Development of Scalable Mission Computers and Data Recorders

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***Abstract*—This paper presents the status of the examination of mission computers and data recorder system configurations based on the application of Software Defined Anything (SDx).**

Keywords—mission computer, data recorder, on-board processor, Software Defined

I. INTRODUCTION

Traditional satellite mission systems have focused on maximizing hardware (H/W) performance, with software (S/W) development tailored individually for each model. These systems have primarily relied on H/W to realize functionalities, resulting in a tightly coupled configuration between H/W and S/W. However, to respond swiftly and flexibly to rapidly changing circumstances, there is a strong demand for the capability to modify and update functionalities even during development. In conventional systems, modifications required either remanufacturing the entire product, including H/W, or updating the S/W. However, due to the complexity of the tightly coupled configuration, these modifications often impacted development schedules and increased costs. Therefore, we are advancing the study of Software Defined technologies (SDx), which define satellite mission systems primarily through S/W, including the development process. This approach allows for continuous enhancement of product value through S/W modifications and updates. This concept is challenging as it extends beyond the application to low-cost small satellites and experimental satellites, encompassing a comprehensive approach that includes large-scale and highly reliable medium and large satellites.

II. SOFTWARE DEFINED ANYTHING (SDX)

A. SDx

To realize SDx, it is necessary to separate H/W and S/W, decouple S/W structures, enable dynamic S/W updates, and ensure flexible connectivity for both internal and external system interactions. Additionally, the H/W must be capable of handling varying processing and data volumes for different missions by networking the input, processing, and output of observational data through standardized interfaces, creating a scalable configuration. On such componentized H/W, the S/W must be divided into foundational S/W and mission-specific S/W with appropriate interfaces. A loosely coupled architecture that supports DevOps (DevSecOps) and agile development is required to enable flexible, rapid, and frequent S/W updates.

B. Software Architechture

The software architecture to realize SDx is shown in Figure 1. The configuration consists of three interconnected components: the onboard S/W deployed on the equipment, the S/W development (Dev) environment for developing the onboard S/W, and the operational environment for managing and monitoring the onboard S/W during operation. The onboard software includes a hypervisor with H/W virtualization which can be used to apply safety/security mechanism, an OS for managing computing resources, an SDx engine providing updates and connectivity services for key SDx functionalities, and application software to realize the mission. We are progressing in our examination of these components [1].

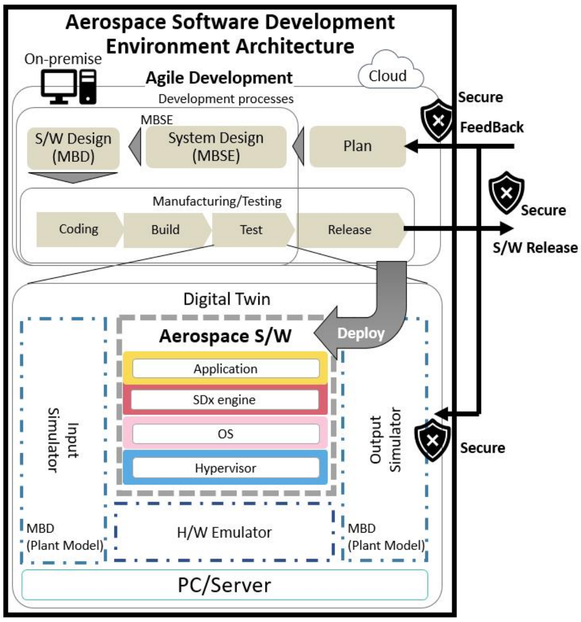

Fig. 1. Softwware Developmen Environment and its architecture

III. SCALABLE MISSION COMPUTERS AND DATA RECORDES

In recent satellites, the advancement and automation of onboard processing have begun to reduce latency, and the amount of data transmitted from the satellite to ground stations by performing processing without relying on ground stations. In SDx, periodic functional improvements using update technology are envisioned, aiming for optimization and simplification through coordination with ground processing.

Satellites are equipped with complex observation instruments, and devices that record data acquired by these instruments tend to become more sophisticated and complex due to satellite operations and customer requirements. Generally, the tight coupling of hardware and software behavior hinders scalability and flexibility. On the other hand, the premise of SDx is to absorb mission-specific differences through software and FPGA, allowing for functional updates via software and FPGA. Additionally, to accommodate the data volume and processing performance required for each mission, networking computers and data recorders with standard interfaces is a crucial element for ensuring scalability. Particularly in recent years, the evolution of high-performance computing boards has progressed, enabling the handling of a wide variety of missions by combining high-performance computing boards like Figure 2.

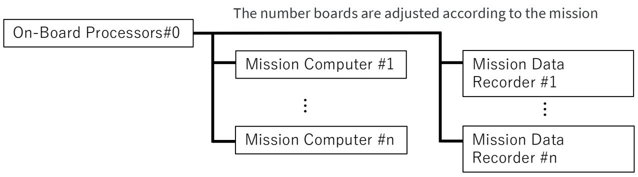

Fig. 2. Combination of mission computers and data recorders

A. *Backplane and Heterogeneous Board*

One of the considerations here is the use of Space VPX for networking with standard interfaces. Space VPX, which is increasingly adopted by many manufacturers, is a high-performance modular system standard designed for use in space environments, featuring interoperability and high-speed communication. By using standardized modules, it is possible to support system expansion and upgrades, ensuring scalability. In the medium term, the aim is to reduce development time and costs.

High-performance computing boards, by combining high-performance heterogeneous boards as shown in Figure 3[2] equipped with FPGA, CPU, GPU, etc., enable adaptation to diverse missions, improvement of data processing capabilities, and efficient resource utilization by leveraging the characteristics of each processor. For example, scalability can be ensured by connecting multiple heterogeneous boards and data recorder boards. In in-house development, from a system perspective, we are evaluating the suitability for various missions and considering the integration of model-based development aimed at the digitalization of system development processes [3]; from a software perspective, we are considering the architecture; and from a hardware perspective, we are examining size and heat dissipation. Additionally, there are data switch and routing cards, power supply cards, memory cards, and multiple payload data input/output cards besides CPU cards, so the generalization of pin assignments is also defined as a challenge, and in-house discussions are ongoing. Figure 3 is an illustration, but for simple mission requirements, one heterogeneous board and one mission data recorder are installed, and for complex requirements, multiple boards are connected via the SpaceVPX backplane.

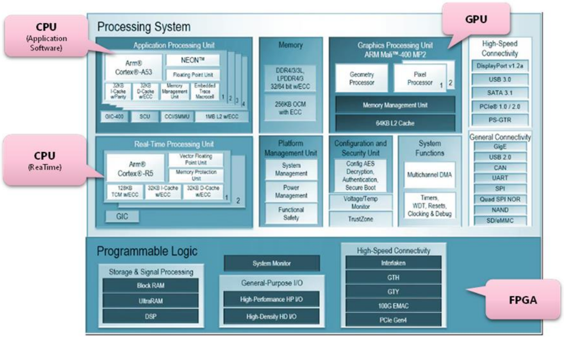

Fig. 3. Example of Heterogeneous Board (Zynq Ultrascale+) [2]

IV. SUMMARY

In recent satellites, the advancement and automation of onboard This abstract discusses the status of the scalable architecture of satellite systems using SDx. The development of satellite systems utilizing SDx is expected to provide flexible, scalable, efficient, and cost-effective solutions. Future efforts will focus on trials, with collaboration across systems, hardware, and software to move towards realization.

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