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MODULAR BOXES FOR A MODULAR ARCHITECTURE

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ABSTRACT

The competitive market of micro and mini satellites opens the space industry to Commercial Of The Shelf (COTS) electronic components. The power electronics used in the Power Conditioning and Distribution Unit was so far designed for a mission and re-used in other missions even though it wasn't fitted to the new mission need. The use of COTS in the design of new a PCDU allow us to re-think completely the design based on a double aspect: modularity and distribution.

1. INTRODUCTION

Thanks to the "New-Space" trend, the space industry has opened to non-traditional space hardware components such as new programmable components as well as to the electronics miniaturization. The combination of size, mass, power and volume of these components make them excellent candidates to work with.

DARWIN is a demonstrator built by the French Space Agency (CNES) for a new kind of avionic architecture in space developments. Its main purpose is to demonstrate the feasibility of a centralized avionics and a modular electrical architecture constructed around a large System-On-Chip (SoC) and the use of modular boxes. HYPERION is the hardware upon which the centralization aspect of our new avionic architecture is built. As for the modular aspect, CNES has studied modular boxes for the electrical architecture called BOMO. As shown in the figure on the next page, the modular boxes, BOMO, are arranged around the OBC HYPERION in order to provide an architecture that fit the mission need.

In this paper, we will only present the BOMO modular boxes, which are pieces of hardware that are the fundamental stones to our new electrical architecture.

2. PURPOSE

The BOMO boxes realize the purpose previously done by the PCDU (Power Conditioning and Distribution Unit). They are interfaced with all the spacecraft functions such as AOCS (Attitude and Orbit Control System) sensors and actuators, power management, heating system… By exploding the former PCDU, the purpose is to better fit the need in terms of power, I/O acquisition, heating control system, number of power lines, and so on using an on-the-shelf product at a low-cost recurrent price.

In complement, the others objectives of BOMO inside the DARWIN project are:

- To work on the "New-Space": low cost and quick concept for Nano and Micro satellites
- To build a common technical aim of all the technical services in CNES
- To build a generic software for the common BOMO interface
- To evaluate an architecture with a non-centralized power supply and distribution
- To be able to follow industrial development
- To have a modular test bench of new avionic architecture
- To acquire information on non-space components that need further SEE qualification

