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Cubesats - From University to More Reliable Satellites and Missions

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Cubesats were at the beginning seen as an educational tool mostly. However as they are acquiring space heritage and the electronic industry is capable of produce more reliable components, at low cost, small dimensions at greater capacity, they start to be seen as potentially capable to perform more complex and ambitious missions at considerable lower costs than missions with related objectives but considerable larger costs due to the use of larger and more expensive satellites. The objective of the paper is to discuss those points that can play a key factor in the decision to use those cubesats based satellites to a more complex mission, and its foreseen limitations. The possibility to use cubesats constellations add to this potential. Also, the possibility to use larger nanosats, based on cubesat standards and assembled using 1, 2 or 3U´s cubesats for better and more refined data is discussed. The paper aims to discuss these points as well as a tradeoff between the costs of testing COTS components to be used in cubesats to increase mission reliability and the cubesat low cost original definition, moreover related to radiation resistance. These components are showing greater capacity over time to perform in space. The cubesat launching possibilities and new small launchers developments with potential possibilities to be used are also discussed. These present limitations to a more ambitious use of cubesats may soon decrease, especially in countries where space technology development could be considered strategic.

University satellites

University satellites have found great impulse with the rising of the cubesat standard. Using COTS components under standard dimensions, ar-

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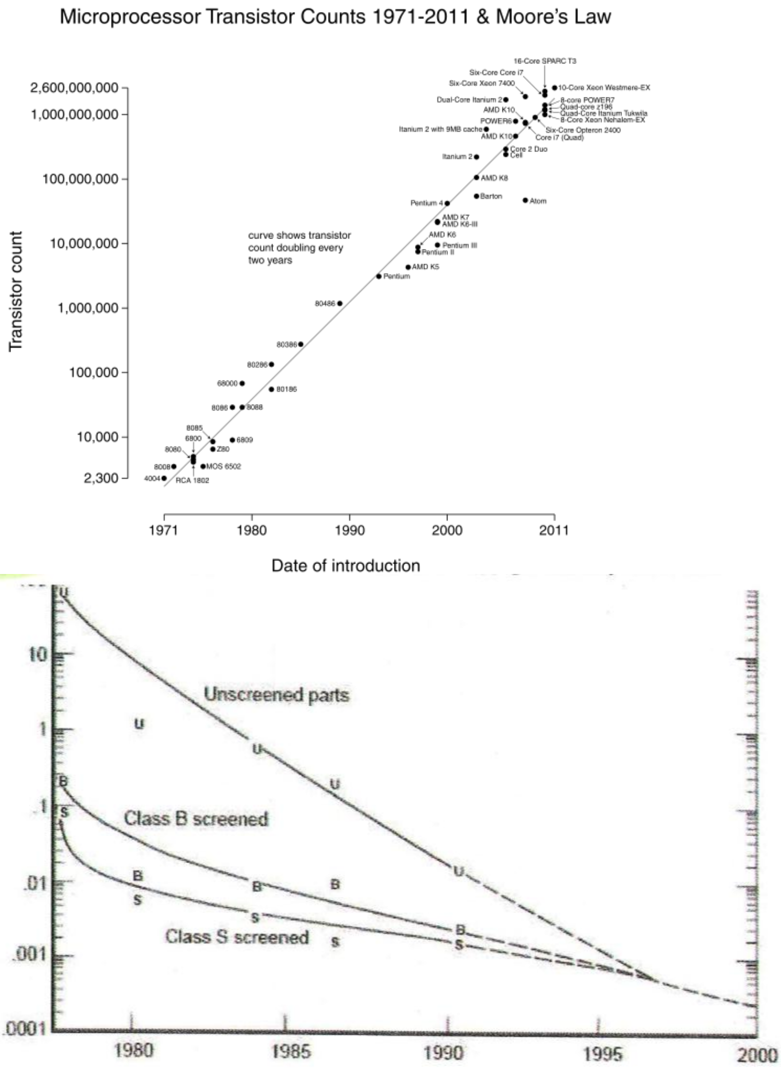
chitectures, communication frequencies and so for, the use of cubesats for educational purpose have spread great enthusiasm over the academic community worldwide. Costs and performance of this type of satellite have made it be thought into more operational missions both for civilian as well as for defense applications [1,2,3,4]. However there seems to be a disbelief of this more operational and commercial use of cubesats even within the own cubesat community, based on the relatively low rate of successful cubesat missions when compared with the number of missions launched. Still some missions have operated for more than nine years now and a significant number have operated successfully for more than four or five years [5,6]. These successes have created a cubesat components heritage that has been used by the cubesat platform provider companies in many of their subsystems as radios, computers and power subsystems. On the other hand not always university satellites are based on the cubesat standards as 1U, 2U or 3U´s. For instance, Japanese universities have developed about seventeen small satellites during the 2003-2012 period. From those very few followed cubetas standards. Presently these universities develop the Hodoyioshi (which means “so-so not expensive” and relates to its reliability) project for the period 2010-2014 with the first satellite launched in 2012 and three others planned to be launched in 2013. These are small satellites in the 50 to 70 kg. mass range in cubic shape and dimensions 50x50x50 (up to 70cm.) cm. [7]. These are larger and more expensive than cubesats and more complex to develop, moreover with the participation of students, but they have larger expected life. The use of cubesat derived standard that could allow its use in larger satellites, in the 10-20 kg. class satellites for instance, and the use of constellations with these satellites could provide a solution for this breakeven point. Especially if these slightly larger but still very small satellites can be assembled using “blocks” of 1, 2 or 3U´s cubesats.

