The ADPMS ready for Flight

An Advanced Data & Power Management System
for small satellites & missions

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Verhaert Space Activities

Verhaert Space

The leading provider of Small Space Systems

- **Satellites & Platforms**
- **Scientific Payloads**
- **Subsystems**
- **Ground Operations**
- **Services**

**Verhaert Space Headquarters**
- Located in Kruibeke - Belgium
- Offices: 3.742 m², Warehouses: 1.200 m²
- 2 Class 100.000 cleanrooms

**Verhaert Space Ground Station**
- Located in Redu - Belgium
- ESA satellite ground station
- Jointly operated with SES Astra

**Verhaert Space**
- Active in Space since 1983
- 110 highly skilled employees

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Small Satellite Missions

Verhaert Space is the principal provider of *Lightsat* satellites for ESA

- Mission Definition: mission analysis, AOCS engineering, requirements analysis
- Design, analysis, integration, testing and operation of turnkey satellite systems including payloads and ground segment.
- Handling of launcher interface, launch campaign and insurance aspects
- In-orbit commissioning and operations
- Satellite engineering training and mission studies

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In a contract for the European Space Agency, Verhaert Space developed a state-of-the-art control unit for small but high demanding satellites.

Built on the experience gained with the PROBA 1 satellite that has been in daily use since its launch in 2001. This next generation avionics has been developed and will have its first in-orbit demonstration in 2009 as the satellite control unit for PROBA 2.

The need for a performant, easily adapted and configured satellite control unit has been identified as crucial to succeed in the system design of small satellites with high autonomy demands.

**ADPMS – Advanced Data & Power Management System**

**The most powerful European Space Computer**
The goal of this contract was to improve even further the PROBA 1 satellite-bus (currently in orbit) in terms of:

- Power consumption
- Mass and Volume
- Design uniformity (complexity reduction)
- ‘Open’ architecture ( <-> proprietary black box design)
- Computing and data-handling performance
- Modularity
- Scalability
- Testability

A detailed look at the above top-level requirements identifies however some contradictions / challenges:

- Low power consumption versus high computing performance
- Low mass and volume versus modularity
- Highly integrated system versus testability
Satellite requirements

• Autonomous Operation
  - Autonomy in planning / scheduling
  - Autonomy in attitude control system
  - Autonomous target prediction and trajectory generation
  - High level payload management
  - Powerful automated on-board functions / FDIR
  - Internet access for payload activity requests
  - Internet access for payload data distribution
  - “Light-out” ground segment

• Pointing Modes
  - Inertial pointing
  - Earth pointing
  - Fixed earth target pointing
  - Complex manouvring – pushbroom forward / backward scanning
Satellite Objective: more resources available for the Payloads

**PROBA 1**
- **Mass**
  - ~30% for the payloads
  - ~70% for the satellite bus
- **Power**
  - ~30% for the payloads
  - ~70% for the satellite bus

**PROBA 2**
- **Mass**
  - ~40% for the payloads
  - ~60% for the satellite bus
- **Power**
  - ~50% for the payloads
  - ~50% for the satellite bus

20% reduction for the bus elements
In order to fulfill the top-level requirements listed before some drastic changes were needed. Therefore the following five essential satellite bus elements have been incorporated into one system:

- S/C Power Conditioning System (PCS)
- S/C Power Distribution Unit (PDU)
- S/C Data Handling System (DHS)
- S/C Mass Memory Unit (MMU)
- S/C Payload Processing Unit (PPU)

A very effective power, mass and volume reduction could be achieved by the integration of these elements. Resulting at Satellite level in a:

- centralisation of all data handling, storage and processing
- centralisation of all analog- and temperature sensor acquisition
- elimination of the harness that interconnected the formerly separate units
- reduction of the mechanics because of the integration into one physical enclosure.
ADPMS Architecture

Architectural overview

- The computer is partitioned into sub-modules in the form of 3U Compact-PCI boards.
  - The main modules consist of:
    - a processor board with memory
    - a TM/TC board
    - a spacecraft interface board
    - one or more data-acquisition boards
    - a camera board with mass memory
    - a reconfiguration board
- The integrated power system consists of:
  - a power conditioning module
  - several power distribution modules
  - a Compact-PCI power supply module.

