessment is implemented in a dedicated software layer.

Acknowledgements

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