NASA NEPP Workshop

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Small missions and CubeSats

Previous small ESA missions

1. PROBA 1 (PRoject for OnBoard Autonomy) launched on 22 October 2001. Originally designed for a two-year mission, Proba-1 is still operating.
    a. LEO, sun-synchronous, 561-681 km, inclination 97.9 degrees
    b. Mass 94 kg

2. PROBA 2 launched on Nov. 2, 2009 – operational
    a. LEO, sun-synchronous, 700 - 800 km, inclination 98.298 degrees
    b. Mass 130 kg

3. Proba V Launched on 7 May 2013 – operational
    a. LEO, sun-synchronous polar orbit, 820 km
    b. Mass 140 kg

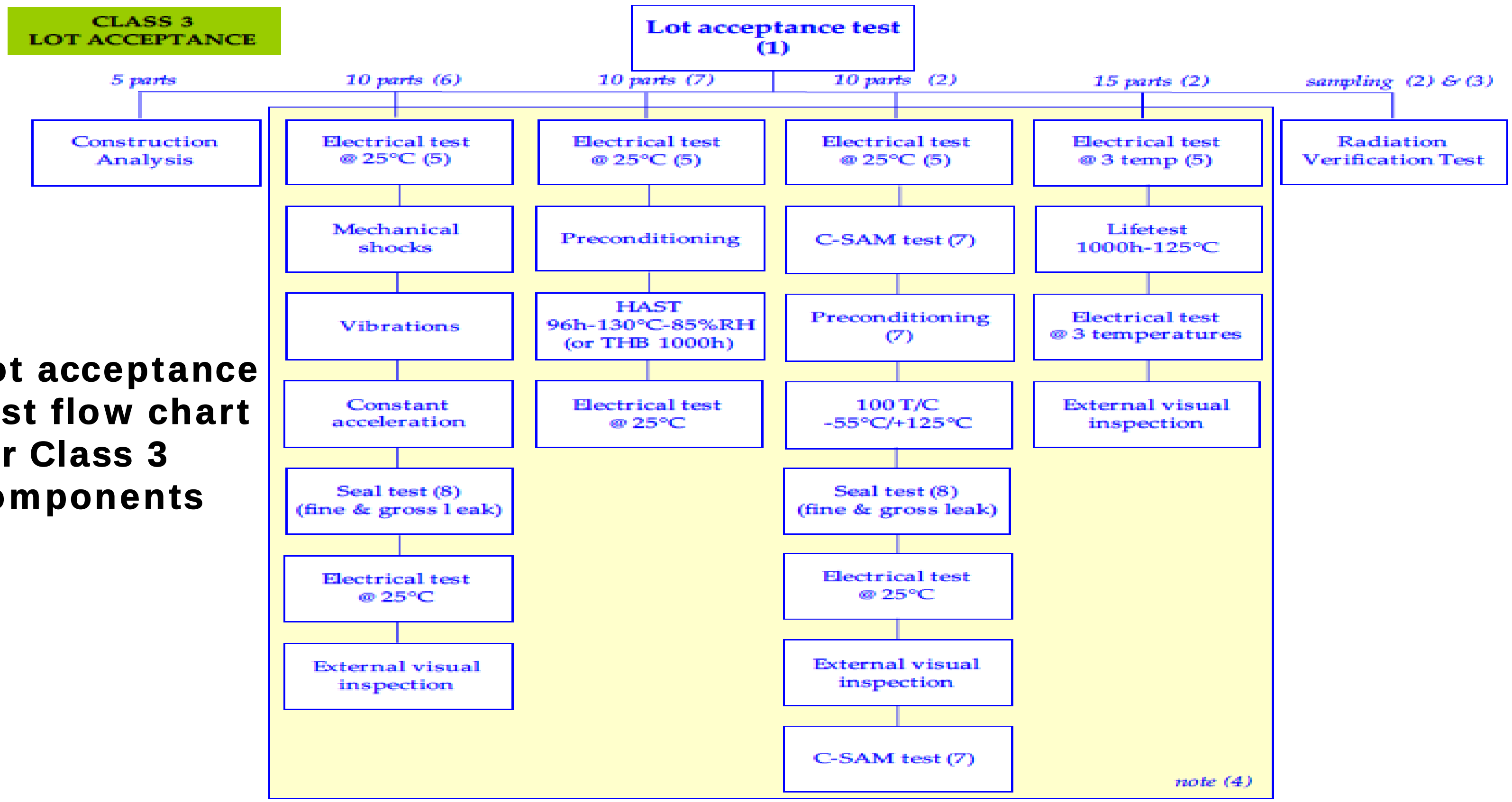
Small missions and CubeSats

Developed and built according to tailored ECSS standards

- From PROBA V the requirements for EEE parts are ECSS Class 3 quality level according to ECSS-Q-ST-60C
- Three quality levels within the ECSS system: class 1, 2, 3 with class 3 as the lowest screening level
- ECSS-Q-ST-60-13C is the standard used for COTS components their up-screening
  a. Applicable to commercial encapsulated active monolithic parts (integrated circuits and discrete)
     - Diodes
     - microwave diodes
     - integrated circuits
     - microwave integrated circuits (MMIC)
     - Transistors
     - microwave transistors
  b. The evaluation of COTS components is limited to construction analysis and radiation tests (TID, SEE)

esa

Lot acceptance test flow chart for Class 3 components



(1) : for the lot acceptance of retinned components, see figure 8-6
(2) : screened parts (if any)
(3) : sampling and testing conditions in conformance with requirements of ECSS-Q-ST-60-15
(4) : if representative data are available, these test groups are not required during lot acceptance
(5) : this test is optional to avoid possible duplication with screening, if any (when done by the same entity)
(6) : applicable in case of cavity package
(7) : applicable to plastic package only
(8) : applicable to hermetic & cavity package

Small missions and CubeSats

Small ESA missions in preparation

- CHEOPS CHaracterising ExOPlanet Satellite.
    - LEO, sun-synchronous, altitude 650-800 km
    - Mass ~250kg
- PROBA 3, Formation flying demonstrator. The satellites will form a 150-m long solar coronagraph to study the Sun’s faint corona.
    - High Earth orbit, 19.7 hours orbital period, 60 530 km apogee, 600 km perigee
    - Coronagraph spacecraft 340 kg, Occulter spacecraft 200 kg
