Appendix H

PEASSS
New horizons for cubesat missions

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(Active Space Technologies GmbH, Germany)

Abstract

A cubesat is a type of miniaturized satellite for space research with external volume starting from 10x10x10cm3 (1U) and multiples of it (2U, 3U...). The cubesat platform is well-known to the academic researchers, small space companies and space amateurs, because of:

- standardized parts and interfaces;
- off-The-Shelf Components usage;
- "group" launches.

For these reasons, universities, small companies and space-enthusiasts have been the main users of this platform in the recent years. On the other hand, cubesat losses because of internal failures, not detailed design and analysis have been common.
PEASSS is a 3U cubsat under development as part of a FP7 European Commission project involving Active Space Technologies GmbH, TNO and ISIS (Netherlands), SONACA (Belgium), Technion and NSL (Israel). The main objective of the project is to develop, manufacture, test and qualify "smart structures" which combine composite panels, piezoelectric materials, and next generation sensors, for autonomously improved pointing accuracy and power generation in space. The system components include new nano satellite electronics, a piezo power generation system, a piezo actuated smart structure and a fiber-optic sensor and interrogator system.
The approach chosen for the design of PEASSS allows to combine the advantages of the cubesat platform to the complexity of the mission (technological demonstrator), achieving the mission success, technologies TRL step-up, while reducing the risk of the mission. This objective is achieved by increasing the level of analysis/verification of the whole satellite and the payloads/subsystems "like a non-cubesat mission", including:

- detailed thermal modelling with orbital and satellite life-time cases analysis;
- design of heaters and other active/passive thermal control solution;
- acceptance on breadboard and qualification on flight model for vibration tests;
- thermal vacuum functional tests;
- correlation and automatized correlation models;
- qualification thermal vacuum tests at payload level;
- acceptance thermal vacuum tests at satellite level.

The whole satellite thermal design and analysis are performed in Esatan-TMS and using AST's internally developed "model runner" and results "post-process" module.


PEASSS
New horizons for cubesat missions
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Luca Celotti
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making space a global endeavour
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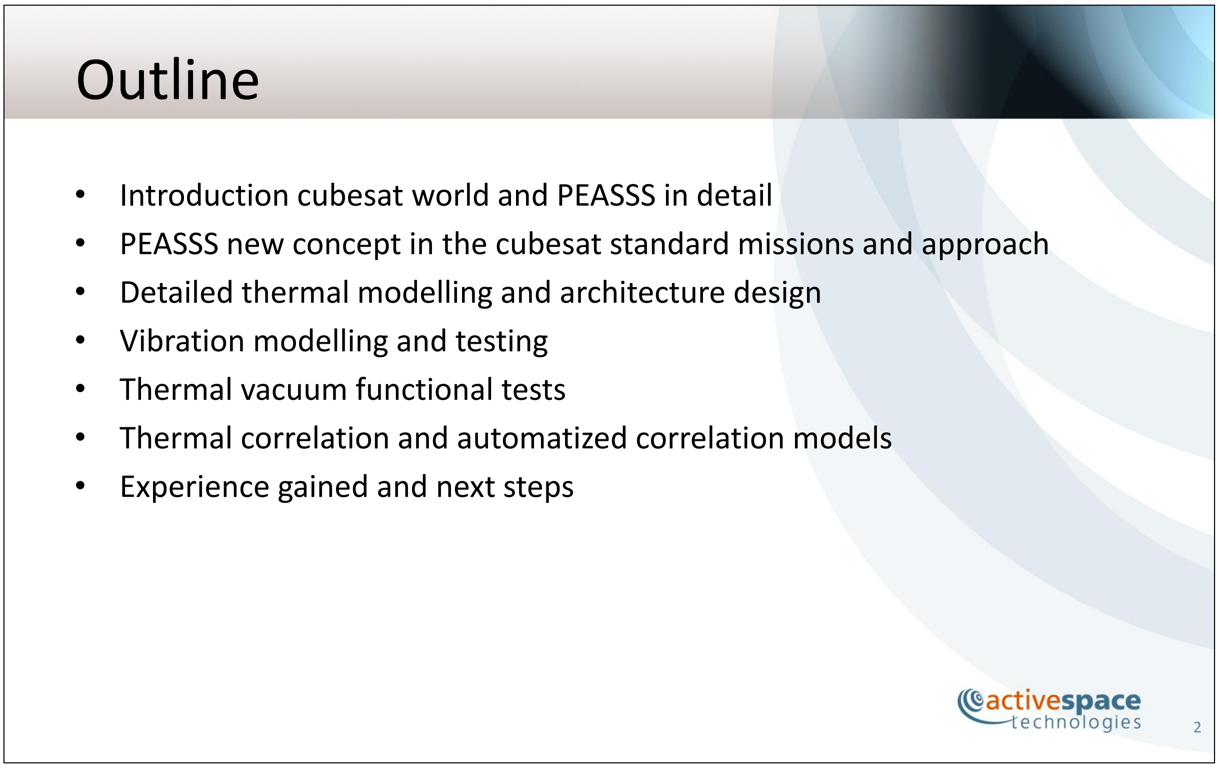
Outline
• Introduction cubesat world and PEASSS in detail
• PEASSS new concept in the cubesat standard missions and approach
• Detailed thermal modelling and architecture design
• Vibration modelling and testing
• Thermal vacuum functional tests
• Thermal correlation and automatized correlation models
• Experience gained and next steps
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Introduction - Cubesats

