Design and implementation of a strategy for handling the telecommands and telemetries of the nanosatellite OUFTI-1

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We describe our strategy for handling the telecommands (TCs) and telemetries (TMs) of the OUFTI-1 student nanosatellite system being developed at the University of Liège. TCs will be sent to, and TMs received from, the satellite via the amateur radio protocol AX.25 on 435 MHz (UHF) and 135 MHz (VHF), respectively. This paper focuses on the structure of the messages that will be carried within the AX.25 frames exchanged with OUFTI-1.

Although we could have designed our own formats, we ended up deciding to use the Packet Utilization Standard (PUS), which is strongly recommended by the European Cooperation on Space Standardization (ECSS). PUS is used by virtually all the ESA missions (e.g. by XMM, ATV, ENVISAT, PROBA, and ROSETTA) as well as by some nanosatellites (e.g. SwissCube). The use of a standardized protocol allows one to reuse code from one mission to the next and eases the collaboration between satellite teams, which is particularly important for educational satellites. The use of PUS will also facilitate the transition towards the future GENSO system, which is essentially a system for interconnecting ground stations and mission control centers.

The PUS protocol defines an operational model for controlling and monitoring a satellite. It is defined at the level of the application layer of the standard OSI Reference Model. Operations are based on several service providers (application processes aboard the satellite) and service users (control processes, ground stations, etc). Each provider supplies one or more PUS services. Users must address service requests (i.e. TCs) to particular application processes, and these requests can in turn result in the generation of service reports (i.e. TMs).

PUS provides 16 standard services such as *Telecommand verification*, *Housekeeping and diagnostic data reporting*, and *Memory management*. It is also possible to define services that are mission-specific. Since the PUS aims to be as generic as possible, and since the resources aboard a CubeSat are very limited (in terms of energy, computational power, memory, etc.), it is clear that one should select among the many features only the ones that are relevant to the OUFTI-1 mission.

Besides the detailed, comparative analysis of the capabilities of the PUS, our research on the TC/TM part of the satellite has focused on deciding which subset of capabilities to retain. For example, we have found it necessary to keep the *On-board operations scheduling* service, but we have found the *Large data transfer* service unnecessary. A specific service for the D-STAR management (the payload) had to be developed according to the PUS. The tailoring process of the TC/TM protocol is a key part of defining a mission.