COMPASS-1 PICOSATELLITE: STRUCTURES & MECHANISMS

Marco Hammer, Robert Klotz, Ali Aydinlioglu
Astronautical Department
University of Applied Sciences Aachen
Hohenstaufenallee 6, 52064 Aachen, Germany
Phone: +49 241 6009-1542, Fax: +49 241 6009-1542
marco_hammer@web.de, robert_klotz@hotmail.com, ali_aydinlioglu@yahoo.de

ABSTRACT

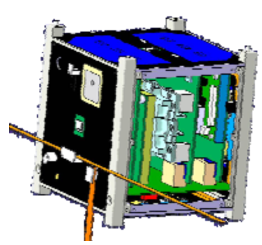
The experiences from the design and development of the spacecraft structure will be addressed in this paper. Basically, the structure must provide housing for the payload and the subsystems. A satellite structure normally appears to be subdivided in a primary structure that carries the spacecraft major loads and a secondary structure that supports wire bundles, propellant lines, non-structural doors and brackets for the components. Because the structure of a picosatellite had to be designed, it seemed advantageous to only consider one general structure. Yet the most important issues when designing a picosatellite structure is to constrain the mass to a minimum. To do so, the material thickness choice is a compromise between the necessary stability on the one hand and a feasible mass reduction on the other.

Therefore dedicated aerospace aluminum was used as raw material for the body frame of the spacecraft. Before that, first estimations based on calculations were done and then, a software-based static and dynamic analyses. Those proofed that the chosen material was really suitable. The paper will present the results of the analyses.

The model of the spacecraft and its mechanisms will be presented at the conference to give the audience an idea about the functionality of this system. The author wants to share his experience with others, in particular those that want to build their own CubeSats.

INTRODUCTION

COMPASS-1 is the name of the first picosatellite being developed at the Aachen University of Applied Sciences in Germany [1]. Since the projects' initiation in September 2003 it is being managed and carried out by students of different engineering departments, with a majority being undergraduate students from the Astronautical Department. The team has about ten members with an increasing number of new participants. The project focuses on a number of goals. Mainly the students will gain essential practical experience in realizing a research and development project from start to end. Moreover, an adequate infrastructure shall be created that enables more space engineering activities to take place at our university in the future. And definitively not least, a fully functional picosatellite is going to be built and finally launched into orbit!



The satellite is being built according to the CubeSat specification documents [2] published by Stanford and Calpoly University, which define a cubical structure with 10cm edges and a mass of not more than 1kg. Powered by solar cells, such a satellite will have an average of 1.5W for operation. Attempting to develop a spacecraft within the stringent constraints mentioned above becomes reasonable when considering the satellite being stored inside a container (P-POD) for simultaneous launch with other CubeSats, which in turn helps decreasing launch costs significantly.

The launch date of COMPASS-1 is scheduled for mid/end of 2006. The final development and qualification testing is scheduled for spring 2006.

OVERVIEW

Structure & Mechanism System Overview

Important key element of the structure design was the philosophy of modularity. Thus the COMPASS-1 structure was designed to be completely modular. In essence, it is a stand-alone frame structure which is covered with an alloy panel on each side. It provides mounting aids for PCBs and other parts. It can be disassembled and re-assembled quickly. Another advantage of the modular design is that the center of mass can be better positioned within the cube. In addition it facilitates the replacement of parts during test phase. The integrated mechanisms of the satellite follows the aspect to fulfill reliably its function under space conditions.

Structure Hardware Components

The different designs aspects of the hardware components are shown in the following. When designing the structure all relevant sketches and parts are in compliance with the Calpoly Cubesat Standards.

Frames & Beams

The focus has been on the frames. The frames are the most important parts of the structure. They take up all mechanical loads during launch and are used during the deployment out of the P-Pod. In addition they built up the platform for all integrated subsystem parts. The *Kill-Switch* mechanics and the Separation Spring mechanism are integrated into the frame. The four beams connected with the two frames build up the main body.