A cubesat is a type of miniaturized satellite for space research with external volume starting from 10x10x10cm^3 (1U) and multiples of it (2U, 3U…).

The cubesat platform is well-known to the academic researchers, small space companies and space amateurs, because of:

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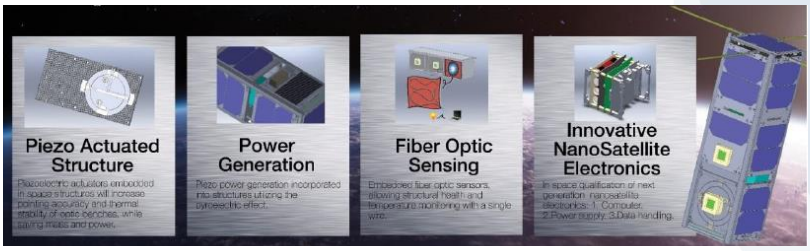
Introduction - PEASSS

PEASSS is a 3U cubsat under development as part of a FP7 European Commission project involving Active Space Technologies GmbH, TNO and ISIS (Netherlands), SONACA (Belgium), Technion and NSL (Israel).



SEVENTH FRAMEWORK PROGRAMME

The main objective of the project is to develop, manufacture, test and qualify “smart structures” which combine composite panels, piezoelectric materials, and next generation sensors, for autonomously improved pointing accuracy and power generation in space. The system components include new nano satellite electronics, a piezo power generation system, a piezo actuated smart structure and a fiber-optic sensor and interrogator system.

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Introduction - PEASSS “new” approach

The approach chosen for the design of PEASSS allows to combine the advantages of the cubesat platform to the complexity of the mission (technological demonstrator), achieving the mission success, technologies TRL step-up, while reducing the risk of the mission.

This objective is achieved by increasing the level of analysis/verification of the whole satellite and the payloads/subsystems “like a non-cubesat mission”:

- Orbit modelling and trade-off
- Satellite attitude study
- Thermal cases evaluation
- Detailed thermal modelling and analysis (ESATAN-TMS) with worst-cases approach
- Detailed thermal design (taking into account the constraints of the mission)
- Structural analysis, vibration test for EM before acceptance for launch
- Thermal vacuum functional tests of payloads
- Thermal vacuum tests of payloads and system

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Detailed thermal modelling

Orbit and cases trade-off:

- Hot and cold cases evaluation taking into account the possible orbits PEASSS can have (depending on the launch).
- Two orbits have been considered:
  - 51° inclination, year period with the longest and the shortest eclipse duration (right ascension 0° and 90°)
  - SSO with 97.8° inclination, also with two sub-cases (longest and the shortest eclipse duration)
- Both orbits have altitude of 600km.

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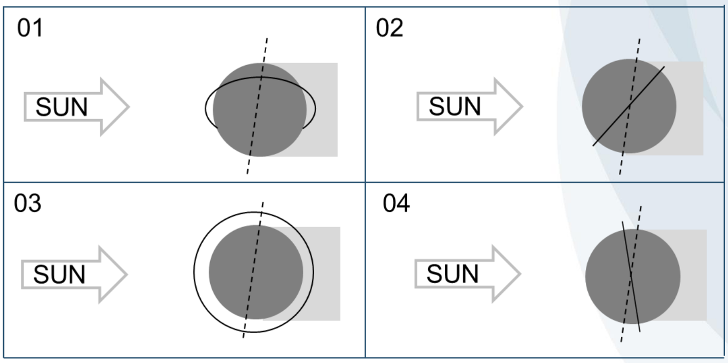
Detailed thermal modelling



