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MACUP: A PROJECT FOCUSING ON DAQ HARDWARE ARCHITECTURE UPGRADES FOR SOLEIL

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Abstract

Since operation start-up more than 10 years ago, Synchrotron SOLEIL has chosen acquisition architectures that are mainly based on CompactPCI systems. The last few years there have however been an acceleration of obsolescence issues on the CPCI products and it has also been identified that this technology would shortly become a bottleneck in terms of performance for new projects. The MACUP (MAterial For data aCquisiton Upgrade) project was therefore created with two main objectives: maintaining the current facility operations by addressing the hardware obsolescence risks, all while searching for alternate high-performance solutions with better embedded processing capabilities to face new challenging requirements. One additional guideline for the project is to facilitate collaborative work for accelerator and beamline projects by evaluating and standardizing a limited set of technologies like the Xilinx ZYNQ SOC, VITA 57 FMC and µTCA standards. This paper describes the adopted methodologies and roadmap to drive this project.

CONTEXT

SOLEIL is a 2.75GeV 3rd generation synchrotron radiation source built in the early 2000s. Since 2006 SOLEIL is running continuously. Today 29 beamlines are open for users with a beam availability of more than 5000 hours a year.

Current Hardware Command/Control Architecture

The ECA (Electronique de Contrôle et Acquisitions) group is in charge of the electronic systems and the embedded software engineering dedicated for the control and acquisition of the accelerators, beamlines, and laboratory infrastructure devices. The group focuses on three main activities: Automation, Motion control, and Acquisition/Embedded processes.

The acquisition and embedded process activity is in charge of the fast analog/digital, instrumentation processes, and field bus. These processes are present in a wide range of applications on beamlines (beam imaging devices, beam-monitoring, attenuators, sample environment setups, detectors…) as well on the accelerators (diagnostics, power supplies, RF devices, Insertion devices…). This management is assured by two families of devices: the industrial standard CompactPCI (CPCI), custom in-house developments; all are remotely controlled over Ethernet in a Tango software command/control framework [1] (see Fig. 1).

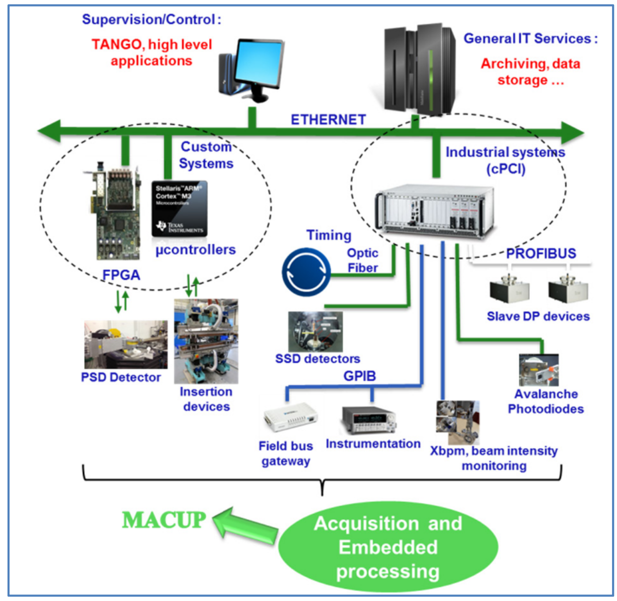

Figure 1: Acquisition and embedded process systems

Industrial COTS CompactPCI Systems

Based on a PC-type architecture but with a 19" chassis ruggedized form factor, SOLEIL has selected and standardized a large portfolio of CPCI COTS (Commercial Off-The-Shelf) analog and digital I/O cards targeting 90% of the applications for beamlines and accelerators. There are currently: 150 CPCI crates, 240 CPUs, and more than 750 peripheral I/Os boards (ADC, DAC, Video, Digital I/O, Counting, RS232, GPIB, TDC, Digitizers) in operation. The operating system mainly deploys Windows because the I/O board's drivers were mainly available for this operating system and functional in 2004.

Customized Systems

In-house systems have been developed (based on FPGA and µController solutions) to meet specific obsolescence needs or requirements not covered by COTS solutions. It is achieved by developing fully or partially customized hardware and firmware solutions (SPI platforms [2], SPEC platforms [3], FPGA CPCI boards).

THE MACUP PROJECT

Obsolescence issues, for all CPCI and custom systems, have been on an increase the last few years (obsolete components, end of life boards, drivers and operating systems out of date) which is normal after 10 years of using the same technology. In this context, the MACUP project was initiated in 2014. It is divided into 2 objectives for embedded acquisition and processing platforms:

- Ensure the operational continuity of the systems in production though MCO strategy (Maintenance in

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Operational Conditions) in order to keep the installed base at its best performance level, by working on obsolescence management (sustaining systems in operation).
- Improve acquisition systems by introducing more performance and improved on-board processing capability through technological surveys.

