BEST PRACTICES FOR ARCHITECTING COTS-BASED EGSE

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INTRODUCTION

Nowadays the rules of the modern global economy require the use of methodologies and technologies enabling such competitive time-to-market, quality of products and services offered by companies.

The increasing complexity of systems, Systems-of-Systems [1], suggests to the engineers and technicians to adopt a virtual model driven development process. Virtual development environments will minimize the need for physical prototypes and accelerate the development time for new products while providing realistic verification against customer requirements. These environments will support a seamless flow of product information across all phases of the system lifecycle, including design, engineering, implementation, test and evaluation, and operational support. Workflow management tools will support the globally distributed, collaborative teams that will utilize these virtual development environments. Management of product data throughout the lifecycle will be enhanced by improved support in the logistics and operations and maintenance phases using design data retained in common repositories governed by data exchange standards.

A space system is considered to be a system of systems: the spacecraft, the space segment and/or the ground segment. System Modelling & Simulation (M&S) [2], [3] is a key technology for a complete virtual model driven development process that reduces the risks and costs of space systems throughout their lifecycle and endorses a collaborative engineering environment between the customer, the prime and sub-contractors. M&S covers simulation models and simulator infrastructure, used to support specification, design, verification and operations of space systems, throughout the following facilities:

- System Concept Simulator (SCS);
- Mission Performance Simulator;
- Functional Engineering Simulator (FES);
- Functional Validation Testbench (FVT);
- Software Validation Facility (SVF);
- Spacecraft AIV Simulator (also called System Test Bench);
- Ground System Test Simulator;
- Training, Operations & Maintenance Simulator.

Fig.1 shows the architecture of the mentioned facilities.

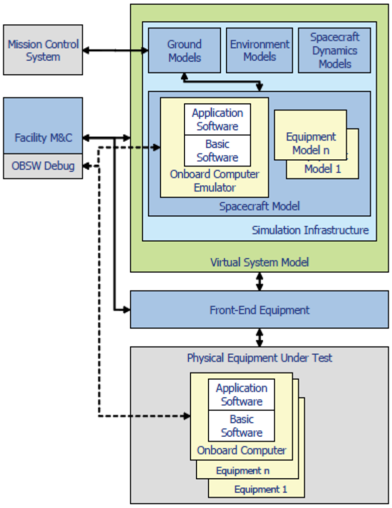

Fig. 1: Simulation Facilities Architecture [2]

During spacecraft qualification and acceptance, in the AIV facility, a simulator replaces missing equipment and also simulates the environment and the dynamics of a space vehicle. This simulator is embedded in the FEE/SCOE components. This allows real-time, closed-loop tests in which the response of the spacecraft to telecommands is taken into account, including the response to the simulated environmental stimuli to which the equipment is subjected.

The AIV Simulator often shares common models and infrastructure with SVF and can evolve to become the operations simulator.

This paper shows how Virtual Instrumentation [4] Fig.2, software-defined instrumentation, helps engineers to build a COTS-based AIV Simulator.

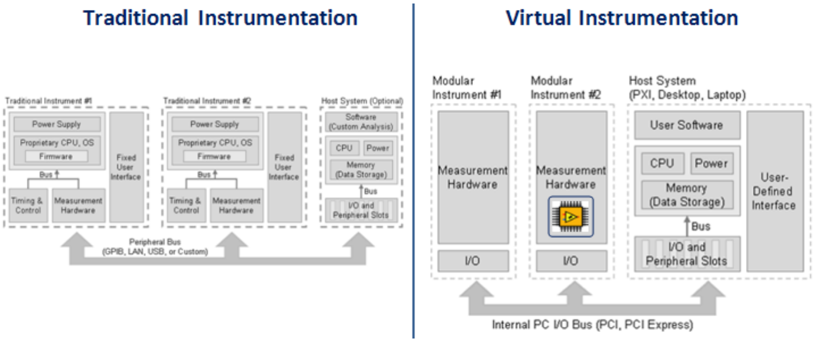

Fig. 2: Comparing Traditional and Virtual Instrumentation Architectures

BEST PRACTICES FOR ARCHITECTING FEE/SCOE

The Spacecraft AIV Simulator shall implement the following key features:

- Soft and Hard Real-Time execution of the spacecraft models;
- Hardware-In-The Loop (HITL);
- Analog Waveform Generation and Digital Pattern Generation;
- Data Acquisition;
- Synchronization, Timing and Triggering;
- Custom and Standard Communications Protocols;
- In-line Signal Processing;
- Data Storage;
- Maintenance;
- Collaborative Virtual Development Environment Fig.3.