Orbit no.	Inclination [°]	Right ascension [°]	Eclipse duration [min]	Case no.
01	51	0	35.5	CC01
02		90	26.8	CH01
03	97.8	0	35.5	CC02
04		90	0	CH02

Cold case chosen

Hot case chosen

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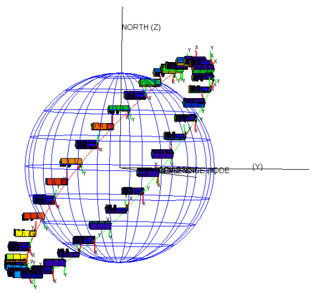
Detailed thermal modelling

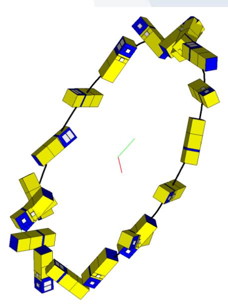
Spacecraft attitude: two attitudes evaluated during the development of the project

Spinned satellite

- Rotation around „Z“ axis

Tumbling satellite





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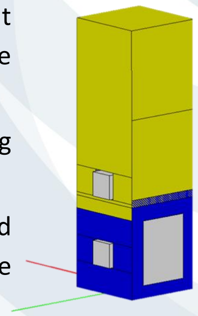
Detailed thermal modelling

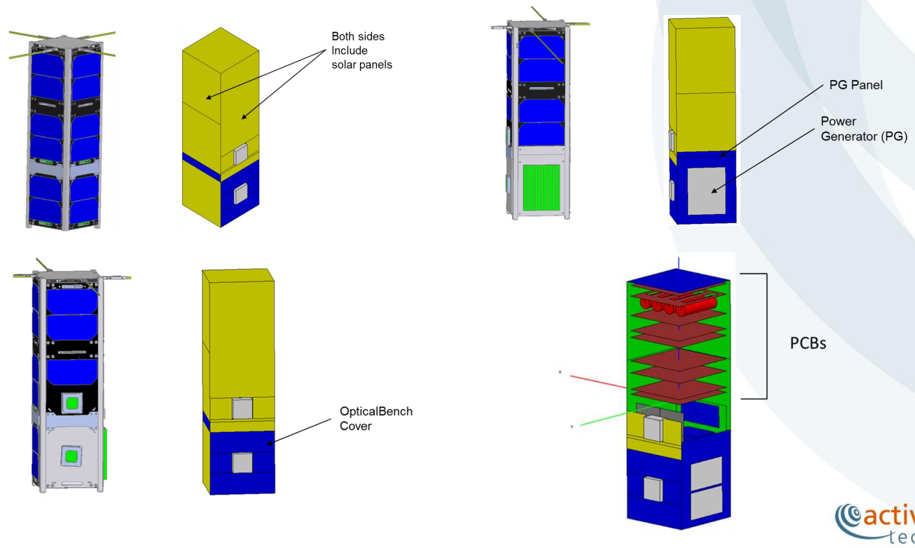
Thermal cases definition in order to cover all possible operative modes of the satellite:

- **Hot case (C01)** - case with the hottest environmental conditions (orbit without eclipse). During the whole orbit payload instruments could operate with a pre-defined duty cycle.
- **Cold case (C02)** - case with the longest eclipse duration. Only during sunlight the payload components can operate.
- **Safe Mode (C03)** - the case with the longest eclipse (as C02) when payload components are not operating and the power dissipation within the spacecraft is as low as possible -surviving mode-.
- **Launch (C04)** - it covers the initial part of the mission, in the worst case scenario (ejecting form launcher in eclipse). Initial temperatures of all components are 15°C and the spacecraft is completely OFF during the maximum duration eclipse (35min).