Methodology

The processes involved in achieving the MACUP objectives are the following:

- MCO work and technology prospecting.
- Identify emerging projects (through a global census with users to identify new needs and get users feedback on systems in production).
- Prospecting manufacturers and other facilities
- Analysis and synthesis work to propose new hardware architectures and operational solutions.

In order to increase efficiency, an advisory committee was set up around the MACUP project. This working group is made up of engineers and scientists involved in accelerators, beamlines, and control/command computing. The goal was to largely cover the requirements from all fields of activity such as requirements for accelerator diagnostics for spectroscopy beamlines.

MAINTENANCE IN OPERATIONAL CONDITIONS

This activity focuses on ensuring the operational continuity of the embedded acquisition- and processing- systems in production, not only on the CPCI systems but also on the custom systems. A medium-term strategy has been defined which was to deal with obsolescence issues (see Fig. 2) based on hardware migration campaigns. If necessary, migrations can imply new architecture evolutions.

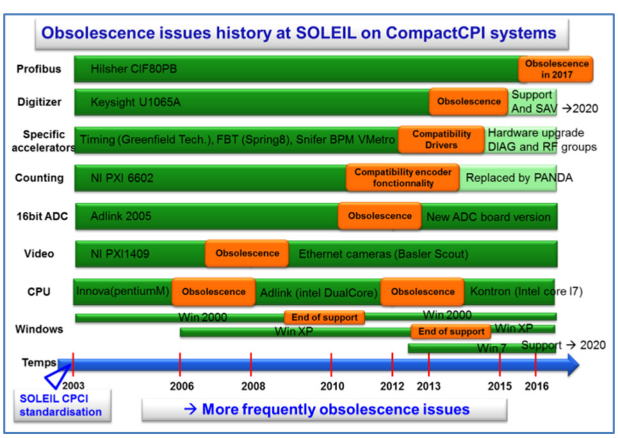

Figure 2: CPCI Obsolescence's issues since 2003.

Strategy on Industrial CPCI Systems

Two approaches were followed:

- Extend the CPCI lifetime (focusing on CPU replacements): a 2-year global migration plan aimed to replace the older CPUs (Intel Pentium M and DualCore) with a newer version (Intel Core i7) in order to fix obsolescence issues and to have homogenous installations. It concerns about 200 CPUs. This will solve critical problems such as: reliability issues with one family of CPUs, and Tango update limitation on old operating systems like Windows 2000. The benefits of this migration are also felt by users with powerful processing units (reduce dead-times, access to continuous scanning techniques such as Flyscan [4] applications).
- Modify the functionalities managed by the CPCI by identifying the functions for which the CPCI doesn't have a real added value; it concerns typically the slow processes, instrumentation, and field bus. The idea is to progressively migrate them to more adapted systems such as PLC (for example to deal with the management of slow control digital I/Os) or standalone Ethernet gateways (for example for GPIB or RS232 instrumentation bus management). This way of working allows us to carry out progressive migrations without any operational impact (for example for new installations or during equipment failures).

Strategy on Custom Solutions

There are a few applications that will not work with off-the-shelf CPCI solutions; these are addressed by internal developments. This family of systems also face obsolescence on their main components (FPGA and microcontrollers). Our approach will be to propose a structured range of products that are based on a mastered set of technologies.

TECHNOLOGY PROSPECTING

The CPCI standard (version PICMG 2.0 R3) currently used at SOLEIL is now more than 15 years old since the first specification release. Technology has evolved considerably especially in terms of bandwidth. It also seems necessary to take a step back on this technology and reconsider all the major players in the Embedded Integrated Computer Systems sector (VITA and PICMG [5], see Fig. 3).

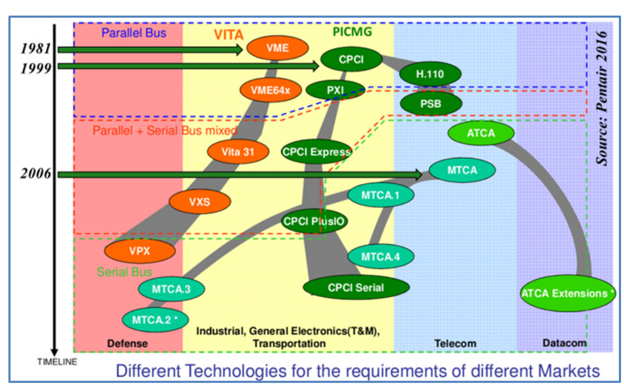

Figure 3: Main VITA and PICMG standards evolution.