Still, many pitfalls seem to justify the caution to use cubesats and university derived satellites for commercial and/or operational use. Among these concerns is the use of COTS components instead of rad-hard components, the lack of dedicated launchers, the debris question and the frequency coordination procedures for this type of satellite.

COTS Components

The electronic industry is responsible for the modern miniaturization revolution with dramatic increase in capacity, reliability and production volumes at considerable lower costs (Fig. 1-a and b). This was the case for computers, communications, entertaining and many other associated industries. And this will also hold for the aerospace sector.



SOURCE: *Quality Magazine* (Plum, 1990, p.53).

Fig. 1. Evolution of the electronic industry capacity over time; (a) capacity (b) reliability.

Every major space agency in the world presently has a program to use COTS components in their satellites [8,9.10]. The use of COTS components in many space projects allow for more capable and efficient performance with considerable gain in mass, power and costs. As opposed to the use of space qualified components, COTS components, and its consequent satellite shorter development time, allow the use of modern electronic technology in space projects. There is no more economy of scale that justify the use of space qualified components as in the past when usually governments were able to pay for these R&D costs for their huge space projects (Fig. 2).

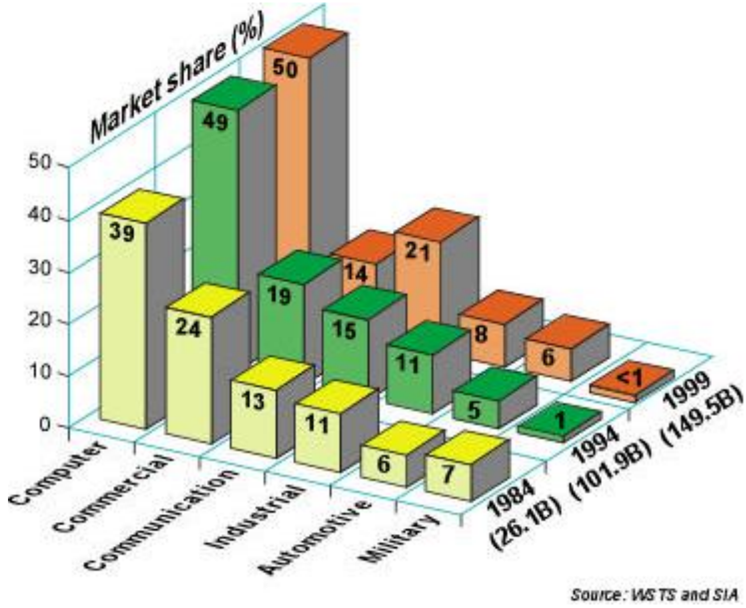


Fig. 2. Electronic Component Industry Market Share

Instead of using space qualified components, it pays to use COTS components and a screening process combined with project/engineering strategy to mitigate risk for using it regarding its failure in space. The choice of the COTS component is the initial step to this mitigation. A few recommendations can be made:

- Choose components used in high demanding reliability applications, such as medical and telecommunications
- Choose from reliable and known industries
- Check for components with space heritage.
- Check for the manufacturing process of the component and the tests and norms through which it went.
- Considering engineering strategies for risk mitigation in the project of the satellite; this can be done with redundancy (both equipments and functional) or fault tolerance, both by software or hardware.

