PEASSS – A NEW DESIGN APPROACH FOR SUCCESS OF CUBESAT MISSIONS

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Abstract Universities, small companies and space-enthusiasts have been the main users of the cubesat platform in the recent years because of several advantages such as: standardized parts (easy implementation), Off-The-Shelf Components (COTS) usage, short development time, "group" launches, low cost. On the other hand, cubesats' failures have been common due to lack of detailed design, analysis and testing.

In order to reduce the risk of the mission, the approach used in "bigger" space projects is implemented in the PEASSS design, including detailed thermal modelling with orbital and satellite life-time cases analysis, design of active/passive thermal control solutions, detailed structural modelling with launch environment cases analysis, qualification on breadboard and acceptance on flight model for vibration tests, thermal vacuum functional tests, correlation models.

The broader goal is to develop a cost- and resource-efficient approach applicable also for small-budget projects like cubesats and in the meantime increase the probability of success of the mission, allowing the in-flight verification of all the technology demonstrators on-board.

Keywords: nanosatellite, design approach, design, verification

1. INTRODUCTION

Trade-off analysis and worst case design approach are the usual design approaches used in space projects in order to guarantee that the design is able to withstand all the worst conditions (with margins) since the initial phases of the project (design). During the project development then, the selection of components and detailed test campaigns are used in order to verify the correctness of the design assumptions and the architecture defined. This approach is not easy to apply in the cubesat world because of low budget (resources and time) and selection of standard components (which are also the advantages of this platform).

PEASSS has as main objective the development, manufacture, test and qualification of "smart structures" including composite panels, piezoelectric materials and next generation sensors, including new nano satellite electronics, a piezo power generation system, a piezo actuated smart structure and a fiber-optic sensor and interrogator system.

In order to guarantee the success of the mission, a thermal and structural approach more sophisticated than the usual ones for cubesats, but not as the standard approach for "bigger" missions (due to: low budget, COTS) have been applied. They are described in the following sections.

2. THERMAL DESIGN, ANALYSIS AND VERIFICATION

The thermal subsystem is responsible for providing proper conditions for components within the spacecraft in order to withstand the mission lifetime conditions, keeping the temperatures of the elements within their thermal limits (operational or non-operational).

The spacecraft design is modelled and analysed with the usage of a thermal modelling tool (ESATAN-TMS) and implementing the necessary design changes if needed (e.g. change of the components' coatings, introducing heaters in the system). The design is then verified with the appropriate thermal test campaigns.

For PEASSS, special requirements from a thermal point of view are connected to the payloads and standard components selected creating sometimes opposite requirements: the power generator (mounted on an external panel for example requires, to operate with best performances, high delta-T, on the other side the interrogator unit has a component inside (light-source) which requires a very stable temperature (delta-T < 0.1°C) and within a narrow operative delta-T (10°C).

The main objective of the thermal subsystem design is to fulfil all the requirements with a passive thermal control approach (coatings, paints, materials…) in order to reduce as much as possible the power requirements of the subsystem.

Considering the many uncertainties during the design phase of the project (no launcher selection, unknown final orbit reached…), an analysis of the mission cases looking for the worst conditions (form a thermal point of view) was performed in order to guarantee to withstand all the possible lifetime conditions and the robustness of the design (Figure 1 and Table 1). This information was also merged with data about the operative modes of the satellite, allowing a worst cases analysis trade-off (Table 2).

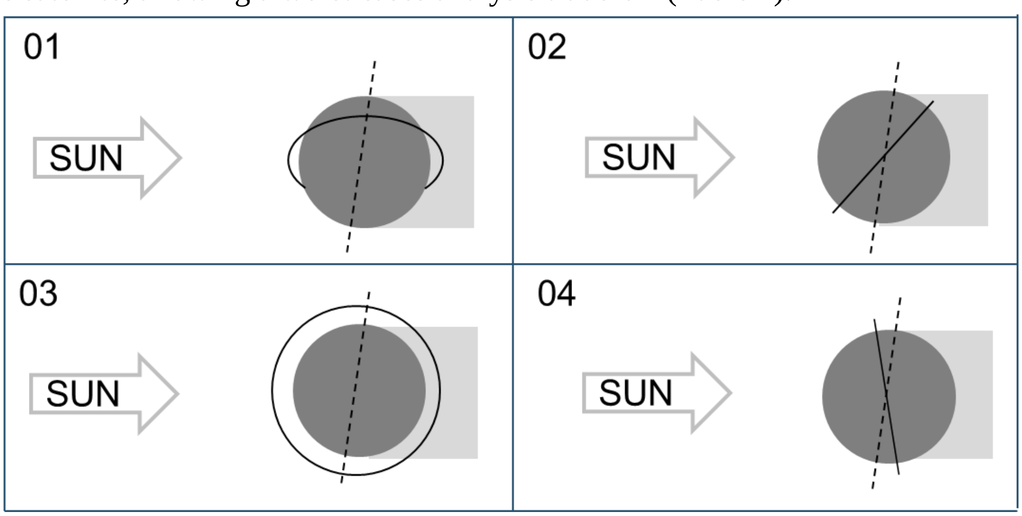


Figure 1 Orbits analysed in the trade-off

Orbit no.	Inclination [°]	Right ascension [°]	Eclipse duration [min]
01	51	0	35.5
02		90	26.8
03	97.8	0	35.5
04		90	0

Table 1: Orbits analysed in the trade-off - description

Case	Case ID	Comments
Hot case	C01	Hottest conditions; Orbit no. 04
Cold case	C02	Coldest conditions; Orbit no. 01
Safe Mode	C03	Coldest case with minimum power dissipation
Launch	C04	Conditions just after launch; SC in orbit with 30 minutes eclipse duration; all components OFF

Table 2: Cases analysed

Moreover, two different attitude modes were taken into account during the analysis: satellite spinning around the Z axis and tumbling satellite (assumed for analysis 3 different rotating rates, 2°/s, 3°/s and 4°/s per axis.

