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On-board Payload Data Processing from Earth to Space Segment

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Abstract

Matching the users application requirements with the more and more huge data streaming of the satellite missions is becoming very complex. But we need both of them.

To face both the data management (memory availability) and their transmission (band availability) many recent R&D activities are studying the right way to move the data processing from the ground segment to the space segment by the development of the so-called On-board Payload Data Processing (OPDP).

The space designer are trying to find new strategies to increase the on board computation capacity and its viability to overcome such limitations, memory and band, focusing the transmission of remote sensing information (not only data) towards their final use.

Some typical applications which can benefit of the on board payload data processing include the automatic control of a satellites constellation which can modify its scheduled acquisitions directly on-board and according to the information extracted from the just acquired data, increasing, for example, the capability of monitoring a specific objective (such as oil spills, illegal traffic) with a greater versatility than a traditional ground segment workflow.

The authors and their companies can count on a sound experience in design and development of open, modular and compact on-board processing systems. Actually they are involved in a program, the Space Payload Data Processing (SpacePDP) whose main objective is to develop an hardware and a software framework able to perform both the space mission standard tasks (sensors control, mass storage devices management, uplink and downlink) and the specific tasks required by each mission.

SpacePDP is an Open and modular Payload Data Processing system, composed of Hardware and Software modules included a SDK.

The whole system is characterised by flexible and customizable building blocks that form the system architectures and by a very easy way to be integrated in the missions by the SDK (a development environment with encapsulated low-level drivers, HW support and testing environment). Furthermore Space PDP presents an advanced processing system to be fully adopted both as on-board module for EO spacecrafts and extra-planetary exploration rovers.

The main innovative aspects are:

- HW and SW modularity - scalability for the Payload Data Processing and AOC S/S
- Complex processing capabilities fully available onboard (on spacecrafts or rovers)
- Reduced effort in mission SW design, implementation, verification and validation tasks
- HW abstraction level comparable to present multitasking Unix-like systems allowing SW and algorithms re-use (also from available G\S applications).

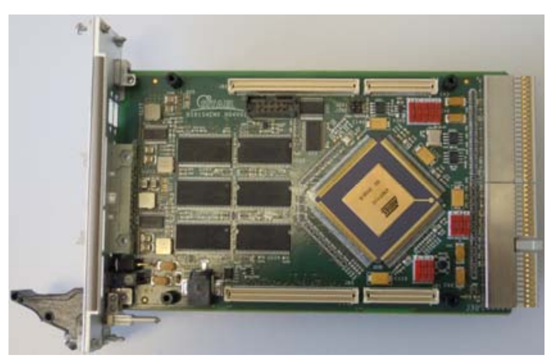

Figure 1: CPU board top view

The development approach addressed by SpacePDP is based both on the re-use and resources sharing with flexible elements adjustable to different missions and to different tasks within the same mission (e.g. shared between AOCS and data management S/S) and on a strong specialization in the system elements that are designed to satisfy specific mission needs and specific technological innovations.

The innovative processing system is proven in many possible scenarios of use from standard compression task up to the most complex one as the image classification directly on-board. The first one is just useful for standard benchmark trade-off analysis of HW and SW capabilities respect to the other common processing modules.

The classification is the ambitious objective of that system to process directly on board the data from sensor (by down-sampling or in no-full resolution acquisition modality if necessary) to detect at flight time any features on ground or observed phenomenas. For Earth application it could be the cloud coverage (to avoid the acquisition and discard the data), burning areas or vessels detection and similar. On Planetary o Universe exploration mission it could be the path recognition for a rover, or high power energy events in outbound galaxies.

Sometimes it could be need to review the G\S algorithms to approach the problem in the Space scenario, i.e. for Synthetic Aperture Radar (SAR) application the typical focalization of the raw image needs to be improved to be effectively in this context. Many works are actually available on that, the authors have developed a specific ones for neural network algorithms.

By the information directly “acquired” (so computed) on-board and without intervention of typical ground systems facilities, the spacecraft can take autonomously decision regarding a re-planning of acquisition for itself (at high performance modalities) or other platforms in constellation or affiliated reducing the time elapse as in the nowadays approach. For no EO missions it is big advantage to reduce the large round trip flight of transmission.

In general the saving of resources is extensible to memory and RF transmission band resources, time reaction (like civil protection applications), etc. enlarging the flexibility of missions and improving the final results.

SpacePDP main HW and SW characteristics:

- Compactness: size and weight of each module are fitted in a Eurocard 3U 8HP format with «Inter-Board» connection through cPCI peripheral bus.
- Modularity: the Payload is usually composed by several sub-systems.
- Flexibility: coprocessor FPGA, on-board memory and support avionic protocols are flexible, allowing different modules customization according to mission needs
- Completeness: the two core boards (CPU and Companion) are enough to obtain a first complete payload data processing system in a basic configuration.
- Integrability: The payload data processing system is open to accept custom modules to be connected on its open peripheral bus.

- CPU HW module (one or more) based on a RISC processor (LEON2FT, a SPARC V8 architecture, 80Mips @100MHz on ASIC ATMEL AT697F)
- DSP HW module (optional with more instances) based on a FPGA dedicated architecture to ensure an effective multitasking control and to offer high numerical computation with huge memory availability.
- Real time OS RTEMS and SW libraries (with C/C++ external interfaces) acting as HW abstraction level
- SDK with a development environment, a tool chain and an integrated graphical user interface
- “Callbacks” management and support to HW events (interrupts, timer, ...), including external devices (via SpaceWire) and priority definition and management.
- Large amount of volatile memory on CPU board (64 Mb Flash Memory, 80 Mb SRAM and 2 Gb SDR-SDRAM) and non-volatile (up to 2 Mb EEPROM)
- Remote programmability of the LEON bootable code.
- Debug access point: for software debug and tuning with LEON serial port (DSU) or for «in flight» monitoring via SpaceWire-RMAP