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THE COMPASS-1 PICOSATELLITE IN SPACE

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ABSTRACT

COMPASS-1 is the first spacecraft of the University of Applied Sciences Aachen, which was developed and managed by students from the department of space engineering. COMPASS-1 targets several mission goals, among those are the verification of: COTS devices in space, a GPS-receiver from the DLR and new developed analog sun sensors from the DTU Denmark. A small commercially available camera module is used as payload. It is taking pictures of the earth. COMPASS-1 is based on a modular system bus, whereby the active attitude determination control system is one of these systems. It is aligning the satellite nadir by using its magnetic coils to interact with the earth magnetic field. On the 28th of April the “Polar Satellite Launch Vehicle” (PSLV) launched COMPASS-1 successfully from the Satish Dhawan Space Centre in Sriharikota, India (SDSC-SHAR). The Mission Operation was conducted by our ground station in Aachen. Furthermore, a lot of amateur radio operators worldwide have participated (and still are) in this mission, also because of the fact that COMPASS-1 is transmitting in the radio amateur band.

1. INTRODUCTION

COMPASS-1 [*Fig. 1*] is the first satellite developed at the University of Applied Sciences Aachen (UoAS Aachen). The project was kicked-off in 2003, and was developed and managed by students from the aerospace department. It was not only seen as an excellent opportunity for the students to practice real satellite engineering, but furthermore, a lot of experimental payloads were implemented, such as new developed solar cells from RWE, LiPo-batteries, a modified GPS-receiver from the DLR and analog sun sensors from the DTU Denmark for the attitude determination. Also a small camera was embedded for taking pictures of the earth. The active attitude determination control system was utilized to align COMPASS-1 in space. Three magnetic coils are interacting with the earth magnetic field to align the CubeSat nadir. After the successful launch on the 28th April 2008 from India, the Mission Operation has been accomplished by students in our ground station at the UoAS Aachen. It has also been supported by amateur radio operators worldwide. In Aachen, we have been using six Yagi-antennas - for sending and receiving - on a rotor, which were mounted on the roof of the faculty building.

Fig.1

2. PAYLOAD

2.1 MOEMS Analog Sun Sensors

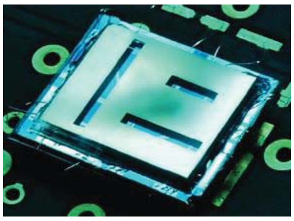

Fig.2

To determine the attitude of COMPASS-1 in space, a sun-sensor [*Fig.2*] is mounted on each side panel, except at the bottom side where the camera sits. These five analog sun sensors were designed and developed by Danish postgraduate students that worked on the DTUSat spacecraft. The COMPASS-1 mission was assigned to verify these new lightweight, small and power saving devices, which were based on the MOEMS technology. The sensors interface logic outputs a unit sun vector in the spacecraft body frame. This information is used by the ”Attitude Determination Control System” (ADCS) to determine and control the attitude, based on a magnetic actuation.

2.2 COTS Camera Module

Fig.3

COMPASS-1 also includes a small “commercial of the shelf” (COTS) camera [*Fig.3*], which is aligning nadir by the active attitude determination control system. It has been shown that it is also possible to utilize a low-cost COTS-camera for space applications. Furthermore, with a weight of 5g and a size of 10mm*9mm*7mm this device is well applicable for a small CubeSat. With this camera it is possible to take pictures of the earth with a surface area of 350km*450km and a resolution of 640*480 pixels. One picture has a data size of 300 Kbit. It is stored as raw-file in the memory of the “Command and Data Handling System” (CDHS). Due to the direct connection of the camera with the CDHS, an additional payload control system was not required.
With telecommands (DTMF-Tones) from the ground station, a picture can be requested from the satellite. After this command has been received, COMPASS-1 sends the raw picture file in data packages (AX.25) to the ground segment. With the aid of the ground station software these packages can be reassembled to a full picture. Afterwards, the obtained data can be calculated “colorful” by using the “Bayer-Pattern” method.

3. SPACECRAFT BUS

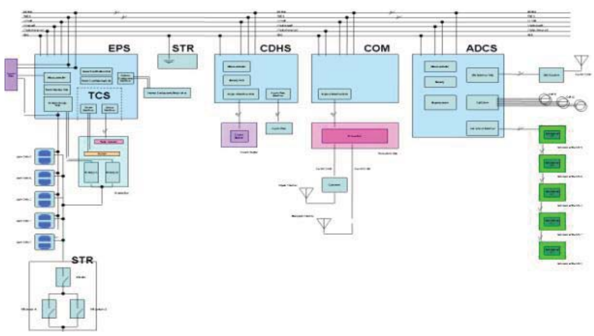

Fig.4

COMPASS-1 includes a modular spacecraft bus [*Fig.4*], i.e. every subsystem has got its own microcontroller and circuit board.
The CDHS was designed as a mainboard configuration in which the other systems were plugged in. The communication of the subsystems and also the data transfer is accomplished through an I²C bus. The energy is generated by ten Gallium-Arsenide solar cells and stored into the two LiPo-batteries by the charging-unit of the “Electrical Power System” (EPS). The “Power Distribution Unit” (PDU) distributes and monitors the energy consumption of the subsystems. In case of emergency, the PDU can switch off the ADCS, CDHS and the “active Thermal

Control System" (TCS) , which heats the batteries. Only the COM is not controlled by the PDU to keep on sending beacons. These beacons contain information about the energy status of the satellite. In case of less energy the COM can control itself to save power. The system is decreasing the transmitting-time of the beacons. In normal mode a beacon is transmitted every three minutes, but in power-safe only every eight minutes. The CDHS is saving the actual data of the whole CubeSat from the last 26 hours to have a long-time monitoring feasibility. The temperature range of the TCS, memory addresses in the CDHS and voltage ranges in the PDU can be set and manipulated with telecommands from the ground station.