Still, if this is the case, critical equipments can use space qualified components or be shielded against radiation. COTS components are nowadays being considered to be used even in deep space missions [11], and have been used in GTO and GPS orbits that are much more demanding in terms of radiation.

Moving to operational missions

In order to move from university satellites to more operational and commercial satellites, the former have to overcome some pitfalls still existent for this transition. A better understanding of the radiation effects, launching availability and costs and some regulatory matters such as frequency coordination and debris legislation, are some of these definitions that need to be done in the near future.

1. Radiation

In electronic circuits radiation causes transient or permanent effects on electrical parameters of the circuit, altering its functionality or even its operation in the system. The origin of the effects can be through cumulative dosages (TID), over a certain amount of time (satellite lifetime) or by single events (SEE) caused by highly ionized particles and they can be reversible or not. For LEO the late projects in Brazil have adopted a specification of 30 krads per year for cumulative dosage and 54 MeV for SEE´s. This was the case for the CBERS program, in cooperation with China, that has so far launched three satellites and has two others programmed to be launched in 2013 (CBERS-3) and 2014 (CBERS-4). One of the satellites launched has experienced problems with its star tracker that reduced the satellite life time, which could have been caused by SEE´s over the South Atlantic Anomaly. Still, to buy electronic components for these projects many times the minimum TID for a space qualified component was 100 krads which made it to be very difficult to buy in the market due to ITAR restrictions. And still many models call for a TID of 15 krads, although this can varies in real space in situ sensory. Brazil has used space qualified components for the sub systems under its responsibility in the CBERS series, but there is no confirmation that the cooperation partner has followed the same procedure. Before CBERS-1, the Brazilian Institute for Space Research (INPE), has launched two small (110 kg) data collection satellites in the 90´s. Just space components were used. Both satellites are still operational, despite they have had their nominal life at project defined for one year each! At the moment INPE works for a replacement of this system using much smaller satellites (around 10 kg.), using COTS components both for the platform as well as for the payload, an S transmitting and VHF receiving transponder. This satellite is based on the cubesat standards, enlarged to an 8U size.

Figure 3 shows curves for annual radiation dose for different orbits and expected failure threshold for failure.