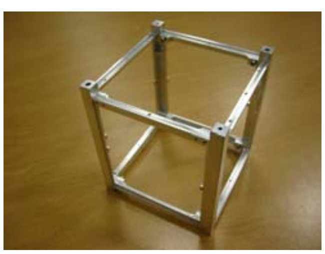


Fig. 1: Main Body

The parts of the main body are CNC-milled out of 6061-T6 aluminum blocks and are anodised.

Panel Design

The panels are designed multifunctional around the main body. The outer surface is in use for the solar cells, which are special glued directly on the panel. The panels also granted all holding possibilities for the sun sensors, magnetorquer, GPS Antenna; Communication antenna release mechanism; remove before flight pin, data access port and last but not least the solar connecting board. All panels are completely laser cut and black anodised.

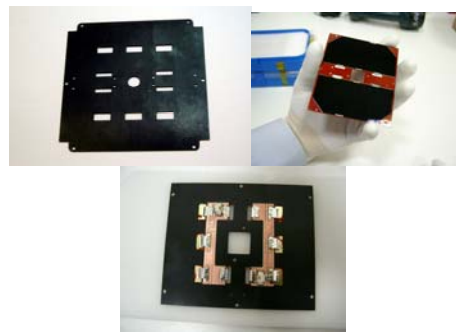


Fig. 2: Side Panels

Battery Box

The Lithium Polymer Batteries are COTS[1] and thus constructed for terrestrial operation. To prevent the bloat up of the batteries caused by the vacuum in space, it is required to protect it inside a container, which takes up all pressure loads. The box is designed in consideration of the loads; therefore it combines a high stiffness and a low mass.

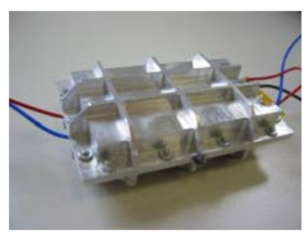


Fig. 3: Battery Box

[1] COTS = commercial off-the-self

Coil Holder

The coil holder allows an easy integration of the magnetorquer on the side panels. These are designed to fix the coils into a defined position; whereas the edges of the magnetorquer are in addition fixed with special glue.

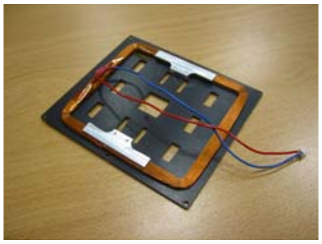


Fig. 4: Coil holder

GPS Board Holder

The GPS Board holder allows an easy integration of the GPS receiver on the ADCS PCB. The main design issue provides enough surface area for electronic components on the main ADCS PCB under the GPS. The GPS system is a Phoenix receiver board which is software modified by the DLR [3]

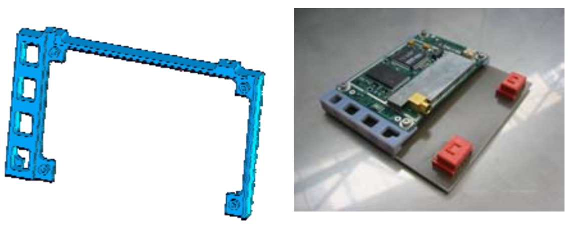


Fig. 5: GPS Board Holder

Camera Holder

The Camera Holder is designed to fix and align the Camera Module to the Structure. In addition it provides holding possibility for an adapter PCB to relieve the sensitive capton cable of the camera.
It is also, like near all other parts, milled out of aluminium.