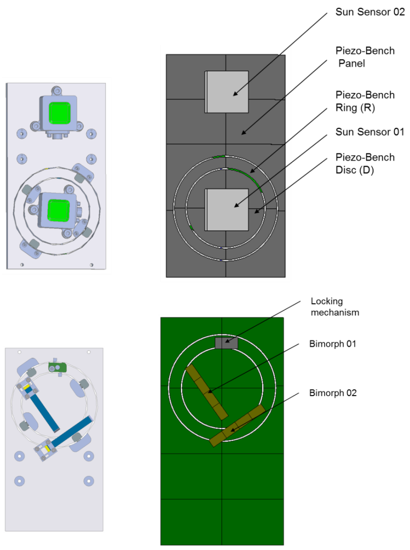
Detailed thermal modelling

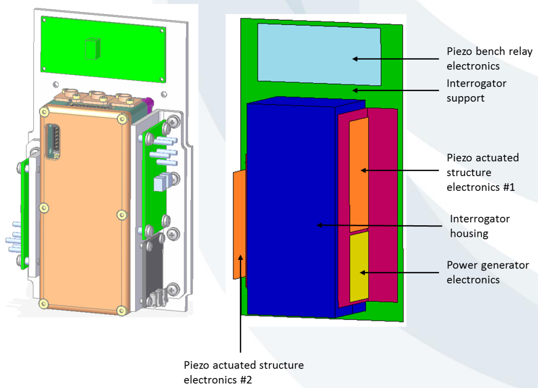
→ From CAD to ESATAN model



Detailed thermal modelling

→ From CAD to ESATAN model – payload components





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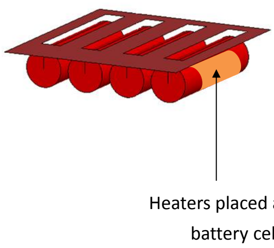
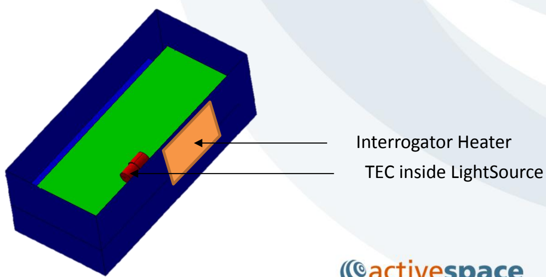
Architecture design - initial approach

- Passive thermal control preferred:
  - Internal and external coatings
  - Mechanical interfaces through the structure and the external panels modelled (insulators if needed)
  - Contrasting requirements form system (components within the temperature limits) and some of the payloads (power generator: maximize the deltaT on the payload panel -also satellite panel and so impacting on it-)
- Active thermal control elements:
  - Heaters on the battery cells (4 heaters, each placed on different cell)
  - Heater on the Interrogator housing – in order to increase the temperature of the payload during operations
  - TEC component inside the LightSource component – to provide stable temperatures during the component's operations





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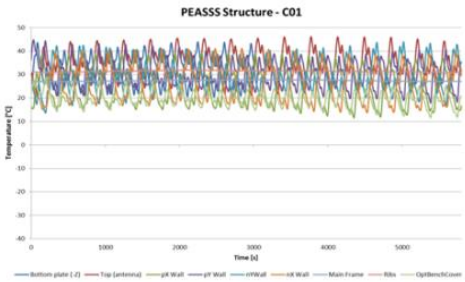
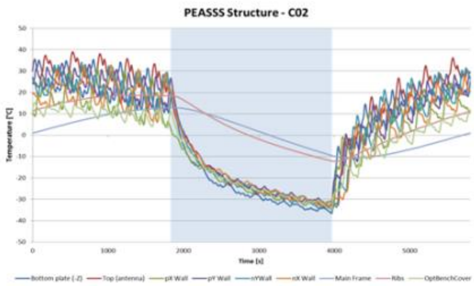
Thermal Results





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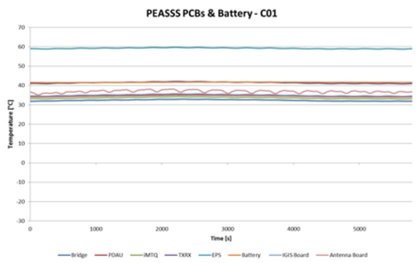
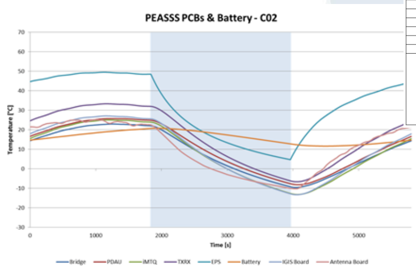
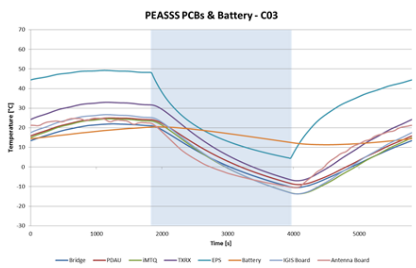
Thermal Results

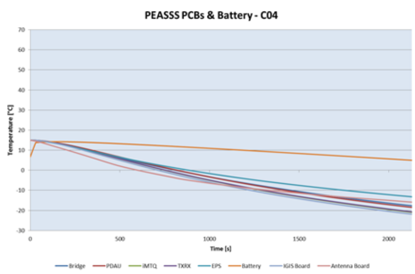
Results of the simulation show that the components are within their thermal limits.

