NEW CHALLENGES IN THE DESIGN OF COMPONENTS FOR MICRO- AND NANO-SATELLITES

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Currently we see drastic change in the requirements of components for Micro- and NanoSatellites, mainly driven by new market players (for multi-MicroSatellites-constellations) and the scientific and commercial application for bigger CubeSats. To face these challenges new approaches for the design and manufacturing of satellite components are necessary. Following paper describes the solutions which are used by Astro- und Feinwerktechnik for its current and future component development.

1. MARKET CHANGES

Driven by new multi-satellite-constellations of new market players we see currently a drastic change in the design requirements for components of MicroSatellites. For these multi-satellite-constellations the satellite delivery time are drastically reduced as well as the acceptable prices for each single satellite. As barter the new players are willing to accept slightly higher risks, because they are backed by system/constellation redundancy. This changes the requirements for the subsystems and components.

Another part is the upcoming market of satellites in the 10 to 50 kg class. Coming from the former educational CubeSat community the actual CubeSat technology used by educational Cubesats is not ready for real scientific and commercial use. Meanwhile a lot of companies as well as scientific institutions are building or plan to build multiple NanoSatellites for such applications, which results in new requirements for this component market.

2. NANOSATELLITE MARKET

At first we see (similar to the micro-satellites) a growing mass because of higher demands in power, volume and mass for the payloads. Former educational satellites are 1 to 3U CubeSats and the current designs for commercial and scientific missions go to 6U, 12U, 16U and 27U satellites to fulfill these payload demands.

2.1. New requirements for NanoSatellite Components

Additional to the increasing size of the components, the commercial and scientific customer wants a higher quality, because of higher lifetimes and higher requested reliabilities, and a tailored “space” documentation, but currently it is unclear if there will be sometimes a accepted “standard” documentation.

One point is the fact, that the price and delivery time requirements are much lower than on the micro satellite market. To combine the new reliability, quality and documentation requirements with the ”old” accepted CubeSat philosophy for educational CubeSats is a big challenge. The question is how to fulfill these requirements, also shown in the following tab, without falling into classical dear “Agency” space approach.

Education/Tech Demo	Science/Commercial
Minimum price	Low price
Tendency to make everything by its own (student labour is free of cost)	Only system integrator. Willing to buy as much items as possible.
Option to fail, Mission goal (education) is fulfilled at 90% at launch	Must be “medium” reliable, mission must be accomplished
Weeks/Months of lifetime in orbit	1 to 3 years in orbit
Typically 1 to 3 U satellites	3U, 6U and bigger
Delivery times <3 month	Delivery times ~ 6 month
No PA requirements	Tailored PA requirements
Docu: Only ICD or spec	ICD, Test reports, Analyses, Specs
Best fit + low price	Performance, price, reliability

TAB 1. Requirements for NanoSatellite components

2.2. Standards for Testing

One point for this is the urgent need for a kind of verification standard to make it possible to compare the different items from different suppliers. How you want to compare things without comparable test results.

This topic was identified by multiple component suppliers on the market. The IAA Study Group 4.18 led by Prof. Cho from Institute of Technology, Kitakyushu, is working on new terminology and new standardized testing requirements for “Lean Satellites”. The term of “Lean Satellites” is used to bridge the gap between the bigger commercial NanoSatellites and the smaller MicroSatellites, because the classical terminology (only defined by mass) is not sufficient anymore.

3. MICRO SATELLITE MARKET

Main topics for the micro satellite (meanwhile 100 to 300 kg) components are driven by the increasing use of microsatellites in commercial constellations:

- reduced delivery times (typically under 6 month for flight models),
- much higher life times (7 years and more in high LEO, e.g. 1100 km),
- increased reliability requirements,
- complete ITAR-freeness and,
- in most cases, exclusion of class 1 and class 2 EEE-parts, due to cost constrains.

Source for this are mainly the new commercial player on the market with the mainly commercial use of multiple spacecraft constellations as well as new launcher opportunities, which allows cluster launches as well as dedicated launches (e.g. LauncherOne, SuperStrypi,…).
Unfortunately this new market cannot live with the current "space" prices of components and subsystems or it will lose much of its competitiveness to bigger satellites or its complete business models. (*Please keep in mind that the primary revenue of these new constellations is to be made on ground, with applications, and not with the space segment itself.*)

4. FIRST COSIDERATIONS

In our view the educational market can only be profitable for companies who are structured and organized at an absolutely low-cost supplier. Astro- und Feinwerktechnik comes from the classical micro satellite business and is, and will be also in the future, also active on the classical agency and medium/high reliability business for commercial micro satellites. This is not compatible with a low-cost – only NanoSatellite – approach.
As result of this consideration Astro- und Feinwerktechnik will be focused as supplier on the commercial and scientific NanoSatellite market as well as the MicroSatellite market for components and subsystems.