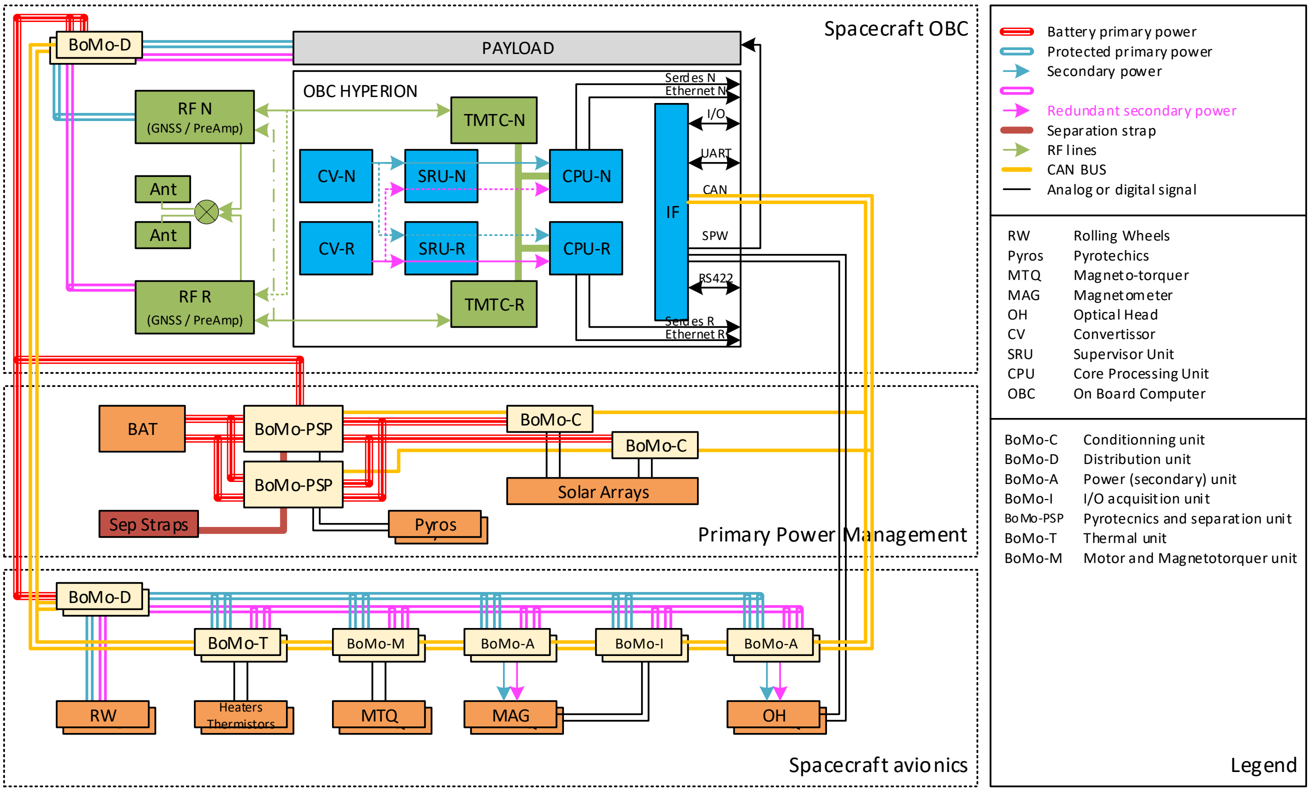
3. AVIONIC ARCHITECTURE

On the drawing below is shown an overview of the French Space Agency new avionic and electrical architecture.

In the DARWIN project, a component Zynq 7100 has been chosen to demonstrate and assess a new centralized avionic architecture in a representative environment. Considering the size of this SoC, it can allow the centralization of all the main functions of a spacecraft platform such as OBC, GNSS, TMTC, AOCS, Star-Sensors control, etc… All these functions were previously physically separated. Each function used to have its own hardware, harness, allowed power and protocol. Centralizing all these functions within a single hardware drastically reduces the associated mass, power and AIT complexity. In order to allow a significant reduction of the harness, communication with sensors and actuators is based on the CAN bus communication protocol or SpaceWire.

4. ELECTRICAL ARCHITECTURE

The electrical architecture presented in this paper is arranged around BOMOs of different kinds distributed all around the spacecraft on board computer (OBC) to distribute and managed power inside the spacecraft. In order to fully replace the former PCDU, 16 BOMO are necessary for a satellite of approximatively 300W.



CNES centralized and modular architecture

5. BOMO

A BOMO is an adaptable “modular box” build around a common core. Each BOMO type realize a specific function that is built around this common core. This core handles the input power conversion from the BNR (Non regulated bus from battery) with all the filtering stages needed to meet the EMC (Electro-Magnetic Compatibility) specifications. The common core is also built on a microcontroller that is used to managed communication with the rest of the spacecraft (common software) and to managed the specific function (specific software). The need and specifications have been identified (Size, power, cost, radiations) allowing to choose among a various number of microcontrollers. One of the goal of a BOMO is to be “low-cost” and in order to do so, the selected components have been chosen among non-space standards components. On the core is also embedded ADCs (Analog to Digital Converter) in order to acquire data concerning the BOMO such as temperature, voltage or currents. The last part of the common core is the communication link, on the BOMO, the CAN bus has been chosen in order to be able to handle a large number of clients. The choice of CAN Bus also allows to reduce the complexity, mass and cost dedicated to the harness in the spacecraft. Indeed, even if a single CAN Bus harness has to go through the satellite, the BOMO can be placed close to the need, reducing harness on the specific side reducing the mass.

As we introduce before, around the BOMO core can be arranged various hardware allowing to handle different purposes. As for now, we identified many useful BOMO, for example for power distribution, power conditioning, thermal control and regulation, I/O acquisition, passivation, pyrotechnics, separation... Each BOMO is dedicated to a purpose and can be arranged in the spacecraft closer to the need. For example, Conditioning (BOMO-C) can be physically placed close to the solar arrays and the battery while distribution (BOMO-D) will be placed wherever it is needed and as close as possible to the equipment. CNES is developing with the French company EREMS, the core block and 3 specifics BOMO:

- Conditioning (BOMO-C) allowing to handle the solar arrays and charge of the battery based on a DET system. The BOMO-C is capable of handling up to 7 array strings thus managing up to 10.5A total (2.5A on each string top).
- Distribution (BOMO-D), based on LCL it will allow up to secondary 6 lines, with maximum 2A per line.
- Passivation, Separation and Pyrotechnics (BOMO-PSP) will handle the detection of separation with the launcher thus powering-on spacecraft as well as passivation at the satellite end of life. It will will also handle enough current to trigger 4 pyrotechnics lines on the spacecraft if enough place is left on the board.

A BOMO is specifically designed to be propagation failure free on this external interface.

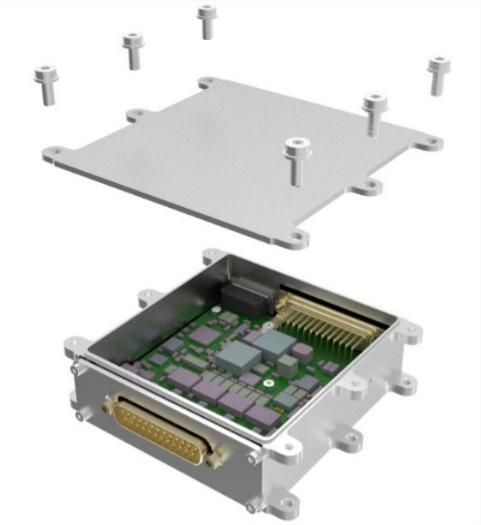
To go further in the CAN bus details, as we said, in order to significantly allow a mass and harness reduction, all these boxes exchange data and commands over a CAN bus as a specific subsystem and can be added or withdraw without complexity depending on the spacecraft’s needs. Using a communication bus instead of a point to point protocol drastically reduces the total mass. A single interface CAN is embedded in each BOMO, thus reducing the reliability of a single BOMO.

