Cubesat mechanical and thermal testing tutorial

Presentation · February 2016

DOI: 10.13140/RG.2.1.3759.4649

1 author:

Dario Hermida
European Space Agency
3 PUBLICATIONS **0** CITATIONS

SEE PROFILE

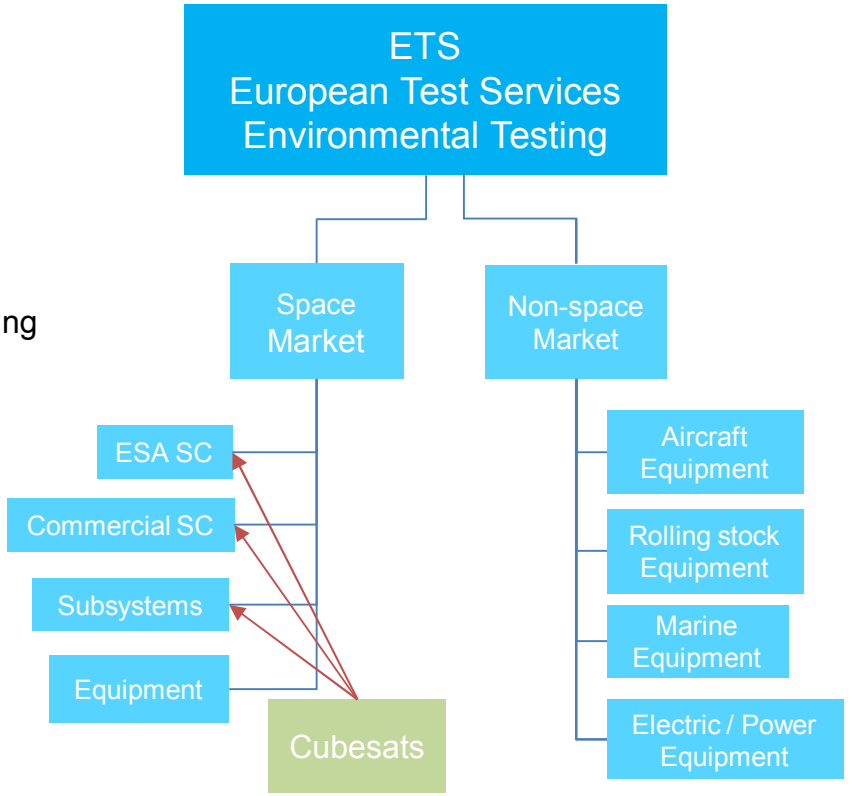
ets european test services

Effective approach to Cubesat environmental testing Mechanical and Thermal

28/02/2016

Dario Hermida
dario.hermida@esa.int
European Test Services (ESA-ESTEC)

Tutorial index



Introduction to environmental testing

ets european test services

1.1.- Fundamentals and effective approach

- Environmental as part of the design process
  - Contribution to phase A, B.
  - Thinking ahead.
  - Foresee challenges.
- Environmental testing standards
  - MIL-STD-810
    - Mostly practical.
    - Full of examples.
  - ISO/TC 108
    - Nice technical approach.
    - Not for free.
  - IEC 60068
    - Not space focused.
    - Plenty of examples.
  - ECSS
    - Difficult to find what you need.
    - ECSS-E-HB-32-20 Part 7A (2011)
      - Nice start.
      - Full of references for thermal and mechanical.
      - Already superseded, but fine anyway.
- Realistic and effective approach

ets european test services

1.1.- Fundamentals and effective approach

- Realistic
  - Being realistic is not nice.
  - Being realistic is tough.
  - Being realistic is usually appreciated years after.
- Effective approach
  - Low budgets
  - Consider testing subsystems before assembly of your Cubesat.
    - Many examples of detecting an early failure.
    - Strongly recommended when developing a new idea using non-flight hardware.
  - Save your efforts for:
    - Acceptance mechanical and thermal tests for your Cubesat.
- Time
  - Mechanical tests usually a matter of 1 day.
  - Thermal tests usually a matter of 5 days.
  - Environmental tests average preparation time for a Cubesat is X months.
    - X can be <1 month with facilities booked, prior experience from facilities operators and Cubesat's team.
    - X can be >6 months facing a full Cubesat test campaign.
    - X is usually expected around 3 months on average, and not easy to achieve.

ets european test services

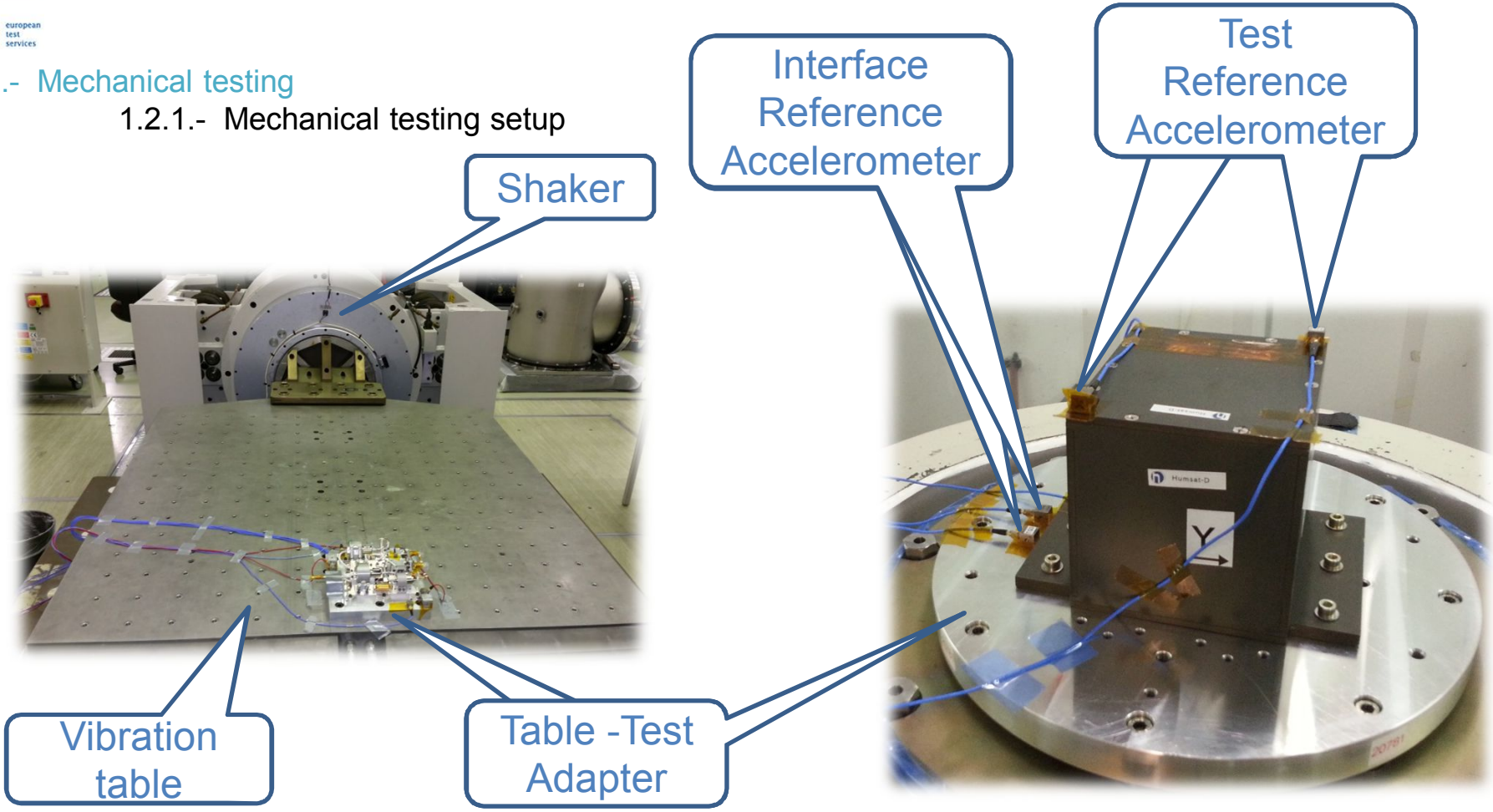
1.1.- Fundamentals and effective approach

