Towards a "concurrent design facility (CDF)" for nanosatellites: a back-of-the-envelope calculation of the overall energy budget of OUFTI-1

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Abstract

We give a very compact account of the overall energy budget of the OUFTI-1 nanosatellite, thereby providing a useful guide for future designs, as well as an explanation of why a nanosatellite can, energetically, survive and do useful tasks in space.

People, whether technically inclined or not, are surprised to learn that a 10-cm cube can operate and survive in space. At the beginning of an amateur, educational satellite project, it is also difficult to know whether the project is feasible from an energy/power standpoint. Even during the early stages of development, it is extremely useful to have some view, even approximate, of the various levels of energies (electrical and thermal) that are provided, transferred, converted, wasted, and/or consumed at different points in the satellite, and at different positions along its orbit. However, in practice, getting this bird's eye, "energetic" view proves to be difficult. Some reasons for this are possible uncertainties in: definition of mission; its unfolding with time; ultimate orbit; electronic components needed and their availabilities; related consumptions; efficiency of solar cells; efficiency of switching converters, etc. Other reasons are a general unfamiliarity and lack of common/"physical" sense concerning the space environment, and the need to use simulation tools (e.g. STK and ESARAD/ESATAN) to get answers. Furthermore, the design process is highly iterative, with each subsystem often waiting for specifications from the others.

Based upon the experience acquired since the beginning of the educational OUFTI-1 nanosatellite project in September 2007, we answer here the challenge of presenting a compact ("back-of-the-envelope", "elevator speech") description of the overall energy budget of this satellite. We identify the providers and consumers of energy, the places where energy is transformed (and the corresponding efficiencies). We have developed the means of analysis that allow us to quickly see the effects of changes in the architecture of the satellite, the orbit, and other parameters. At one extreme, there is the conversion of solar energy into electrical energy (stored in the battery and/or provided directly to client subsystems), and, at the other, the radiofrequency (RF) power/energy required by the downlink budget. In between, there are the electrical-energy conversions (mainly in the switching converters), the other clients, and the various losses. The bottom line for us is to know how much communication time is available in amateur-radio D-STAR communication mode (digital voice and data), once the vital needs of the satellite have been satisfied, such as powering the on-board computers and the emergency beacon (which is always "on-the-air").

Having, early-on, such a high-level view of the overall energy budget in a nanosatellite would have been extremely useful for us. We thus hope that our contribution will help other nanosatellite teams to quickly master the energy considerations aboard their satellites. Our contribution is also a first step towards the design of a full-fledged "concurrent design facility (CDF)" for nanosatellites, similar to those used by space agencies for designing larger satellites. In addition, it offers to anyone a concise explanation of why a 10-cm cube can, from an energy standpoint, accomplish a useful mission in space.