		Temperatures [°C]					
Component		Non-operational min	Operational min	Operational max	Non-operational max	Maximum calculated	Margin to max
Battery		Always on	-5	45	Always on	41.8	3.2
EPS		Always on	-20	60	Always on	59.7	0.3
On Board Computer (OBC)		-30	-20	60	70	49.6	10.4
PDAU		-30	-20	60	70	35.2	24.8
ISIS TXRX		-30	-10	60	70	42.1	17.9
Antenna module		-50	-30	70	85	38.1	31.9
Bridge Board		-30	-20	60	70	32.9	27.1
IGIS board		-50	-30	70	85	35.8	34.2
iMTQ Board		-50	-40	70	85	34.3	35.7
Structure	Ribs	-50	-40	80	90	32.0	48.0
	Frames					27.8	52.2
	pX panels					39.5	40.5
	pY panels					44.8	35.2
	nX panels					41.2	38.8
	nY panels					44.0	36.0
	Top					44.0	36.0
	Bottom					46.2	33.8









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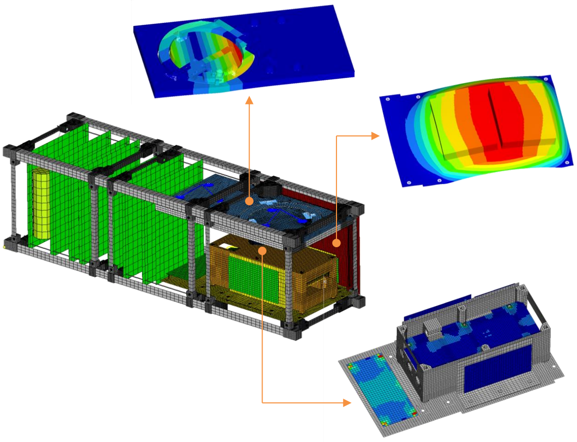
Vibration modelling and testing

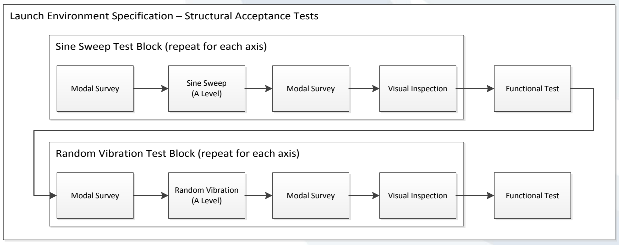
FE Simulation

- Dynamic characterization
- Strength analysis

Testing

- SQM+FM Philosophy
- Test-Analysis correlation





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Thermal vacuum functional tests

In order to investigate the thermal behaviour of the interrogator, a thermal vacuum test has been performed in AST facilities.

The objectives of the test were:

- to collect data for thermal model correlation and reduce the thermal modelling uncertainties
- to verify whether the provisions for cooling and heating are sufficient and in correspondence with the simulations
- to check whether the interrogator perform within specifications over the specified temperature range.

Testing took place in AST facilities in Berlin, Germany.

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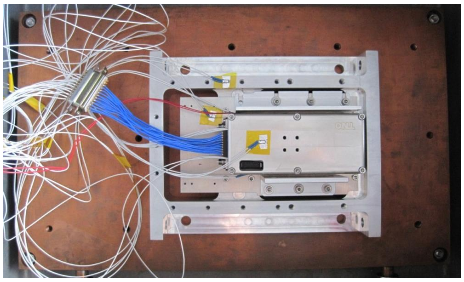
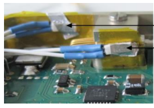
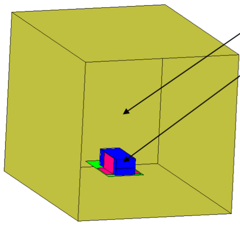
Thermal vacuum functional tests

Sensors installation and thermal modelling of the test assembly and cases tested.