- Consider outcome data
  - Early thermal testing on Electrical Power System.
  - Early mechanical testing on Antenna Deployment System.
  - Early platform testing
    - Doubtful data to be used as a reference for the mission.
    - All teams are getting involved in the design process.
- Re-use of data/tests/qualification for future missions.
- This tutorial:
  - It is NOT comprehensive.
  - It is an overview based on:
    - Experience on Cubesat design.
    - Facility operators experience.

ets european test services

1.2.- Mechanical testing

1.2.1.- Mechanical testing setup

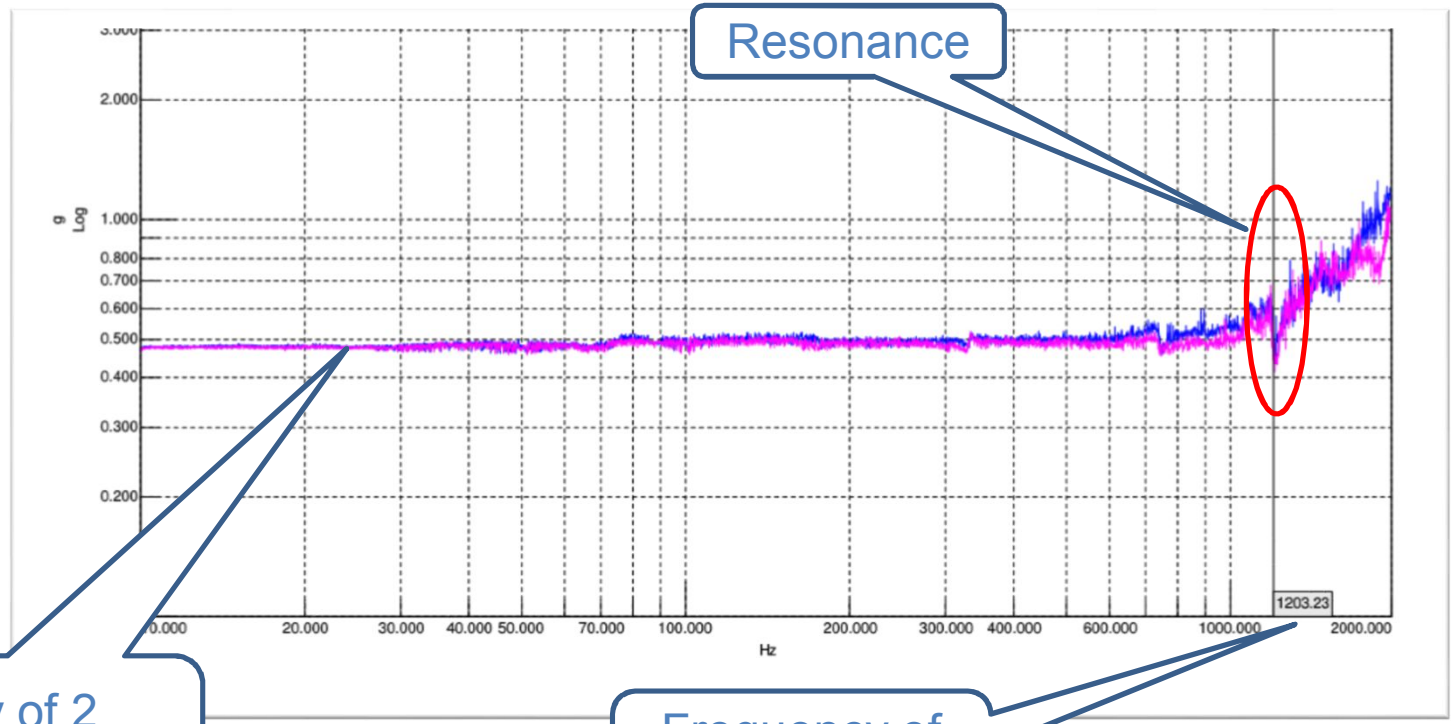


ets european test services

1.2.- Mechanical testing

1.2.2.- Resonance search

- First thing you should do. It is used as a reference for further testing.
- Use a low level input (*0.5g is fine*) and low sweep speed (*1 oct/min*).
- It is usually a sine vibration, but random is also fine.
- It defines how your Cubesat behaves to vibration vs frequency.

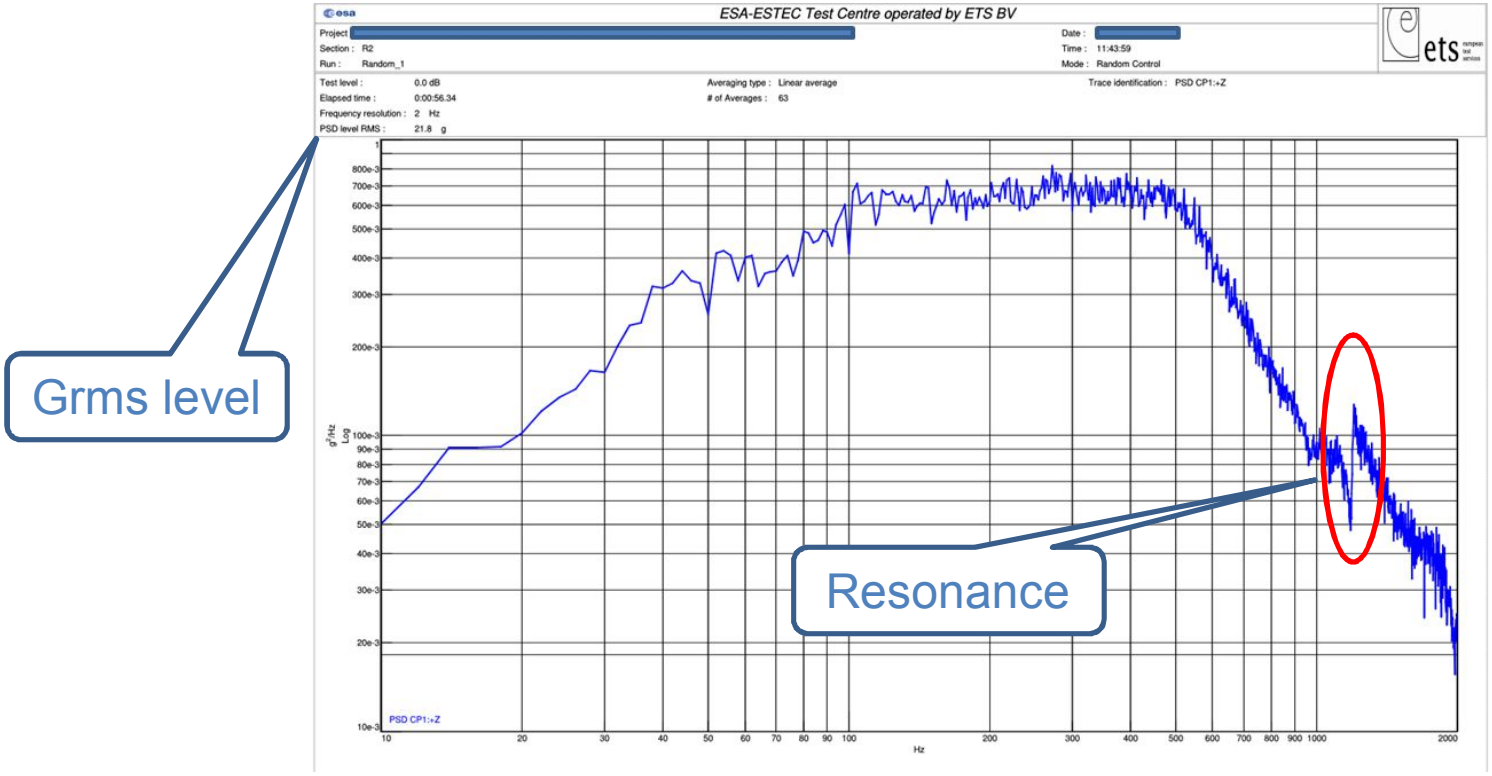


ets european test services

1.2.- Mechanical testing

1.2.3.- Random vibration

- Usually mandatory for flight acceptance.
- Really scary if you do it for the first time.
- Usually done between 20 to 2000 Hz during 60 s.
- Typical maximum Grms = 25 g