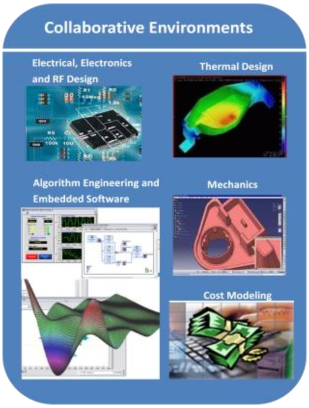

Fig. 3: Collaborative Virtual Development Environments

Next section will deal with the latest hardware and software technologies that help engineers to face the challenges of testing increasingly complicate design with ever-shrinking timelines.

Hardware Best Practices

The FEE/SCOE typically require higher data throughput because HITL and Hard Real-Time execution, continuous data streaming for in-line signal processing and data storage, and signals generation/acquisition. There is not a single ideal bus for all applications, although the bus choice determines maximum possible data throughput and the associated latency Fig.4, Fig.5. Additional throughput provided by the latest bus technologies such as PXI Express (up to 6 GB/s) [5].

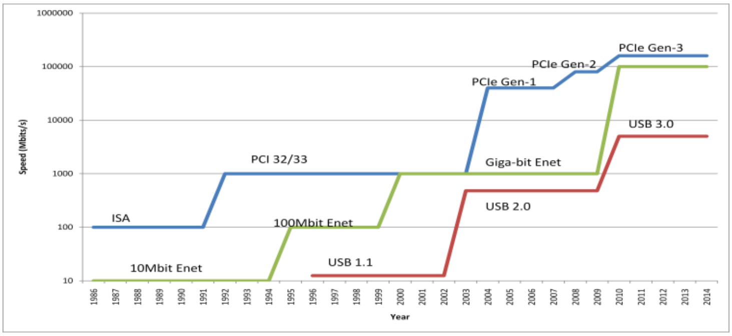

Fig. 4: Evolution of Buses Throughput

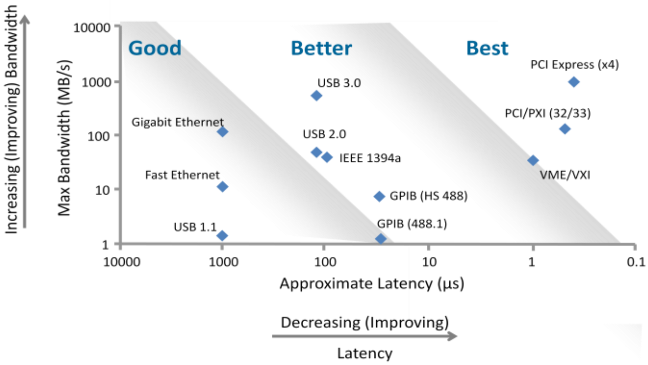

Fig. 5: Industry Bus Performance - Bandwidth vs. Latency

Moreover, synchronization, timing end triggering are critical requirements that are often overlooked aspects of a measurement and test platform. PXI Express, an open industry-standard platform, also provides all the functionalities required by application based on tight timing relationship among signals, systems test bench, or measurement synchronization tasks: differential system clock, differential signalling, and differential star triggers. By using differential clocking and synchronization, PXI Express systems benefit from increased noise immunity for instrumentation clocks and the ability to transmit at higher frequency clocks. In addition to allowing engineers to improve the performance of the system, high-frequency clocks also match well with modern processes and allow lower cost products to remove clock multiplication circuits.

PXI Express [6] enables direct point-to-point data transfer between multiple instruments without sending data through the host processor or memory. This enables devices in a system to share information without burdening other system resources. NI P2P technology Fig.6 is supported on PXI Express NI FlexRIO field-programmable gate array (FPGA) modules and PXI Express digitizers and vector signal analyzers.