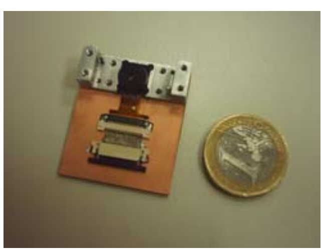
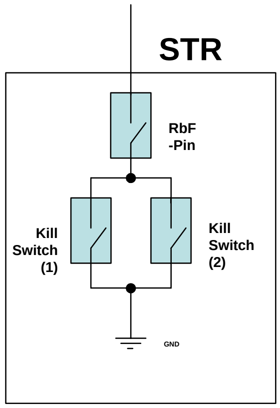


Fig. 6: Camera Holder

Mechanisms

Normally you have to avoid mechanisms and complex systems. Every mechanism enables new sources of errors. Because of service and security reasons, on the CubeSat, a few mechanisms are needed. Additionally the entire Structure is connected to power ground.



Kill- Switches

The *Kill-Switches* are for keep the system powered off during the launch. We use a simple spring mechanism which is integrated in the frame, combined with a micro switch. In detail the micro switch is a D2F-D1L micro switch from OMRON, which is recommended and tested in space by a Japanese Cubesat group.

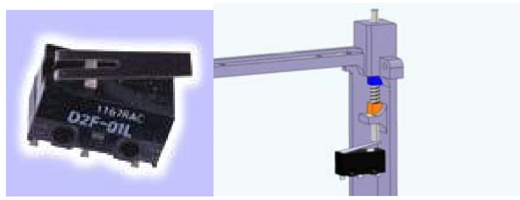


Fig. 7:Kill- Switch

We have one mechanic and one micro switch in each frame; so our *Kill-Switch* mechanism is fully redundant.

Antenna Release

We use an enfoldable antenna system with one monopole and two dipole antennas. During the launch, in the deployer the antenna system is packed and fixed with a nylon wire. In order not to interfere with the other satellites. When the satellite leaves the deployer, after a short time the nylon wire will be melt by an heating coil. And the antenna can unfold. To protect the batteries, a micro switch is integrated in the mechanism, to cut off the current from the heating coils when the nylon wire is melt.

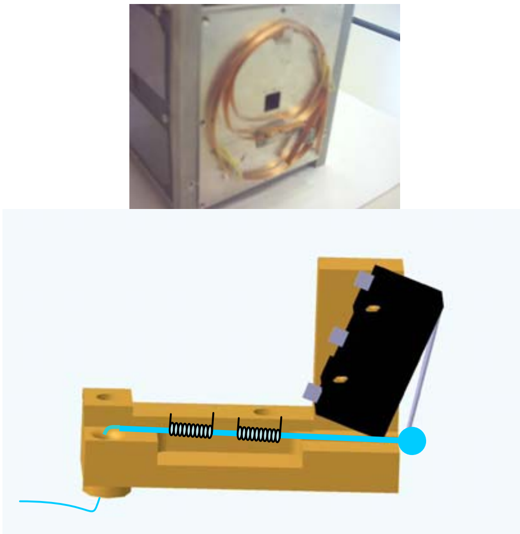


Fig. 8: Antenna release mechanism

Seperation Springs

The Separation Springs are screwed in into the frames. They separates the different Cubesats in the the deployer during launch and take up vibrations. We chose the spring plunger Model No# 84985A45 from Mc Master Carr Inc. which are recommended and tested by Stanford University.

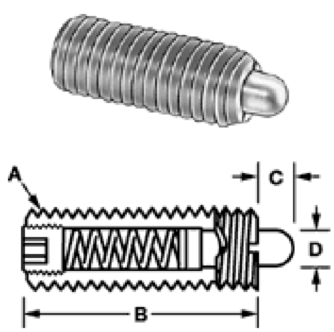


Fig. 9: Spring plunger

Remove-Before-Flight Pin

In our case it is not really a Pin to pull out but a slide switch with a very high self holding capability. It also can handle all current peaks and a mean current of 3A. Chosen is the miniature slide switch 25136NLDH from APEM.