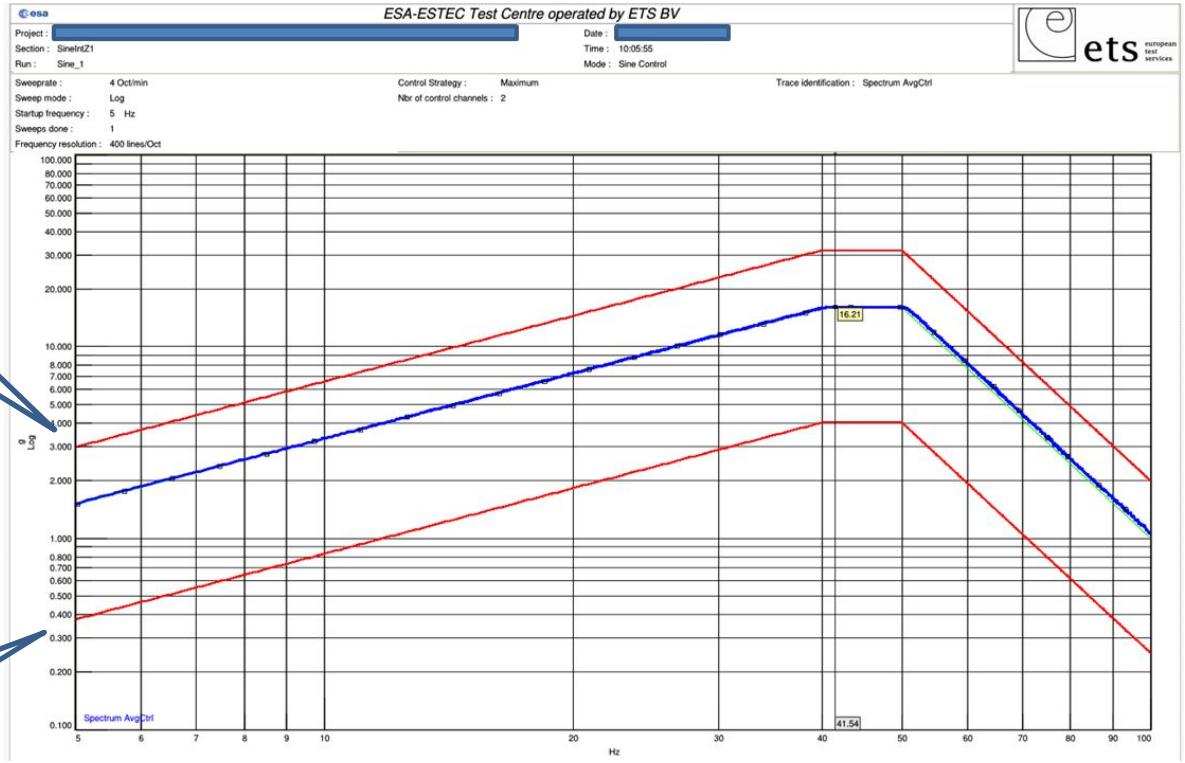


ets european test services

1.2.- Mechanical testing

1.2.4.- Sine vibration

- Same principle as Resonance search.
- Higher amplitude, usually up to 20g.
- Typical sweep goes from 5 Hz to 100 Hz, 4 oct/min.
- Resonance might appear highly amplified.