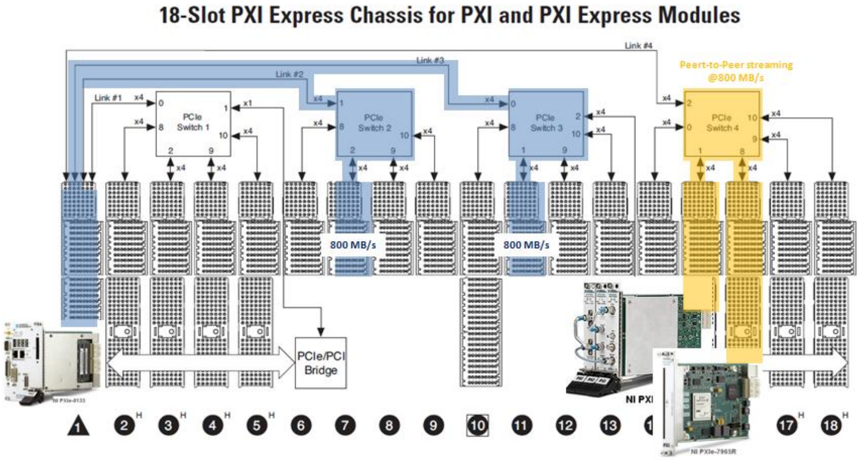

Fig. 6: PXI Express Architecture - Peer-to-Peer Streaming

FPGA technology continues to gain momentum, and the worldwide FPGA market is expected to grow to $2.75 billion by 2010. Since its invention by Xilinx in 1984, FPGAs have gone from being simple glue logic chips to actually replacing custom application-specific integrated circuits (ASICs) and processors for signal processing and control applications. Commercial off-the-shelf (COTS) hardware is also available with different types of I/O already connected to a user-programmable FPGA chip. The growing availability of high-level software tools decrease the learning curve with layers of abstraction and often include valuable IP cores (prebuilt functions) for advanced control and signal processing.

The latest technology improvement in multi-core processors [7] enables parallel processing with the capability to manage higher data rate (up to 8 GB/s). These new features [8] open new scenarios in the test, measurement and control application such as the Spacecraft AIV Simulator.

PXI Express thanks to its features, bus throughput, timing, synchronization and triggering, and the capability to host multi-core CPU, NI FlexRIO, NI Modular Instrumentation and third-part modules, is a platform that matches in one box all the requirements of the Spacecraft System Test Bench. Moreover, the built-in modularity of the platform gives to the engineers an easy way to support any future expansion of the FFE/SCOE. System modularity is the key design method (designing systems for adaptability [9]) to operate and maintain the systems throughout their lifecycle, enabling the introduction the latest technologies available and the obsolescence management.

Software Best Practices

A software development environment suitable for the Spacecraft AIV Simulator has to perform: models execution, embedded signal processing, testing, 2D/3D Human-Machine Interface (HMI), data management and reports. Moreover, it has to take the full advantage of the latest FPGA and multi-core technologies improvements.

Because the development team could be global it’s mandatory, for such kind of tool, to support the best practices of software engineering.

NI LabVIEW, Graphical System Design platform [10], supports the multi-compilers, different operating systems, and toolkits for software engineering. Like text-based languages, LabVIEW compiles to machine code in case of processors and bitfiles in case of FPGA. Performance is comparable to that achieved with text-based languages.

Typically a Test Facility consists of a simulation kernel, a database, a test supervisor, and a front-end. NI TestStand is ready-to-run test management software designed to help engineers develop automated test and validation systems faster. You can use NI TestStand to develop, execute, and deploy test system software. In addition, you can develop test sequences that integrate code modules written in any test programming language. Sequences also specify execution flow, reporting, database logging, and connectivity to other enterprise systems. Finally, you can deploy test systems to production with easy-to-use operator interfaces and take the advantages of ATML (Automatic Test Markup Language, IEEE-1671) support [11].

CONCLUSION

We examined the System Modelling & Simulation methodology for a complete virtual model driven development process of space systems and in particular the requirements of the Spacecraft AIV Simulator. Through the use of proper software architecture and highly configurable hardware Fig.7, engineers can meet the current and future requirements of the Spacecraft System Test Bench.

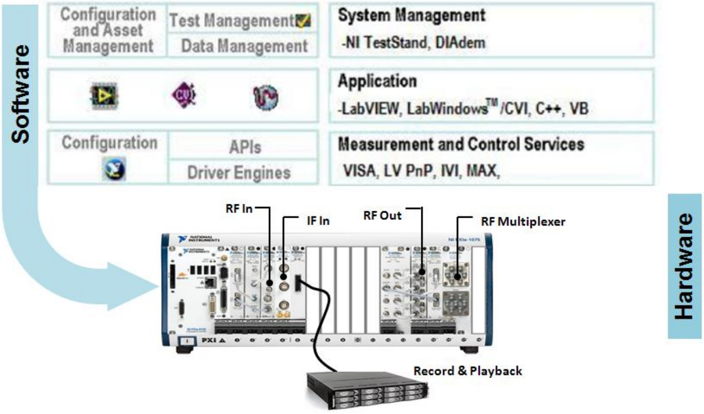

Fig. 7: PXI-based EGSE

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