4. GROUND STATIONS

Fig.5

To ensure the Mission Operation of COMPASS-1, students installed a ground station on the roof of the faculty building. The mounted antennas [*Fig.5*] are computer-base aligned to the passing by satellite. Four 70cm Yagi-antennas for downlink and two 2m Yagi-antennas for uplink were assembled with the help of professional radio amateurs to ensure an excellent radio communication. The telecommands are transmitted by DTMF-tones. The frequencies doppler-shift is corrected by the ground station software. The regular generated data of COMPASS-1 is decoded by a software emulated TNC and decoded by software from Mike Rupprecht. The packets include picture data, housekeeping data, attitude and GPS data. The beacon is transmitted in Morse Code. The TNC device decodes the incoming data into manageable information for further processing. By using amateur radio frequencies a worldwide network of amateur radio operators are participating in the Mission Operation of COMPASS-1. The global received data are collected at the Mission Operation center in the FH-Aachen for evaluation. To make sure a faultless Mission Operation, the COMPASS-1 Team has the feasibility to resort to a backup ground station in Tainan, Taiwan.

5. LAUNCH AND MISSION OPERATION

Fig.6

After the final tests of COMPASS-1 were completed, the spacecraft was delivered to the "University of Toronto Institute for Aerospace Studies - Space Flight Laboratory" (UTIAS SFL). The final integration of COMPASS-1 into the single XPOD and last vibration tests with the whole launch unit (spacecraft and XPOD) were accomplished. On the 2nd of April the spacecrafts arrived from Toronto at the Satish Dhawan Space Centre in Sriharikota, India (SDSC-SHAR). The final qualification tests of COMPASS-1 and its XPOD were achieved in the clean room. On the 28th of April, the Indian "Polar Satellite Launch Vehicle" (PSLV) launched COMPASS-1 and 8 other CubeSats successfully into a sun-synchronous polar orbit with an altitude of 630 km and an inclination of 98° [*Fig.6*]. After the first interpretation of the data from the circling COMPASS-1 in space some energy problems arose [*Fig.7*]. These caused a setting into emergency-mode and forced COMPASS-1 into hard-resets later. To avoid losing the spacecraft the heater-range from the battery-heater was decreased to cut down the energy consumption.

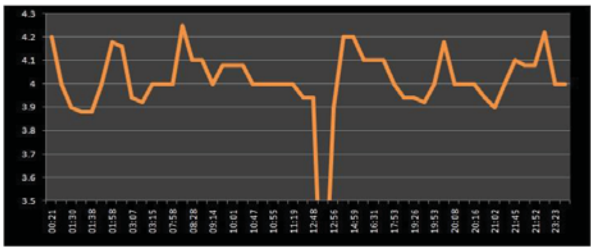

Fig.7

This activity was supported by ambitious amateur radio operators. The adjustments immediately showed improvements and now the Mission Operation is performing well. Now beacons, housekeeping data, GPS data, attitude data from the ADCS and pictures [*Fig.8*] are being received.

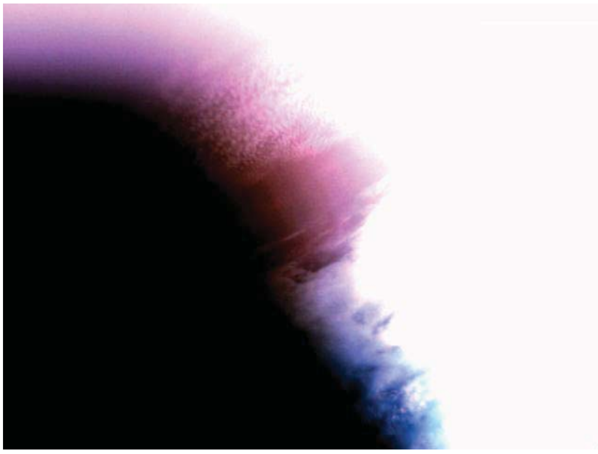

Fig.8

Due to the triggering of the data downlink rate from originally 1k2 (1200 bit/s) to 4k8 (4800bit/s) it is now possible to receive requested data considerably more quickly. Based on the worldwide network of amateur radio operators the contact times for downloading data have added and increased the data volume for evaluating and monitoring the spacecraft and also obtaining precious measurement data and pictures.

6. CONCLUSION

Looking back over the last few years and also in respect to the actual Mission Operation and the generated data during this time the COMPASS-1 can be indicated as successfully completed. Not only COMPASS-1 was an invaluable knowledge-gain in a “real spacecraft” project for the students, it also generated a lot of diploma thesis and student research projects. COMPASS-1 is also a knowledge base for further projects like COMPASS-2 (Triple CubeSat). The COMPASS-1 spacecraft is now continuously working in space since its launch, and continues to provide mission data and useful system information.

7. ACKNOWLEDGMENTS

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8. REFERENCES

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