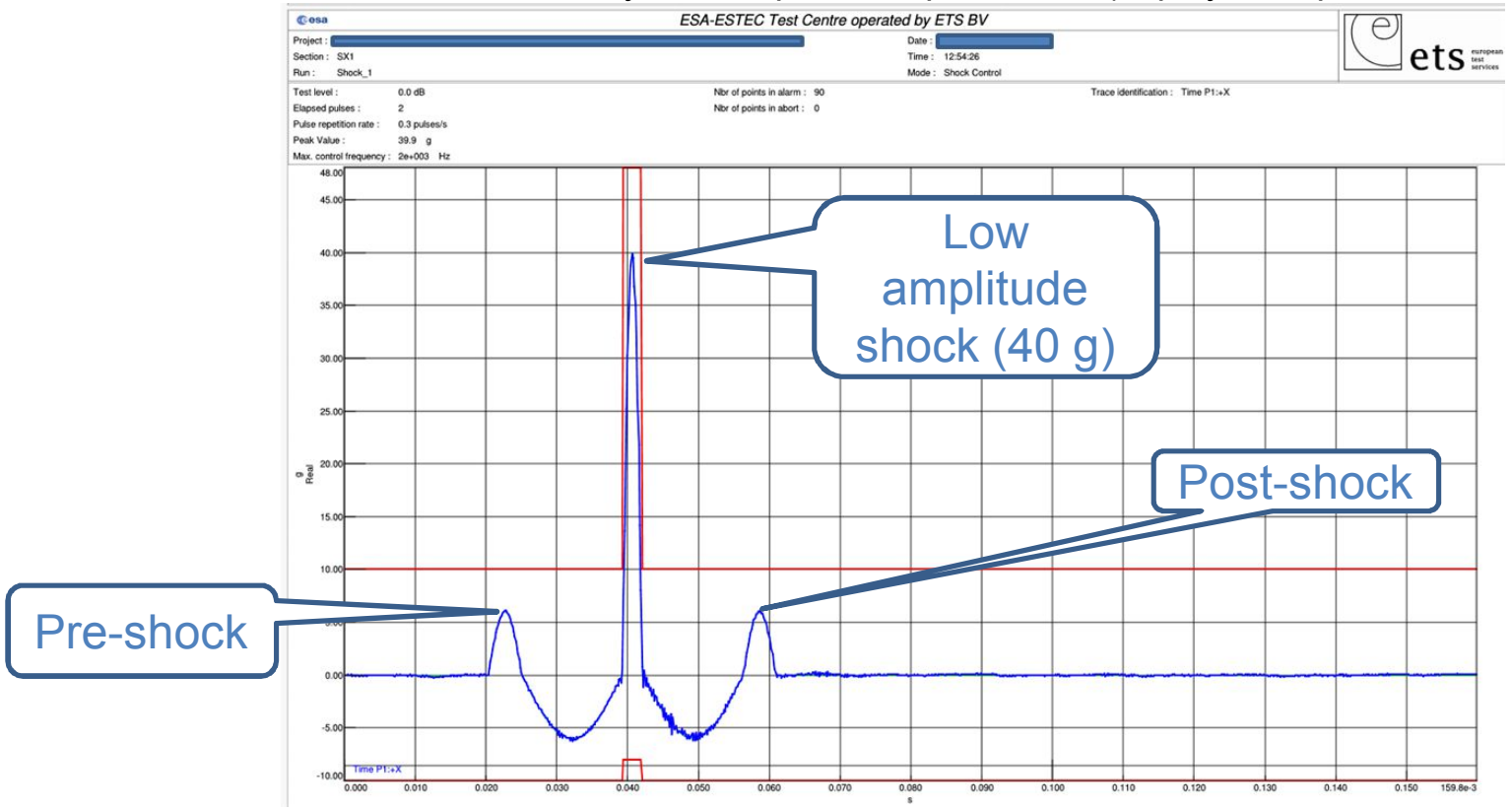


ets european test services

1.2.- Mechanical testing

1.2.5.- Shocks

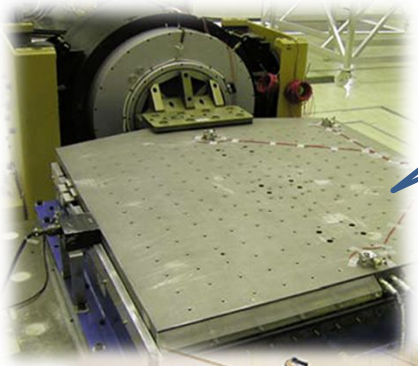
- Usually not mandatory.
- High amplitude shocks (> 100 g) difficult to setup.
- Your Cubesat will not like the idea of repeating this test.
- Consider them only under special requirements (deployment panels, heavy components).