The analysis results showed the spacecraft is able to survive in all conditions defined, with components within their operational or non-operational limits.

To verify part of the obtained results and improve the thermal modelling, a functional thermal vacuum test of the interrogator was performed. The test included the investigation of the temperature distribution within the payload instrument and functional check on the light-source measurements. The test results have been later correlated and included in the improved thermal model of PEASSS, allowing the characterization of COTS for which limited technical information was available.

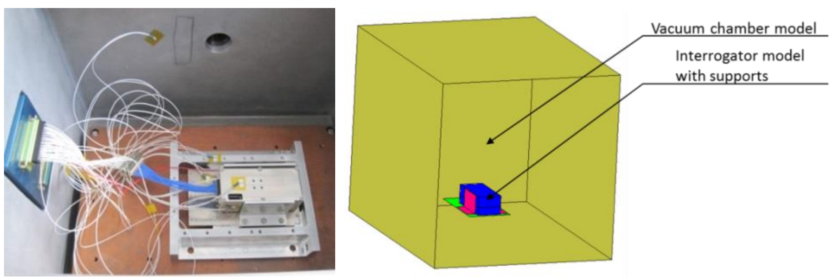


Figure 2 Functional thermal vacuum test of the interrogator and correlation model

3. STRUCTURAL DESIGN, ANALYSIS AND VERIFICATION

PEASSS has a modular structure which is composed by a combination of frames and ribs. While most of these parts are standard for the manufacturer, some others are customized for this particular project. On the other hand, the mission main payloads are tailored for PEASSS and need special attention. This is even more critical considering that they include not only metallic parts, but also composites and piezo-electric materials. The following payloads are included in the structural modelling.

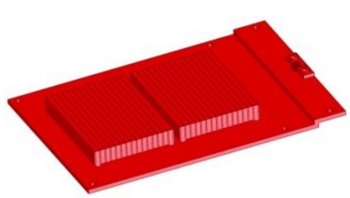
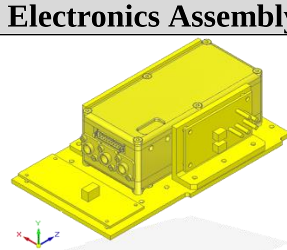
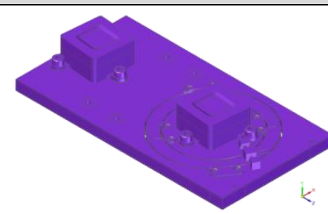
Power Generator	Interrogator and Other Electronics Assembly	Optical Bench
		

Figure 3: Mission payloads in PEASSS

The intended model philosophy for PEASSS is SQM+FM (Structural Qualification Model + Flight Model). This implies that two sets of system level tests are carried out: a qualification campaign in a structural qualification model, and an acceptance campaign in a flight model. In addition, testing at equipment level is also performed in order to reduce the risk of failure for some sensitive payloads. This approach allows the team to gain confidence in the reliability of the design, and it reduces the risk of overtesting flight units, increasing the probabilities of mission success.

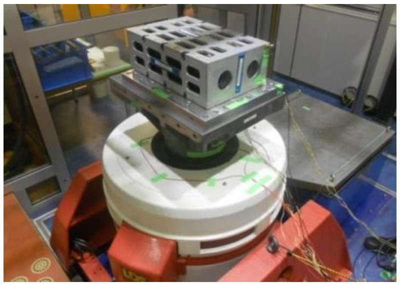


Figure 4: PEASSS inside 6U deployer during vibration qualification campaign

In order to support the structural design and testing tasks, detailed FE simulation is performed. In particular, a FE model was developed so as to do the following tasks:

- calculate margins of safety and failure indexes for stresses;
- calculate modes and resonance frequencies of the system;
- calculate modes and resonance frequencies of the payloads;
- define the location for sensors during the vibration campaign;
- perform trade-off of different launch systems.

The mathematical validity of the model was verified by following the guidelines from the ECSS standards [1].

4. CONCLUSIONS

The approach adopted for PEASS allowed obtaining a thermal and structural design of the satellite able to withstand the possible conditions on-flight.

In particular the test campaigns helped identifying the critical points of the design (components used not space qualified, interfaces unknown…) and implementing the necessary design modifications and optimizations.

The vibration campaign on the SQM proved the ability of the system to withstand qualification loads for the launch campaign (also in an early stage of the project).

5. REFERENCES

[1] ECSS-E-ST-32-03C(31July2008) – Structural Finite Element Models