- SAOCOM-CS, SAtélite Argentino de Observación COn Microondas - Companion Satellite – still in Phase A development. A receive-only satellite to be launched with Argentina's L-band SAR satellite SAOCOM
    - LEO
    - Mass ~400 kg

Developed and built according to tailored ECSS standards

- The EEE parts are of ECSS Class 3 quality level

CubeSat

- Demonstrational, low TRL – technology readiness level
- No standard is yet available for CubeSat projects– nor planned
- Only three hard requirements are made generally applicable
    - Compliance to the space debris mitigation requirements
        - Don't create debris
    - Compliance to the launch authority safety requirements
        - Don't be a safety hazard for other equipment
    - Materials compliance to the vacuum environment
        - Don't contaminate other flight equipment of vacuum test chambers
- A guideline document for CubeSat projects is under preparation directed to newcomers in the space business
    - Considering particular CubeSat conditons
        - Low-Cost Developments, High-Risk Tolerance, Educational opportunities, Universities & research institutions

CubeSat – applicable standards

- The minimum set of standards that are applicable to any CubeSat project are:
    - ECSS-Q-ST-40C Safety/Launch authority safety requirements
    - ECSS-Q-70-71A Data for selection of space materials and processes
    - ESA-ADMIN-IPOL(2008)2 - Space Debris Mitigation for Agency Projects
- Other requirements are tailored to each specific project

CubeSat EEE components

- Considering that hi-reliability components, as well as radiation testing, may be out of scope for Cubesat projects the standard is to be seen as informative, although the equipment still needs to survive the space environment
    - Careful tradeoff between available resources and risks is needed
- In case a project is driven by specific needs radiation tolerant or rad-hard components may be needed but this would raise the costs of the project significantly
- Implement derating of EEE parts
- Certain design provisions need to be followed to make the design tolerant to SEE:
    - Using latch-up free components
    - Implementing automatic reboot after a SEU has occurred (autonomy)
    - Implementing EDAC
    - Implementing redundancy

CubeSat – some ongoing projects

GOMX-3 – Miniaturzed technology payload on a 3-unit CubeSat nano-sat platform deployed from the ISS demonstrating advanced pointing while receiving both L-band and ADS-B signals

QARMAN – QubeSat for Aerothermodynamic Research and Measurements on AblatioN.