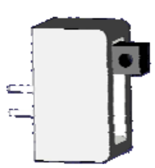


Fig. 10: Remove-Before-Flight Pin

Data Access Port

To assure access to housekeeping data or for software modifications and updates during phase of integration, while in the P-Pod, we use an Data Access Port. Chosen is a simple 8 pole mini DIN socket. Type 738359-V3

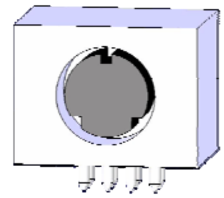


Fig. 11: Data Access Port

Simulation & Testing

The dynamic analysis and simulation of the CubeSat structure is to verify the structural integrity and localize weak points in the structure at an early design stage to prevent major modifications later. The structure of the satellite must assure integrity during the whole life cycle. Especially the high loads acting during the launch must be considered. A software-based analysis and simulation with appropriate programs is able to compute stress values under static load and behavior of the structure under dynamic loads. These computed values have to be in accordance with the material properties and the launcher requirements. The next step is going to the tests with real hardware.

Static & Dynamic Analyses with CATIA

A simulation based on the CATIA V5 software was able to calculate the first modal frequencies of the parts and the assembled structure, and maximal deflection and stresses under static loads.

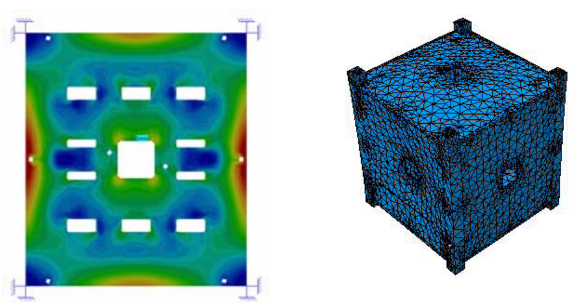
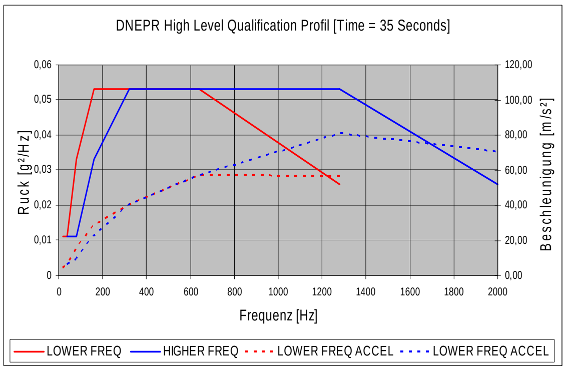


Fig. 12: Load simulation

All analyses are made with CATIA V5R13.

Vibration Tests on Shaker

Up to now, we carried out some shaker tests with the Side Panel solar cell assembly and the main frame. Diverse launcher scenarios, natural frequency and damping tests were simulated. Especial focuses are made on High and Low Level Qualification Profile tests from the DNEPR launcher.



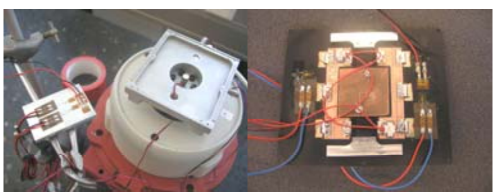


Fig. 13: Vibration Test Stand

More vibration tests, in particular with the full integrated engineering model will be conducted in order to provide results of qualification testing for possible launch provides.

SUMMARY

The model of the spacecraft and its mechanisms will be presented at the conference to give the audience an idea about the functionality of this system. The author wants to share his experience with others, in particular those that want to build their own CubeSats.

REFERENCES

[1] The Compass-1 Picosatellite Project at the FH Aachen. www.raumfahrt.fh-aachen.de

[2] Calpoly and Stanford University. (2003). ***CUBESAT Design Specifications Document***, Revision VIII. http://cubesat.calpoly.edu/

[3] DLR Homepage www.weblab.dlr.de/rbrt/