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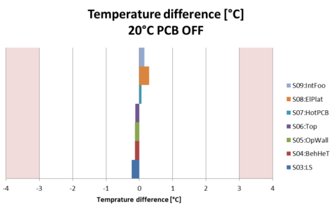
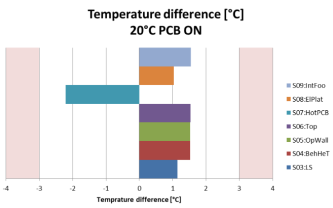
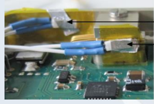
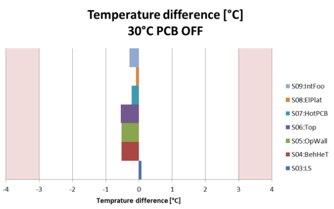
Thermal test correlation

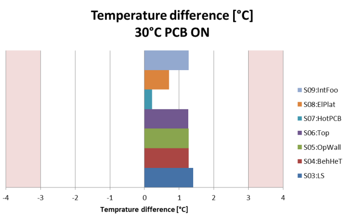
The results of the thermal vacuum test of the interrogator have been correlated with the thermal model developed (manual correlation).











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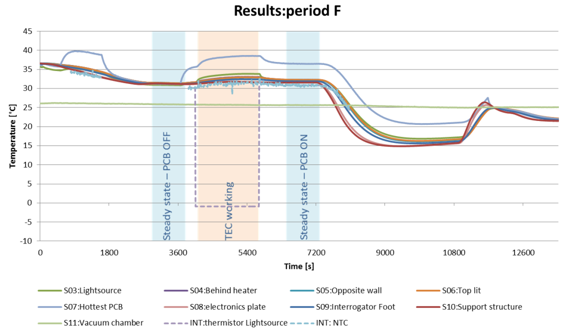
Thermal test correlation

Conclusions:

- the thermal model representing the test was correctly correlated
- the payload performed well in every vacuum conditions (“low” vacuum level, but COTS used, not space qualified components)
- unexpected thermal behaviour of the light-source:
  - COTS component (never used previously in space applications), but verified in vacuum via this test
  - internal thermal interfaces of the light-source unknown



Design (hardware) changes

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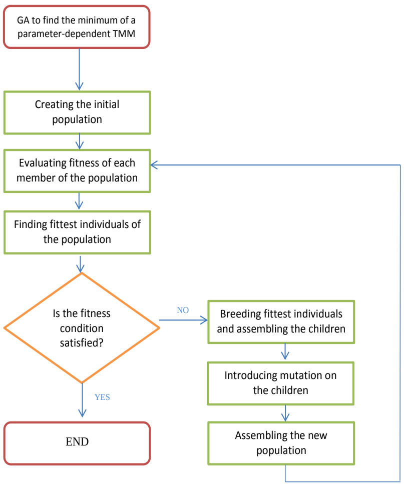
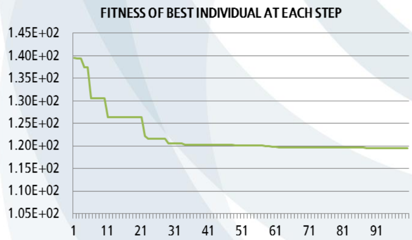
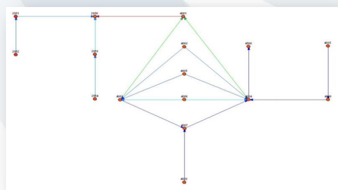
Automatized correlation models





P01	GL_PANEL_RIB
P02	GL_SUPP_INERR_01
P03	GL_SUPP_INERR_02
P04	GL_INTERR_PCB_01
P05	GL_INTERR_PCB_02
P06	GL_INTERR_PCB_03
P07	GL_INTERR_COVER_01
P08	GL_INTERR_COVER_02
P09	GL_INTERR_SUPP_01
P10	GL_INTERR_LS

GL



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Experience gained and next steps

Conclusions:

- the cubesat world is a promising one also in terms of detailed modelling and analysis
- cubesat missions are continuously growing in popularity and complexity
- “bigger” satellites thermal design approach can fit to cubesat missions increasing the mission success
- detailed analysis and tests performed for PEASSS allowed to implement changes in also in the design to assure better performances and mission success

Next steps:

- Implementing a qualification-acceptance path for the payloads and the whole satellite, both for thermal and structural aspects

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Thank you for the attention!

For further information, please visit our website

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