It's a plug and play system, easily allowing integration of other third-party cards
A new processor

A trade-off was made between LEON2 and LEON3 in both FPGA and ASIC implementation.

Where the LEON3 (implemented in an ACTEL RTAX2000 FPGA) gives slightly better performance than the former ERC-32. For this project there was a need to demonstrate high computing performance. Therefore the LEON2-FT (AT697 from ATMEL) has been selected. It has a superior performance with respect to its successor the ERC-32 not only because it can run at a higher clock frequency but especially because of the following key-features:

- The on-chip PCI host bridge makes the connection to a high throughput PCI backplane straightforward
- The availability of a powerful debug support unit made it very suitable for this application
- The LEON supports via its PCI-target interface direct memory access which allows the onboard software to concentrate on its processing tasks while all data movement is done with a minimal software interaction
- the high clock frequency
- the 7-stage pipeline
- the data- and instruction cache
  - less sensitive to slow memories
- the little power consumption.
- the SDRAM memory controller
  - large memory footprint for minimal board space and little power consumption
A battery regulated bus

The power-bus topology that has been selected for the ADPMS is a battery regulated bus built around the effective utilisation of a Li-Ion battery.

- Compared with traditionally used Ni-Cd cells, the new Li-Ion cell is reducing considerably the difference between the maximum EOC and the minimum battery voltage for the same DOD.

- Typically small satellite bus-units and payload requirements in terms of supply bus regulation are not very stringent, the actual regulation is locally realised by their manufacturers with built-in DC/DC converters.

These facts reduce or eliminate the need for a complex and bulky PCS. The advantages being that the complexity of the electronics and the number of components decrease. Which has an immediate effect on the amount of testing involved and increases the reliability significantly.

The Power Conditioning Module designed for ADPMS takes advantage of the above elements and is therefore more suited for small satellite application in terms of mass, volume and cost.
ADPMS Architecture

Mechanical improvements

The housing design is very suitable for small satellites with a high level of integration or a large payload to accommodate, because of the following key-features:

Small form factor of the electronic boards
- Limited height for the housing
- Housing can grow in the length for the same height

Test connectors on the opposite side of the box
- easy test access guarantied even after S/C integration

Vibration levels compliant with a wide range of launchers
- facilitating a piggy back launch. selection

Detailed 3D modelling and multiple design iterations
- optimal highly integrated housing design.

Thermal control fully passive
ADPMS New technologies

The ADPMS has benefited from today rapid evolution of electronics

- the usage of low power, low voltage components (3,3V & 1.5V).
- the availability of high pin-count packages
- the selection of lightweight connectors
- the extensive utilisation of surface mount technology
- the recent availability of large radiation tolerant FPGA
The ADPMS is a high reliable computer…

All parts, materials and processes used in this programme are of known or recognised standard or have been approved by ESA after testing/qualification.

Components selection criteria:
Screening to SCC level C or:
- for microcircuits: MIL-PRF-38535 class Q or MIL-M-38510 class B
- for passive circuits: ER-MIL failure rate P
- for transistors and diodes: MIL-PRF-19500 JANTXV
- for hybrid circuits: MIL-PRF-38534 class H
- for switches: MIL-STD-1132
- for relays: MIL-PRF-39016

ECSS-Q-60-01, SCC QPL, NASA PPL, GSFC-PPL-21 and COL PPL have been used as a source information during initial components selection.