ets european ecsc services

1.2.- Mechanical testing

1.2.6.- Example: European Test Services facilities

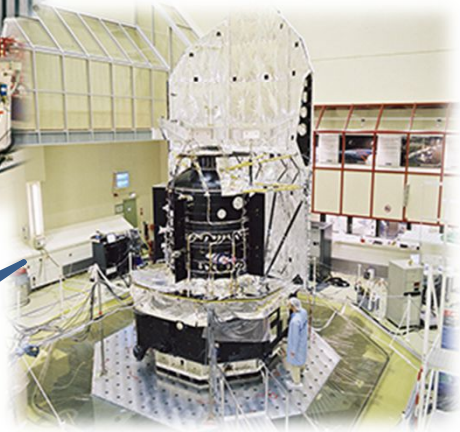


Small Shaker

Acoustic Chamber

Multi Shaker

Quad Shaker



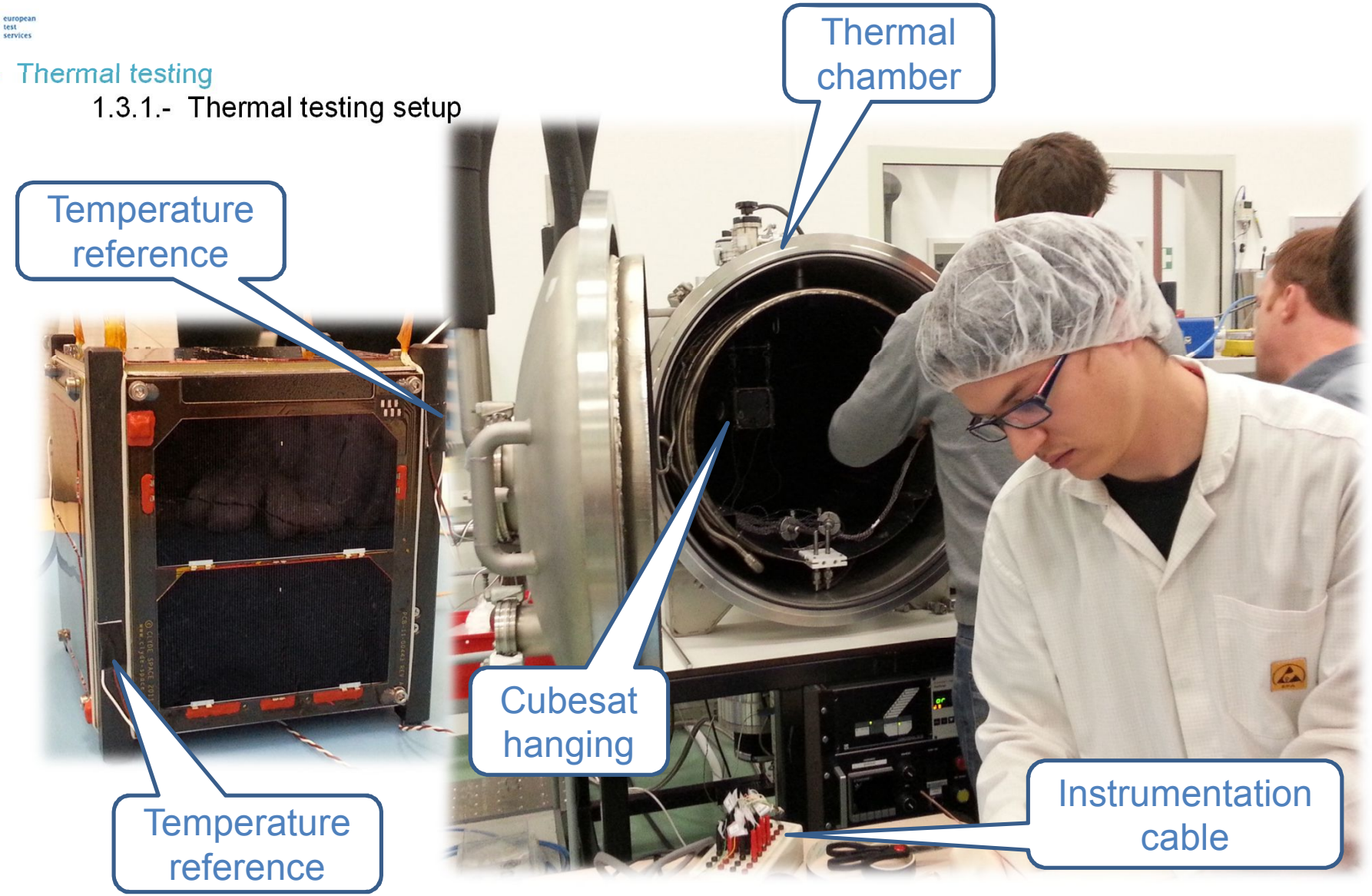
Hydra

Quad Shaker

ets european test services

1.3.- Thermal testing

1.3.1.- Thermal testing setup

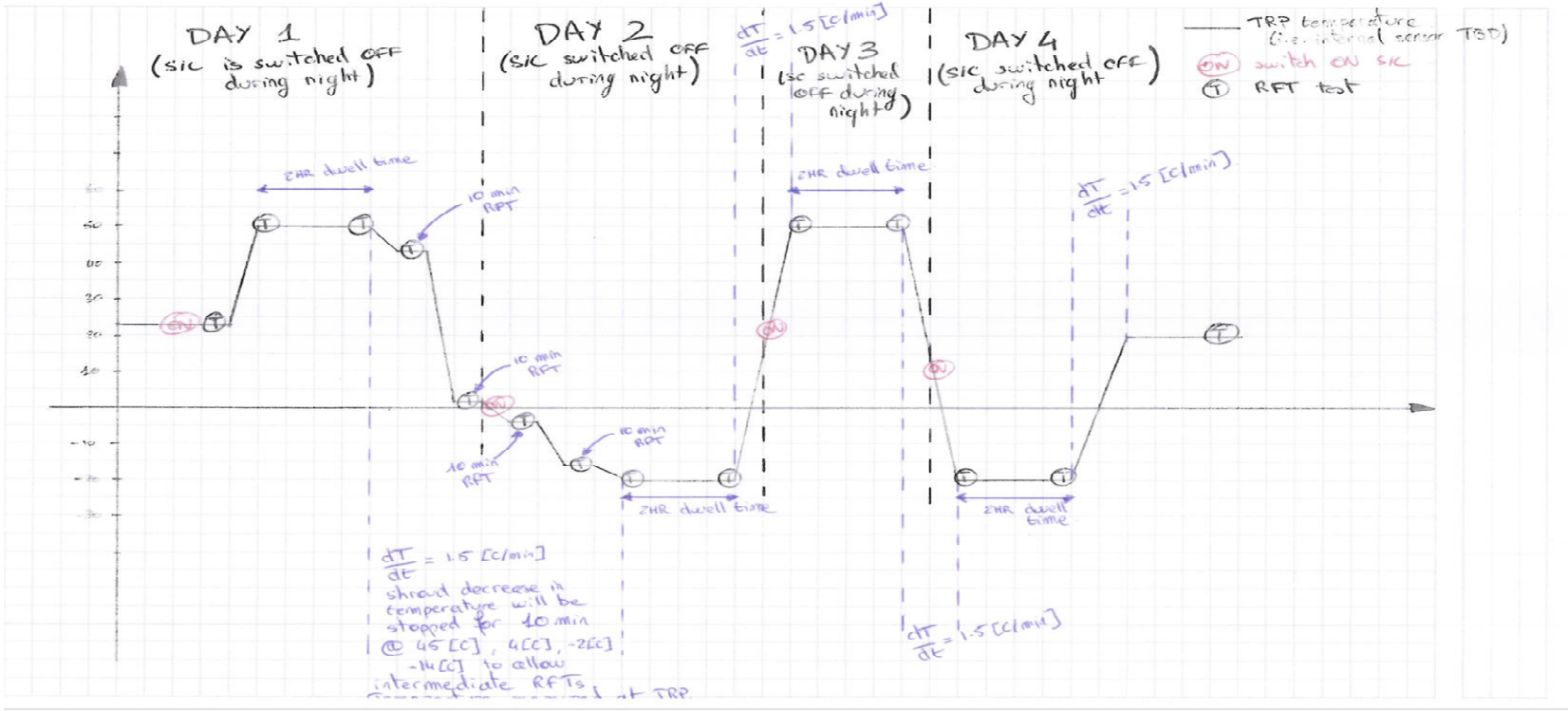


ets european test services

1.3.- Thermal testing

1.3.2.- Bake-out and Thermal vacuum cycling

- Bake-out is used to “clean” and prepare your Cubesat for vacuum.
- Mandatory in most launchers (Dnepr, Vega, Falcon-9, etc.).
- Mostly mandatory for your Cubesat’s mission.

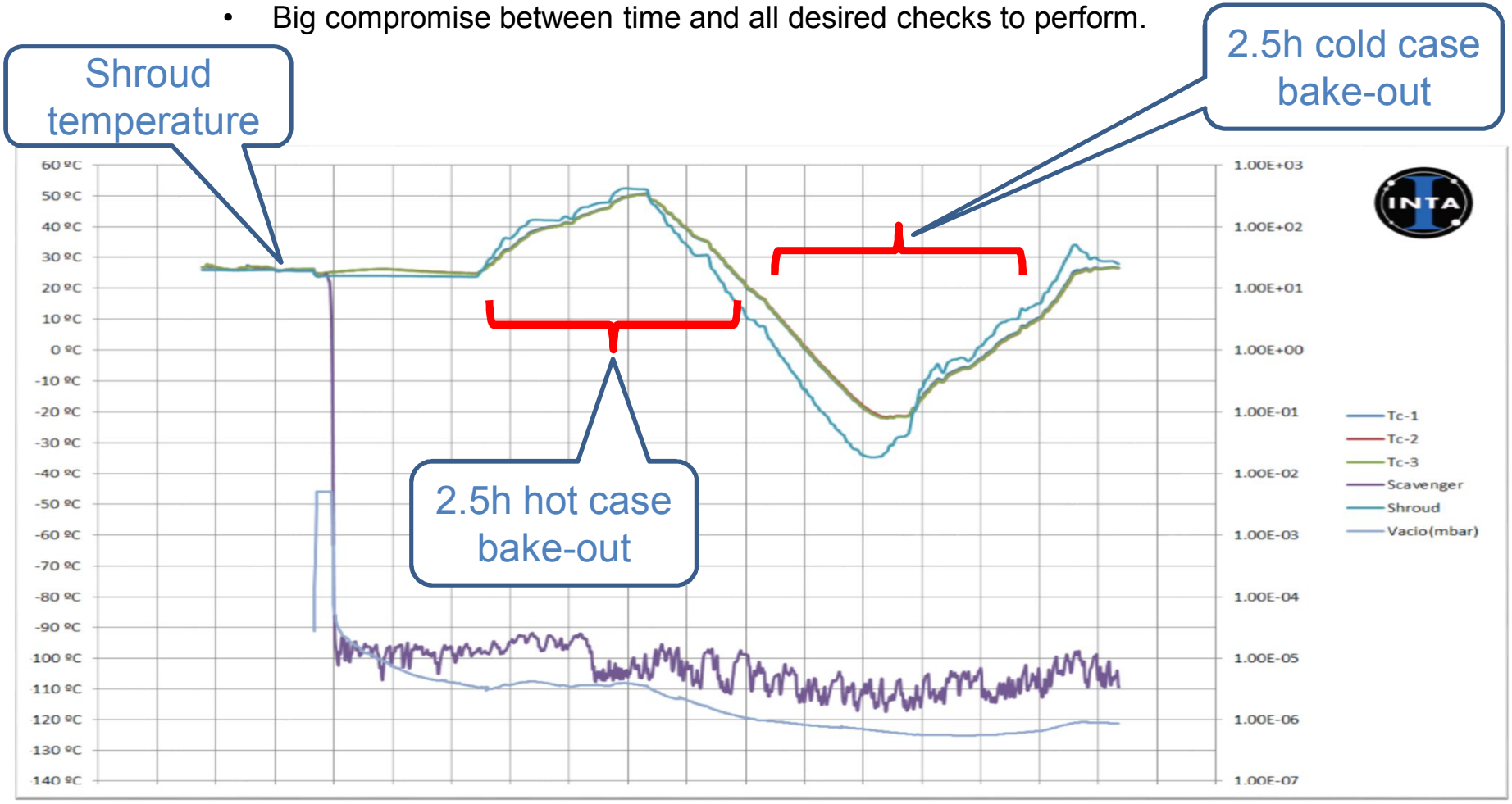


ets european test services

1.3.- Thermal testing

1.3.2.- Bake-out and Thermal vacuum cycling

- 1 Hot cycle and 1 Cold cycle should be enough to validate your hardware.
- Big compromise between time and all desired checks to perform.

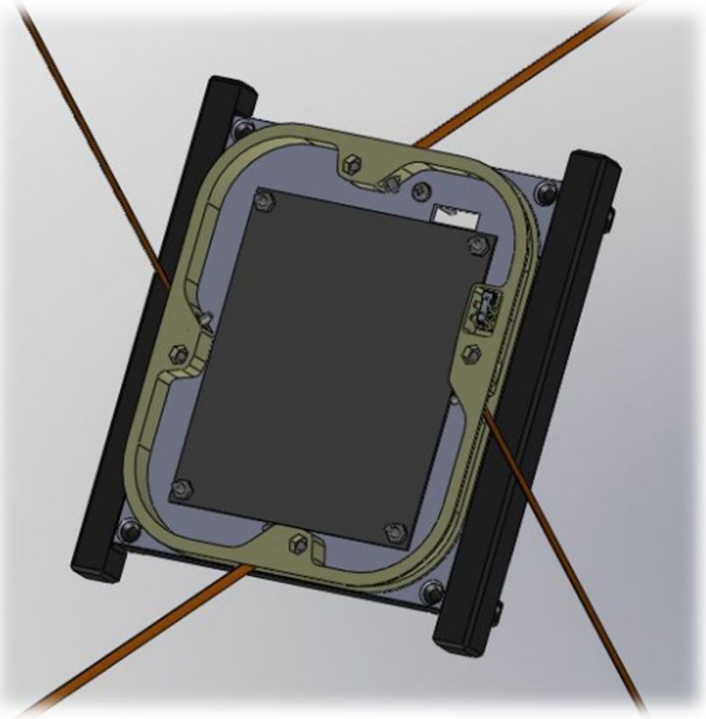


ets european test services

1.3.- Thermal testing

1.3.3.- Ambient pressure thermal

- Thermal testing without vacuum.
- Cheaper than previous options.
- Can be really useful on early phases of the design for subsystems.
- Antenna Deployment Mechanism for Xatcobeo Cubesat:
  - More than 5 ambient pressure thermal tests during development.
  - 2 deployments under full vacuum cycling.