SIMBA – Sun-arth IMBAlance, measuring essential climate variables of total solar irradiance, earth radiation budget and sun-earth radiation imbalalnce.

PICASSO – PICo-satellite for Atmospheric and Space Science Observations. Demonstrate the ability of a low-cost nano-sat to measure ozone distribution.

- Product and Quality Assurance Requirements for In-Orbit Demonstration CubeSat Projects TEC-SY/129/2013/SPD/RW
- Implemented a web based tool for document control
- Review documentation and rid system
- NCR control system

CubeSat – project PA requirements contents

CubeSat some trends

CubeSat Industry days held at ESTEC 15-16 June 2015

- Eduaction
    - Technology demonstration
    - Small scale science demos
    - Operational missions
- Going towards:
    - More capable systems
    - Non-leo, high-radiation –propulsion and rad tolerant parts
    - High-reliability – no more low cost
- Change in design approach from a low cost educational tool (anything goes) to a constraint based cost effective LEO demonstrator (live with its limitations) to a niche market design
- CubeSat growing from 1 kg to 25 kg (optics don’t scale down very well)

Product Assurance – why for CubeSat?

- Why do we need PA for CubeSat?
  - Space systems are expensive and complex, take a long time to develop and failure consequences may be very severe – and we are not willing to face failure as an option – not even in CubeSat projects
- Main purpose of PA is to ensure
  - Space systems are developed properly and all requirements and met
  - System is qualified
  - System is safe
  - Probability of success is high
- The purpose of the PA activities are to prevent things from going wrong, and when things do go wrong, to minimize the consequences
- The question to ask may not be “will this work or fail” but rather “when will this fail and how” and “what will happen when it fails”

This is why we encourage CubeSat projects to perform =>

FME(C)A – Failure Mode Effect and (Criticality) Analysis

- The objective of the analysis is to identify possible critical failures (SPF) in the design and correct them before going into manufacturing – not to provide a nice report on paper
    - The design engineer is typically focused on haw to make his unit work and not thinking about what happens if a certain part fails in a certain way
    - By considering what happens if a certain part fails in a certain way already at the early design stages the most common design mistakes can be easily avoided
    - The FMECA can be applied to processes as well
- HSIA – HW/SW interaction analysis also needs to be considered
- Consider Common Mode and Common Cause failures CM/CC

CubeSat design phase

- Some design concerns that we are encouraging CubeSat projects to look into since what goes wrong in the design phase will have severe consequences further on.
  - Early FMECA to eliminate common mistakes
  - Overvoltage protection and current limiters to minimize the impact of failures and transients
  - Redundancy concept to improve the reliability
  - Review of I/Fs and in particular connector pin-out and harness design to avoid errors that easily occur
    - Typically overlooked because tedious and boring activity
    - Failures can be critical
- Design reviews: SRR, PDR, CDR
- Implementation of a process for traceability, documentation and configuration

Manufacturing

- Materials and parts control
    - Correct, traceable, conforming and within their usable life
- Production equipment control
    - Fit for use and calibrated
- Cleanliness and contamination control
    - Maintain and protect instead of having to clean after things have gone wrong
- Control of manufacturing processes and workmanship criteria
    - Trained personnel applying a qualified process
    - Perform inspections
        - Incoming, solder inspections, KIP/MIP, final…
- Control of manufacturing documents
    - Traceability and configuration control
- Implementation of a non-conformance control process
- Testing and test reviews TRR, PTR, TRB
    - Test reviews TRR, PTR, TRB documented
    - Model philosophy and test sequence – test as you fly

Flight heritage for CubeSats

- Flight heritage is commonly misused as a concept
- In order to have flight heritage we need:
  - Identical units manufactured with identical materials, components and processes
  - Same operational conditions
  - Same environmental conditions
  - Qualification and acceptance test levels
- If all the above criteria are not satisfied we don’t have full heritage

Thank you