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The process leads us to:

- Identify emerging technologies
- Identify potential industrial partners
- Identify the potential facility collaborations (Laboratories, accelerators ...)
- Reinforce our decision-making on strategic and technological orientations

As part of this project, particular attention was paid to:

- Work exchange with other facilities and industrial partners (Workshops, seminars, ...)
- Platform evaluations
- Market studies of various industrial standards

Criteria

This technology prospecting takes into account and optimizes a number of criteria (maturity, cost, performance, complexity, maintainability, scalability…, see Fig. 4).

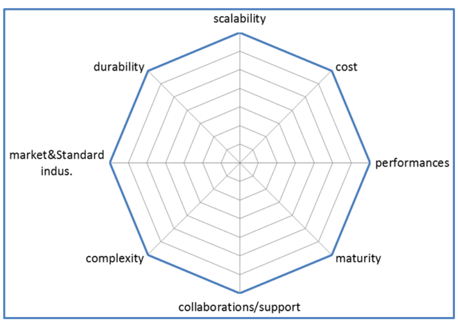

Figure 4: main criteria for evaluating new acquisition platforms.

They are defined according to our working experience at SOLEIL, especially by considering our existing systems in production and our feedbacks of operational experience at SOLEIL. They are very useful to consolidate our decision-making.

The Axes of Study

Two directions of prospecting were defined:

- Study of backplane based architectures, in order to find a CPCI alternative at SOLEIL. Through various comparative studies (see Fig. 5), a focus on µTCA technology evaluation was decided.

	CompactPCI Serial	CompactPCI Express	µTCA
Advantages	• Potential of growing up market • Hybrid backplane available (CPCI-CPCIS)	• A lot of plugnplay I/O boards available • Hybrid backplane available (CPCI-CPCIS)	• A large set of I/O boards (including FMC carrier boards) • FPGA I/O board fully customizable • High potential of collaborations between research institutes
Inconvenients	• Small set of I/O boards	• Small set of CPUs • Only one big manufacturer	• No hybrid solutions available (CPCI-µTCA) • Complex to setup

Figure 5: Comparison table between three technologies.

- Study of architecture-based standalone Ethernet solutions in order to provide compact and modular systems with reduced implementation complexity. This can be achieved by using SOM (System On Module) solutions in order to reduce development times and allowing the developers to focus efforts on adding differentiating features and unique capabilities. One of the platforms identified is the Picozed SOM from AVNET [6].

This prospecting work was conducted by trying to find interoperability capabilities between these 2 orientations, for example through the industrial standard of the mezzanine card FMC (VITA 57 standard). It also focuses on the use and standardization of programmable components such as the Xilinx Zynq SoC [7] (device integrating dual-core ARM based processor and FPGA architecture in a single device).

At the end of this process, our decision was to standardize complimentary platforms by addressing the different needs: applications requiring large embedded computing power and large I/O volumes, and compact and portable platforms with less processing capabilities with moderate number of I/Os but reduced cost.

CENSUS OF NEW NEEDS

In this phase of the project the objective was to get feedback on the existing acquisition systems and embedded processes and to identify the new incoming projects. A global survey of each concerned group was done from the accelerator part (RF, Diagnostics, and Power Supplies), beamlines (hard and soft X-ray beamlines, imaging, tomography ...) and some of the support groups (command/control computing, detectors).

Nineteen groups were interviewed. Several projects were identified and classified into the following subjects:

- Projects expressed by beamlines:
  - Experiment dead-time reduction.
  - Reconsider acquisition electronics in order to be ready for higher photon flux intensity.
  - Sample and detectors protection.
  - Flyscan Standardization for all beamlines.
- Projection for accelerators upgrade:
  - Modernization of diagnostic systems.
  - Low Level RF, RF distribution upgrade.
- Waiting for collaborative developments in detectors and electronics groups:
  - Fast feedback photon beam.
  - Pico amperemeter.
  - New imaging detectors.

At the end of the census process, 47 applications have been identified: 13 from the accelerators groups and 34 from the beamlines and detectors group. All these applications require new functionalities (by embedding the processing algorithms at the hardware level, developing embedded image processing...), better performances (better ADC resolutions, higher sampling frequencies…), and the ability to embed third party processes or hardware (custom mezzanine boards, custom FPGA IPs …).

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SYSTEM SELECTION

The census showed a real expectation in terms of new solutions in material acquisition to adapt the offer of services taking into account the degree of customizable platforms, and turnkey solutions versus collaborative solutions with a scalable range of performance. In this context, two categories of platforms have been selected for investigation: one oriented on µTCA technology, and one to work on custom solution based on Zynq SOM technology (PandABox [8] is one of these platforms nearly available for users) well adapted for beamline requirements (see Fig. 6).