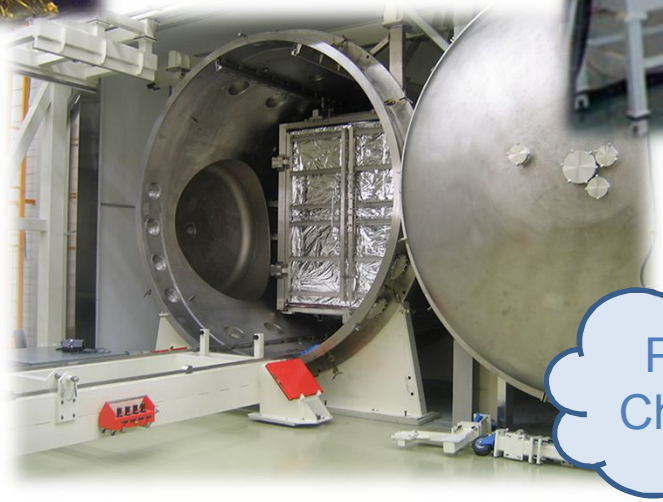
ets european test services

1.3.- Thermal testing

1.3.4.- Example: European Test Services facilities

Large Space Simulator

VTC 1.5



Phenix Chamber

ets european test services

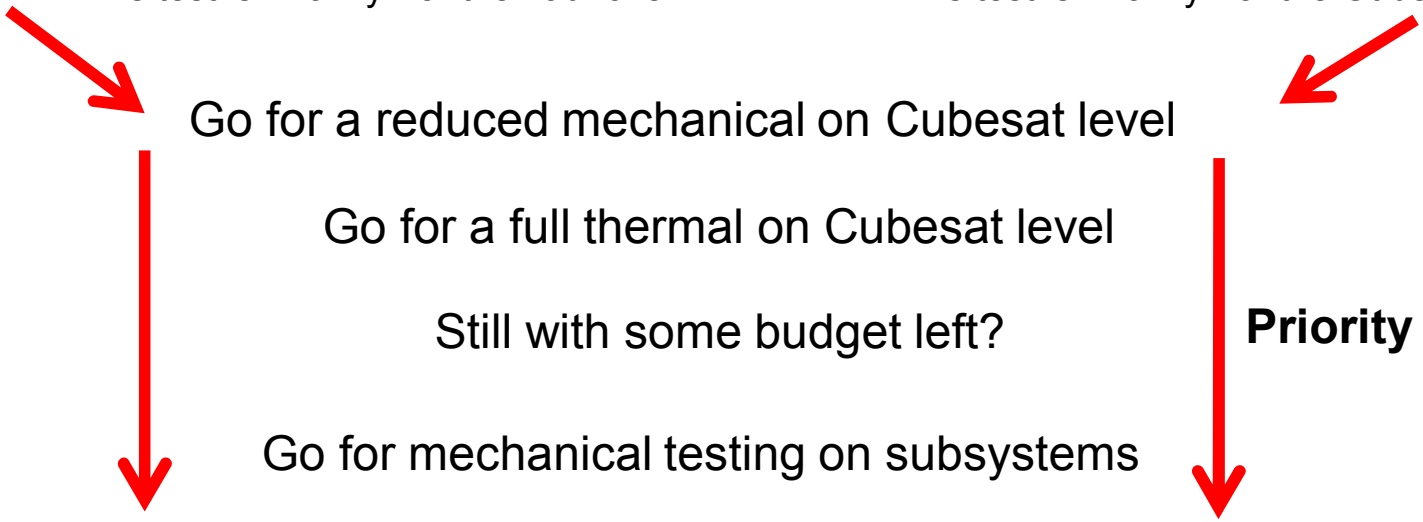
1.4.- Ok, but should I do this with my Cubesat ?

Mechanical testing ?

- You must do Resonance Searches.
- You must do Random Vibration.
- You probably only need acceptance levels. Try to avoid qualification levels.
- You will probably do a vibration with a deployment mechanism as an interface:
  - You will gather few relevant data regarding your Cubesat mechanical behavior.
  - This test is “mainly” for the Launcher.

Thermal testing ?

- You might be able to do only a simple thermal vacuum cycling.
- Extremely valuable information about your Cubesat mission capabilities.
- Cubesat designers have more capabilities to influence on this test. Thermal tests can be tailored to your needs.
- This test can save you hundreds of theoretical simulations.
- This test is “mainly” for the Cubesat.



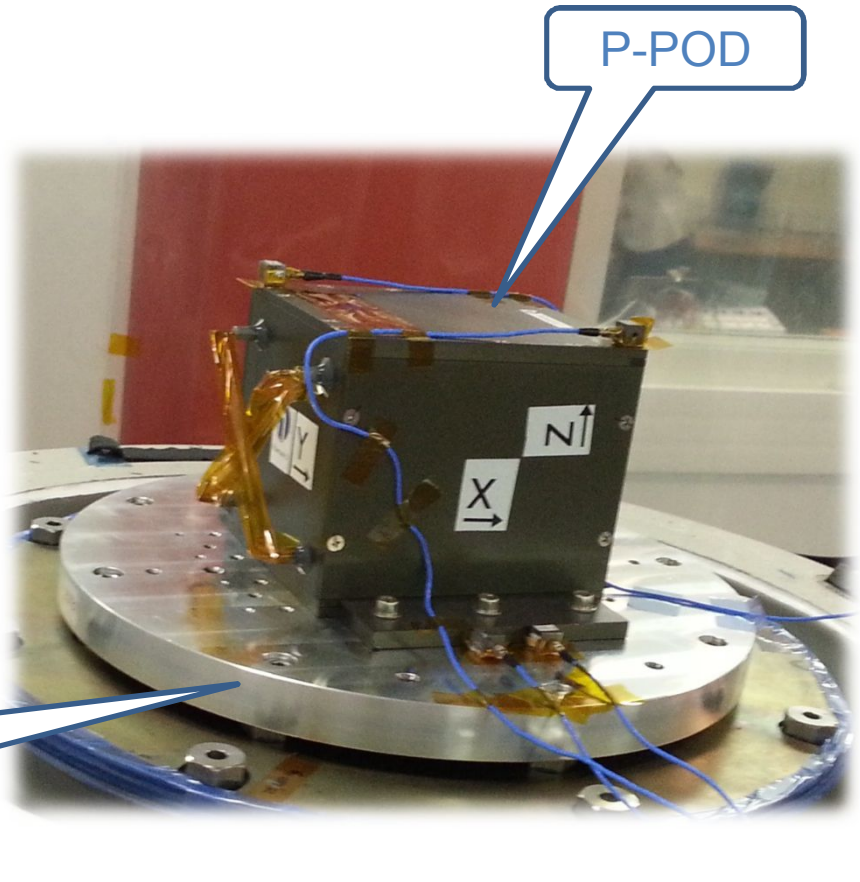
Test preparation

ets european test services

2.1- Pre-test activities

Mechanical testing

- Contact facilities and check availability.
- Provide initial feedback about your Cubesat's team experience and needs.
- Check with facility responsible about needed equipment.
  - *Usually you need to manufacture an interface adapter between Cubesat and Shaker.*
  - *Usually you will test with a deployment mechanism (P-POD or similar).*
- Make an extensive inventory of all equipment needed for the test.
- Perform a **simulated test** within your laboratory premises.