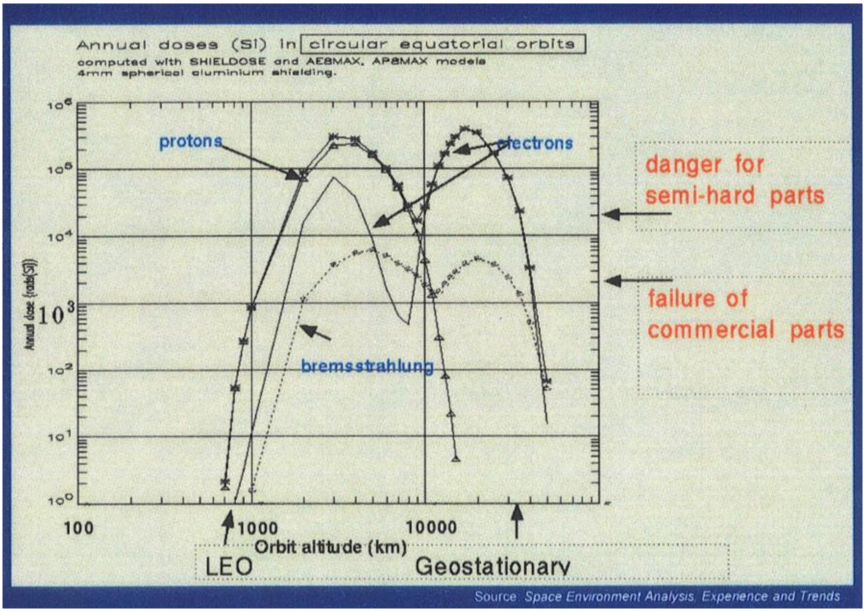


Fig. 3. Total annual dose in space

In Brazil, the Institute for Advanced Studies – IEAv/DCTA-MD. has performed radiation tests in COTS components in its irradiation facility[12]. Results have shown so far that many modern components have accepted tolerance for total dose. Additionally, fault tolerance engineering can be used, both in hardware and software, as well as other engineering solutions to increase reliability when using COTS components in space projects.

2. Frequency coordination

So far, there is not a standard procedure for university satellites to coordinate its frequencies. More over if these type of satellites will perform operational or commercial missions, there is not yet a procedure that is compatible with the development schedule of these type of satellites. Amateur radio frequencies can not be used for commercial purposes either in S band or in VHF/UHF. Many cubesats have their frequencies allocated by the International Amateur Radio Union – IARU, but this procedure is not suported by ITU[13].

3. Debris regulation

The so called UN “25 years rule” for reentry of small sats such as cubesats and university needs to be better defined for this class of satellites. The drag area/mass ratio for most cubesats when using DAS - Debris

Assessment Software, from NASA may prevent the launching at slightly higher limits in LEO. That´s was the case with NANOSATC-BR1 that can not be lauched at 780 km., piggy back with CBERS-3. A new launching is being contracted at 600 km., in order to guarantee its reentry within 25 years after end of life. Furthermore many satellite developers question the application of the rule independently of the mass and volume of the satellite, due to diferences in the debris generation probabilities when considering these variations.

4. Launching

Despite the low cost of piggy back launching for cubesats and other university satellites, the fact that one can not chose the orbit is a drawback in many cases, especially for countries located in the tropical region of the world to which low inclination orbits are preferable. Usualy piggy backs are offered with remote sensing missions and therefore polar orbits. Dedicated launching so far for these type of satellites are not economically feasible due to their high cost relatively to the satellite cost. Small launchers are being developed but so far there is none that can solve this problem.

Among these developments there is the Brazilian Microsatellite Launch Vehicle – VLM[14], being developed by the Aeronautics and Space Institute – IAE/DCTA-MD, in cooperation with the German Aerospace Center – DLR, (Fig. 4).

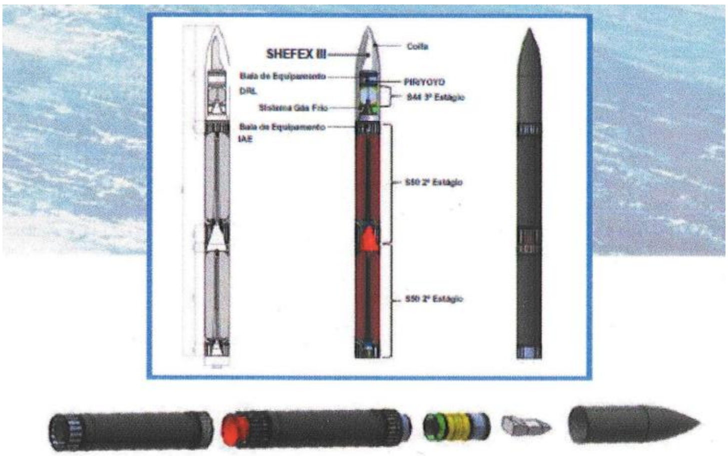


Fig. 4. The VLM[14]

This launcher has its first flight planned for 2015 and will be capable to launch 200 kg. in an equatorial orbit at 300 km. altitude or 180 kg. at 23º which is a preferable orbit for the Brazilian territory revisit.

Conclusions

Despite some difficultites to move reliable and operational missions including commercial ones, the so called university satellites may have paved the way to a new scenario for space projects. With the use of more reliable, capable and powerful electronic components, new possiblities for low cost space projects are being offered. To explore these possibilities is a challenge both to industry as well as for the R& D community.

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