5. NEW APPROACH FOR COMPONENTS

5.1. For NanoSatellite Components

Here we need a solution for very fast, low cost but acceptable reliability approach for the current CubeSat/NanoSat requirements.
The solution can be divided in technical part and programmatic part.
The technical part of the solution contains the following points:

- Use only COTS parts in a Common Part Procurement inside company
- Reuse exchangeable "building blocks" for the different components
- Use only established and digital interfaces
- Design it for easy manufacturing and assembly

The programmatic part contains of:

- Tailoring of the PA requirements to the absolute minimum
- Definition within the community and installation of the minimum testing standards
- Building of partnerships for combining your equipment with items of other companies

5.2. For MicroSatellite Components

The main challenges are the delivery time and cost reduction, without losing too much performance and reliability. Especially the establishing of new processes is not as easy as it sounds if you do not want to lose the ability to still work on the classical high-reliability market, e.g. agency projects or GEO stationary projects). One reason is that it is very complicated if you have very different PA procedures in one company without getting into trouble.

First point is to reduce the high EEE-part cost. This can be done by:

- Common parts and "building blocks" with other products of the company
- Availability of three EEE-part versions of each component by common footprints
  - Up-Screened COTS
  - Mil or similar, but ITAR/9x515/600series free
  - HighRel/ITAR
- Use of military heritage and new redundancy approaches to compensate the reduced EEE part reliability

As example for new redundancy approaches: For a three axis gyro – do not use two complete systems in cold redundancy. Better to make a cold redundancy of each axis inside one unit.

Up-screening is a process that is established on component as well as board level. The following two figures show a typical approach of Astro- und Feinwerktechnik for this process.

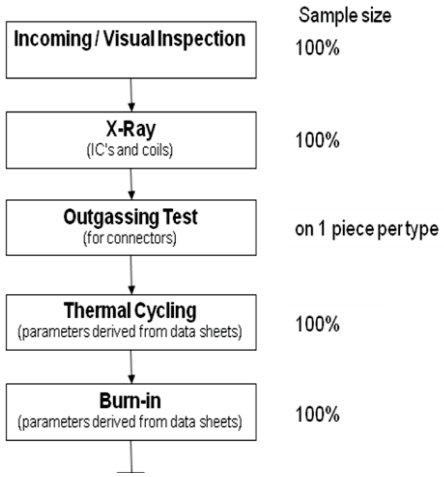

FIG 1. EEE-part Up-screening on component level

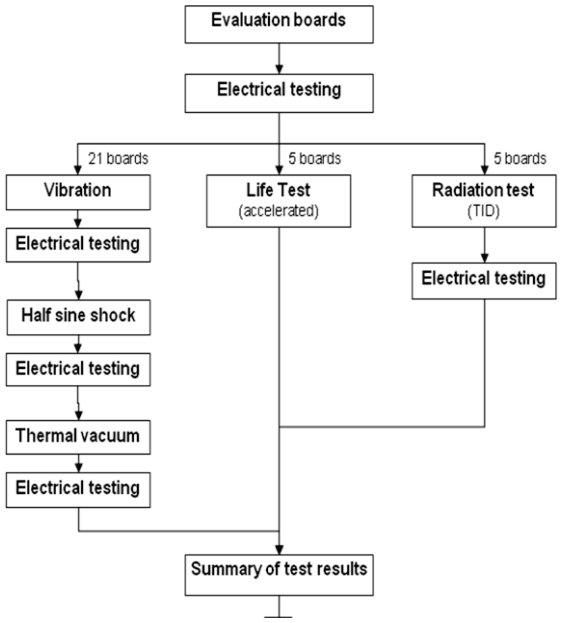

FIG 2. EEE-part Up-screening on board level (with 31 boards/populated PCB's)

After successful completion of this process the EEE-parts are used for as many different components and building blocks as possible. This allows also a common part procurement inside the company for different products and different projects.

The second part is the reduction of the costs during the manufacturing, assembly and verification:

- Strictly digital interfaces for fast testing
- Redesign the units for easy and fast manufacturing
    - e.g. low milling times (easy geometries)
    - Fast assembly (less or no calibration)
    - Easy assembly (not by engineers)
- Reduced and automatic testing

What means reduced testing? For producing components for big constellations (>400 satellites to be launched during 1 or 2 years) it is not longer possible to make environmental testing of each unit according to ECSS. This will increase time and cost above the limits. This means testing needs to be reduced in performance testing of each unit and environmental testing of random sample, e.g. one unit per batch).

The installation of such new approaches and design rules will result in a bit less advanced but much cheaper and faster to produce products. Less advanced means that such a unit will have some draw backs in comparison to "classical" space component. This could be a slightly higher mass or less reliability or higher power demand. But the advantage in price and delivery times overtops this and fulfills the requirements of the new multi-satellite constellation.

To say it in easy words: It is like buying a mass produced motor cycle instead of a custom bike. There will be still the market for custom bikes which fits perfect to the customer. Unfortunately not every customer is willing to pay and wait a long time for it. For them we need the mass produced ones. And the way seems clear how to reach that goal….