As we can see on the architecture overview, reliability of the system is obtained by implementing a cold redundancy of the BOMO. In our architecture, the redundancy is at equipment level. A BOMO is specifically designed to be propagation failure free on this external interface.

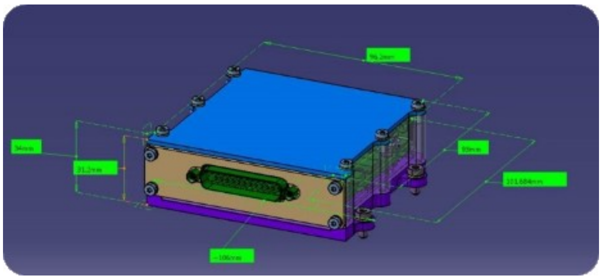
Despite the use in a global architecture, a BOMO is studied to be autonomous and can be used as a piece of equipment. For example, a BOMO distribution can be used as a single point of distribution for a payload.

6. DIMENSIONS

As we said before, a BOMO is a small box, mechanically the electronic board is designed to be 80mm*80mm. Adding on this dimension the size of the mechanical frame, the total dimensions of the BOMO are roughly 100mm*100mm*30mm as we can see on the next picture.



BOMO 3D artist representation



BOMO 3D mechanical representation

In order to fit into the specified dimensions, board are highly densified in terms of components as seen in the next picture. And to do so boards have also to be dense in terms of layers, on the BOMO-C, a 10-layers boards had to be designed to fit the mechanical specifications.

BOMO C engineering model

7. CONNECTORS

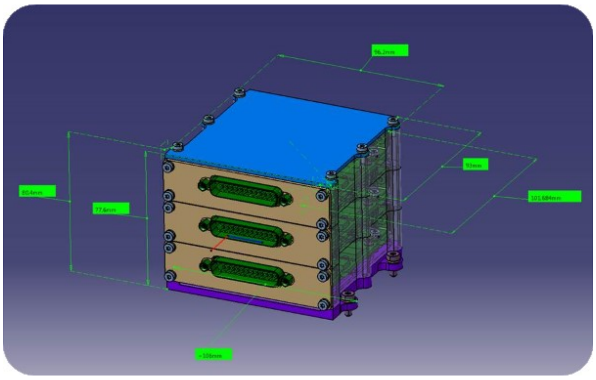
Three connectors are available on the BOMO sides. The first two, are used for the common core interface, one SubD25 for power from BNR and one MicroD9 for CAN Bus communications. The last connector is on the opposite side of the BOMO and is used for the BOMO specific interface. For the BOMO-C it is for example a SubD25 for the Solar Array interface.

8. MECHANICAL DESIGN

The BOMO mechanical box shall be the same amongst all the different BOMO types. This allow a single definition for all BOMO.

The mechanical frame has a common baseplate with 3 fixed faces. An adaptable face is available and is the only mechanical piece that can be different between BOMOs. It shall allow to change the connector type or size on the specific interface.

Mechanical qualification is realized by the contractor in order to be able to stack up to 3 BOMO as shown in the figure below:



BOMO stacking design

9. DIE CHOICE

Regarding thermal qualification, the quality level is either obtain by selecting automotive grade which is sufficient for our goals or by qualifying a complete set of die

Regarding to Natural Radiative Environment in LEO, dies behaviors such as latch-up and Single Events Effects are tested in dedicated labs.

For example, the microcontroller used in the common core has been subject to a whole SEE qualification.

Each component is specifically chosen regarding the information we have at the time and if doubts still exist, dedicated tests are planned in order to had additional information about the component.

10. STATUS AND PERSPECTIVE

At the moment, a BOMO is under validation, another is under design and another is under specification. By the end of 2019, the 3 BOMO should be all design and validated in order to have an EQM level available.

During the year a feasibility study and design has be done concerning a BOMO-M. The purpose of this BOMO is to handle the drive of a step-by-step motor or 3 magneto-torquers. The design has been done and the electronic fit into a single BOMO. Test are currently ongoing onto a breadboard in order to develop the associated software.

By the end of 2020, one other BOMO should be designed, a thermal management BOMO, it is for now under specification and should be soon developed.

And by the end of 2022, we are hoping to have in-flight data to assess the reliability of the BOMOs