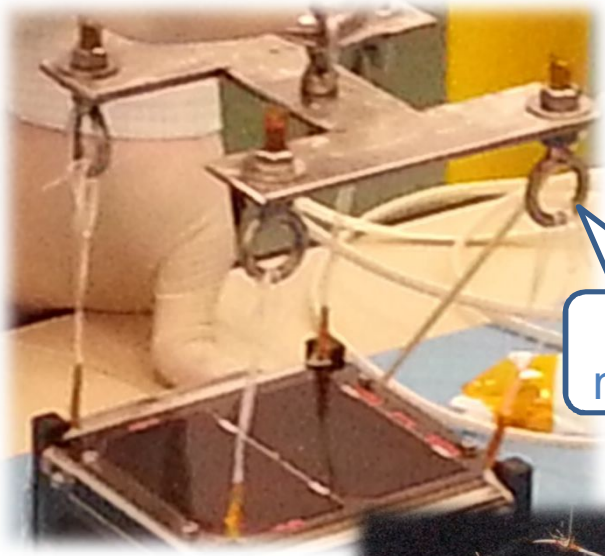


ets european test services

2.1- Pre-test activities

Thermal testing

- Contact facilities and check availability.
- Provide initial feedback about your Cubesat's team experience and needs.
- Check with facility responsible about needed equipment.
  - *Usually you need to manufacture a hanging equipment which will be needed inside the chamber.*
  - *Usually you need to manufacture 2 EGSE cables (internal and external) to communicate with your Cubesat when it is inside the chamber.*
- Make an extensive inventory of all equipment needed for the test.
- Perform a **simulated test** within your laboratory premises.



ets european test services

2.2- Documentation

Mechanical testing

- Prepare a test procedure which includes:
  - Small description of your Cubesat mechanical interfaces.
  - Clear purpose of the test (Subsystem checks, full Cubesat acceptance, etc.).
  - Clear definition of items provided by the facility. Usually they provide interface adapters, instrumentation and acquisition systems.
  - Step-by-Step procedure during the test.
  - Expected results in case some analysis is available (operators don't like surprises).
  - Success/Fail criteria and emergency actions to be taken in case of failure.
    - Try to foresee problems, but keep it realistic.

Thermal testing

- Prepare a test procedure which includes:
  - Small description of your Cubesat subsystems.
  - Power budget for your Cubesat during the different tests you will perform.
  - Clear purpose of the test (Subsystem validation, full Cubesat mission validation, etc.).
  - Clear definition of items provided by the facility. Usually they provide interface adapters, instrumentation and acquisition systems.
  - Step-by-Step procedure during the test.
  - Success/Fail criteria and actions to be taken in case of failure.
    - Try to foresee problems, but keep it realistic.

1 procedure for each test

ets european test services

2.3- Test material

Mechanical testing

- Carefully check the delivery times for all items you will need.
- Bring some spare components (bolts, connectors, etc.) if you can quickly replace them during the test.
- Bring full subsystems in case you have doubts about survival.
- Be careful with ESD protection and cleanliness. Mechanical testing is not well-known for being clean or ESD aware.
- Make sure you bring to the test someone with knowledge at system level to evaluate emergency actions and impact. 1 System engineer and 1 AIV/AIT operator is highly desired.
- If you have a P-POD or similar with you, delivery it beforehand to the testing facility.

Thermal testing

- Additionally to all mentioned for mechanical:
  - Bring your Software engineer.
  - Plan carefully your emergency procedure, you will need to execute part of it. Difficult to imagine a Cubesat test campaign without corrective actions taken during the test.
  - If possible send your EGSE cables to the facility to perform a fit check with their interface to the chamber.
  - For battery charging keep in mind the impedance of the line, most likely your Cubesat will be charged slower than usual.

Test execution

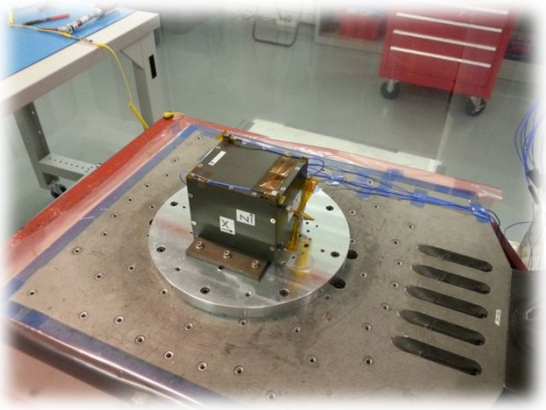
ets european test services

3.1- Social skills

- Most often disregarded, pay attention to it.
- Facility operators are professionals, but :
  - They perform the test you describe on your procedure.
  - They are not obliged to take care about your Cubesat as much as you do.
- You need to ensure a good communication with the facility responsible and especially with the facility operators.
- We tend to believe that operators will do whatever it takes to make successful our test campaign.
- Fact:
  - For your Cubesat testing is the last step before launch.
  - For the operator it is a test.
- You might be lucky and find an operator deeply involved on your Cubesat test, helping you and taking care everything goes smoothly.

ets european test services

3.2- Mechanical test examples [videos]



- Cubesat test from Humsat 1U
  - Random vibration (*MecanoID-Toulouse*).
  - Post-test antenna deployment check.
- Cubesat test from Xatcobeo 1U
  - Random vibration (*INTA-Spain*).
- Vibration from industrial equipment
  - Fatigue testing for industrial equipment on Multi-Shaker (*ESA-ESTEC*).
  - Low level sine vibration for Resonance search on Hydra (*ESA-ESTEC*).
  - Shock testing on Hydra (*ESA-ESTEC*).

Test analysis

ets european test services

4.1.- Data during testing

Mechanical testing

- Try to do a quick assessment with the facility operator before proceeding to the next step.
- You are about to test 3 axis:
  - Make a quick assessment with the facility operator before proceeding with the next axis.
- Firstly do a quick analysis and then dismount. Not a good idea to save time on these activities.
- Perform a functional check on your Cubesat as often as you can. Usually 4 times should be enough.
- Ask for preliminary data plots during the test, so you can do further analysis if needed.
- Make your own photos. Most operators will take photos during testing, but you're the one who really knows what is really important.

Thermal testing

- Perform a functional check on your Cubesat:
  - Before mounted inside the chamber.
  - Once mounted inside the chamber, before starting test.
- Also keep in mind your functional checks might affect your Cubesat's capabilities of survival during cold cases.
  - Save battery for the cold case, you will need it.
- Automate as much as you can your checks. Ideally you should be monitoring only.
- Make predictions based on live data about the temperature trend on your subsystems. This is quite difficult, but will help you to foresee problems.
- Make a lot of photos. Photos with timestamps might be the quickest way of documenting your activities.