Component acceptance criteria:
For all flight components not meeting the selection criteria a Parts Approval Document (PAD) has been initiated and approved by ESA.
Listing all actions to be performed to accept the components:
- Lot acceptance testing (LAT)
- material analysis
- outgassing testing
- Destructive parts analysis (DPA)
- Burn-in testing
- Total dose testing
- Single event upset testing
- …

Radiation specification:
Compatible with LEO orbit
* Total dose of 20KRad at component level
* Single event upset are limited to 10-4 per day.
* Latch-up immunity is better than 100 Mev-cm²/mg

The design however taken into account more stringent radiation environments.
The ADPMS configured for the Proba 2 satellite offers the following functionality for the following budgets:

**Processor board**
- 100MIPS
- 64 Mbyte SDRAM
- 4 Mbyte SRAM
- 4 Mbyte Flash
- 256 kByte Prom

**Backplane data throughput**
up to 1 GBps

**Telecommand**
- 2 Mbps uplink capability
- 4 virtual channels or more
- configurable N° of MAP-ID
- 56 CPDU channels

**Power distribution**
- 24 outputs of 28V / 50W
- current protected with auto restart
- switchable or non-switchable
- battery undervoltage protected with auto switch off

**Mass memory**
- 4 Gbit
- with EDAC

**Context memory**
- 128 kbyte
- with EDAC

**Centralised time synchronisation**

**Telemetry**
- 100 Mbps downlink
- 5 virtual channels
- 2 packetwire inputs
- full encoding

**Power conditioning**
- Up to 300W satellite peak power
- Up to 6 solar sections

**Communication Interfaces**
- Up to 25 UART channels
- Up to 6 TTC-B-01 channels
- a camera interface
  - with frame grabber
- 2 packetwires

**Analogue Interfaces**
- Up to 80 analogue inputs
- Up to 32 temperature inputs

**Multi processor support**

**Time interfaces**
- 8 programmable clock outputs
- 3 clock datation inputs

**H/W generated emergency telemetry**

**H/W recovery TC decoder**

**H/W generated emergency telemetry**

**ADPMS The Result**

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**Budgets**
- Mass 13 kg
- Volume 455x160x267mm
- Power 17 W

**Time interfaces**
- 8 programmable clock outputs
- 8 clock datation inputs

**H/W generated emergency telemetry**

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Thanks to its modularity, the ADPMS can be easily configured for other applications:

- **120 Gbit Mass Memory**
  - Mass: 4.3 kg
  - Volume: 5.3 dm³
  - Power: 30 W

- **Proba 2 configuration**
  - Mass: 13 kg
  - Volume: 19.4 dm³
  - Power: 25 W

- **300W Power System**
  - Mass: 3.9 kg
  - Volume: 4.9 dm³
  - Efficiency: 98%

- **Data-Handling System**
  - Mass: 3.3 kg
  - Volume: 4.2 dm³
  - Power: 16 W

- **800MIPS Processing Unit**
  - Mass: 4.3 kg
  - Volume: 5.3 dm³
  - Power: 25 W

- **Custom configuration**
  - Mass: ? kg
  - Volume: ? dm³
  - Power: ? W

- **Payload Processing Unit**
  - Mass: 2.4 kg
  - Volume: 3.0 dm³
  - Power: 12 W

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ADPMS Key features

**High performance**
- 100MIPS LEON processor
- 1GBit/s high throughput backplane
- 4Gbit mass memory (easily expandible)
- 100MBit/s downlink capability

**Low power consumption**
- Low power, low voltage components (3,3V & 1,5V)
- Utilisation of large radiation tolerant FPGA’s

**Miniaturised avionics (mass & volume)**
- Optimal highly integrated housing design
- Qualification of new high pin-count packages (CGA)
- 99% surface mount technology (SMD)

**Easy satellite integration**
- Easy test access guarantied after S/C integration
- Open architecture (↔ black box design)
- Improved testability
- Thermal control fully passive

**Growth potential – High re-use factor**
- High throughput backplane
- Multiprocessor support
- Modular & scalable design
ADPMS Pictures

The LEON processor board (folded open)...

1,5 Watt
300 gram

The ADPMS under test...
ADPMS Pictures

Environmental testing...
Thank you for your attention