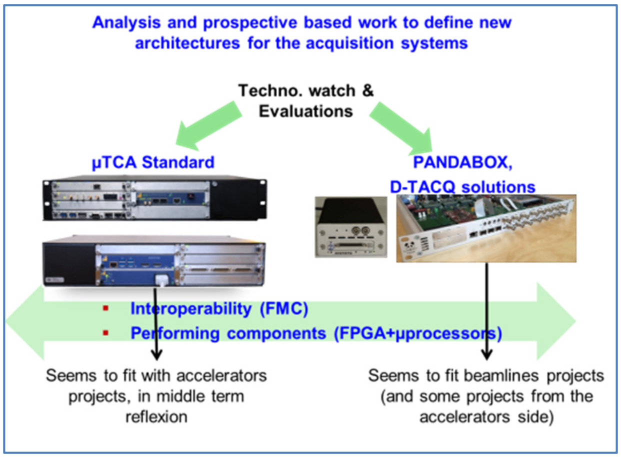

Figure 6: The two main set of hardware platforms.

Platforms According to their Degree of Openness

The census phase showed that the needs were expressed according to two categories of users: those who have limited knowledge of acquisition electronics and embedded processing, and those who are able to design electronic systems such as FPGA or µprocessor developers like in Detectors, Diagnostics, Radio Frequencies and Power Supplies groups. To satisfy these two user communities, two categories of platforms were suggested:

- Provide collaborative platforms (see Fig. 7) based on open FPGA and µprocessor architectures of which it is possible for the user to embed their process. In this case the specification is more technical: integrate an ADC (24bits SAR ADC…), embed a specific process (I/Q modulation, beam interlock algorithm…).

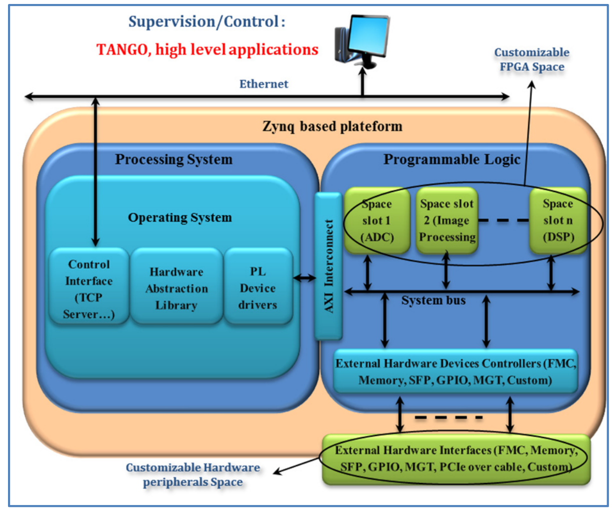

Figure 7: Our opened platform model.

- Provide "turnkey" platforms to meet the requirements of a higher functional level (managing control of a new detector, developing a Pico amperemeter …).

Platforms According to their Performances Capabilities

Given the wide range of identified projects, the offer of services was structured around a scalable set of platforms (see Fig. 8) in order to address the newest projects:

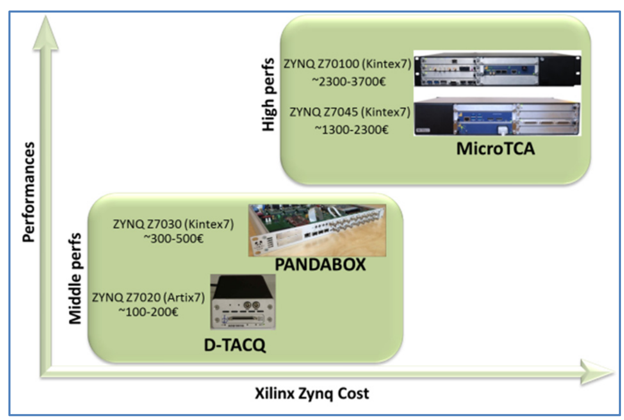

Figure 8: Hardware solutions according to performances requirements and cost.

- A set of high performance technologies such as powerful Zynq SOC available on µTCA industrial architecture. This ensures robustness, processing of a large number of I/O, high embedded processing capabilities. This approach will be evaluated soon through an FPGA developer's community from various SOLEIL groups considering the µTCA.
- A middle performance set of platforms based on architectures developed internally (or in collaboration) that will offer compact, standalone Ethernet solutions with reduced costs.

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CONCLUSION AND PERSPECTIVES

The MACUP project will permit to extend the life time (maybe for another 10 years) of the current in-production acquisition systems. It will also provide new platforms in order to address new futures challenges for beamlines and accelerators.

The next steps of the project are:

- Conduct MCO activity according to the defined orientations
- Evaluate µTCA platforms (NAT manufacturer selected for the evaluation phase)
- Develop in-house skills centered on µTCA and SoC Zynq technologies by providing test platforms and training sessions in order to optimize development cycles from development to operational solutions.
- Develop and structure the services catalogue for these new platforms (in particular through the standardization of hardware and software components).
- Conduct and support the identified projects.

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