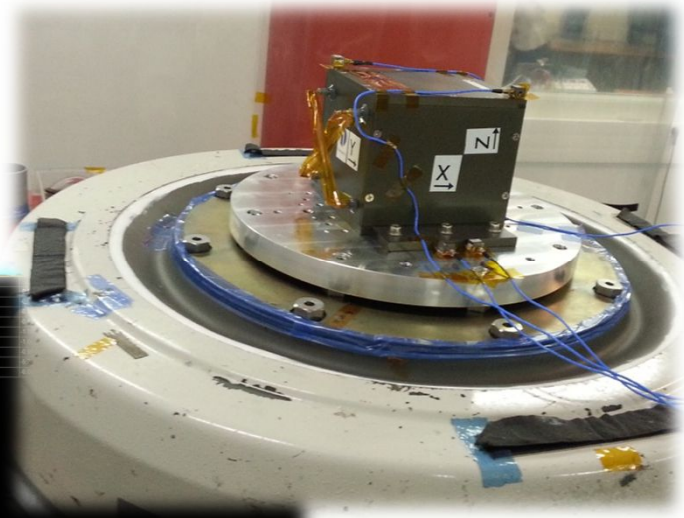
You have to quickly evaluate the situation:

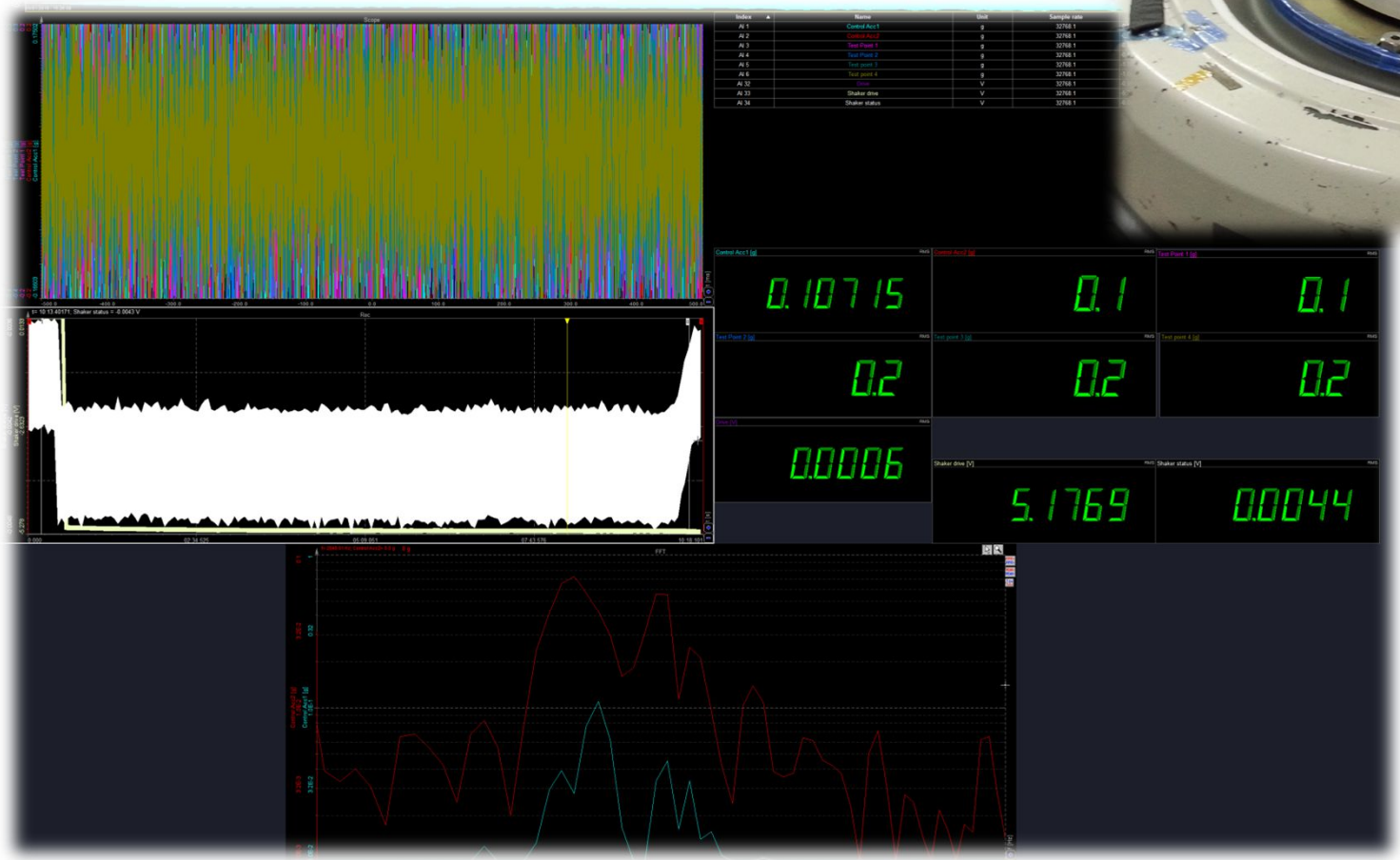
- For mechanical you might have 1 hour to find a solution.
- For thermal you might have 1 day to find a solution.

ets european test services

4.1.- Data during testing

Mechanical testing live

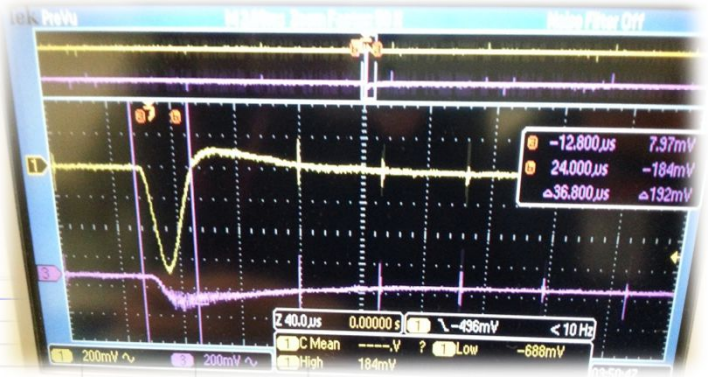




ets european test services

4.1.- Data during testing

Thermal testing live



ets european test services

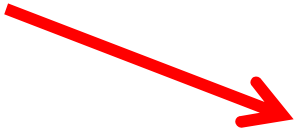
4.2.- Data after testing

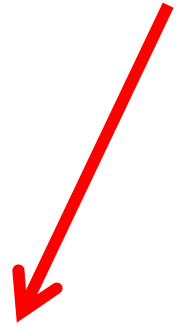
Mechanical testing

- Make sure you have the following data:
  - Resonance:
    - Individual harmonic plots for all channels from all runs.
    - Overlays before and after doing Sine or Random vibrations.
  - Sine:
    - Individual harmonic plots for all channels from all runs.
  - Random:
    - Individual Power Spectrum Density plots for all channels from all runs.
  - Shocks:
    - Individual time histories plots for all channels from all runs. Limit the duration of this time histories to your shock.
- Make sure you can make your computations with big data files.
  - Time data recorded from mechanical tests can lead to really big files (1GB).

Thermal testing

- You will have the opportunity to perform analysis after each day of testing. This time will be really important. Use it accordingly.
- Make sure you have a clear timestamp to correlate facility data and your Cubesat's data.
- Make sure you are provided with the following data vs time:
  - Pressure inside the chamber to check vacuum.
  - Shroud temperature.
  - Individual Thermocouple temperature vs Shroud.
  - Control temperature.





- Make sure you have all data in both formats:
  - PDF for plots.
  - .xls, .txt, .unv, or any other format you like.

Learning by experience

Learning by experience

- Cubesat's community is really nice:
  - There is a huge number of people willing to help.
  - There is a large number of people that can really help.
  - There is a reasonable number of people that will help you.
  - Usually Cubesat people do that for free.
- Share your results and your reports:
  - You will get comments, not all of them nice.
  - You will improve for next time, you will do it better.
  - Others will learn from your experience.
  - Others will avoid your mistakes.
- Know people related to testing field:
  - They will guide you and provide valuable feedback.
  - You will get used to testing facilities, which usually leads to less expensive and shorter tests.
- Testing is always about time and money. Make the best use of it to **generate nice science**.

Thanks for your time!
Questions?

Dario Hermida
dario.hermida@esa.int
European Test Services (ESA-ESTEC)