WHITE PAPER

VNX+: A MODULAR, SCALABLE COMPUTING ARCHITECTURE FOR AUTONOMOUS VEHICLES

Mark Littlefield, Director, System Products
Elma Electronic Inc.

Uncrewed vehicles often experience severe space, weight, and power (SWaP) constraints over other platforms when it comes to control and payload electronics. The new VITA 90 (VNX+) and VITA 93 (QMC) standards give small-to-medium sized uncrewed vehicle integrators the potential for applying the Modular Open System Approach (MOSA) and leveraging commercially-available standards-based components for their systems. This approach can dramatically decrease the cost and time-to-deployment of complex autonomous platforms and their sensor payloads. In this presentation, we examine how the Sensor Open Systems Architecture Technical Standard, or SOSA®, has incorporated VNX+ as a key element of its architecture. Additionally, we examine how components based on these stand-ards can be brought together to form systems, how QMC I/O mezzanines play a critical role in these systems, and how by leveraging VNX+ and QMC as part of a MOSA system design approach, integrators can realize dramatically better time to deployment and lower cost versus a custom design approach. We will also look at both the advantages and disadvantages of the VNX+/QMC approach to system integration, including thermal and other environmental considerations, and examine design decisions one might make when designing a system using VNX+ and QMC components.

INTRODUCTION

VNX+ (VITA 90) is a new, modular component standard designed specifically for complex electronics assemblies requiring high-performance interconnects and I/Os in space-constrained environments. QMC (VITA 93) is a new, small I/O mezzanine card standard created to complement modular components based on standards such as VNX+ and to provide a flexible, standards-based method of adding mission-dictated I/Os to a system. These two standards and the components being developed in alignment with them give autonomous system integrators a valuable new tool for quickly integrating and deploying platforms with advanced, high-performance sensor payloads.

The small size of VNX+ and QMC are obvious attributes making them attractive architectures for uncrewed systems. While 3U VPX is a popular form factor for larger autonomous vehicle control and sensor processing systems, there are many platforms that require something substan-tially smaller. Until now system integrators working on these SWaP-constrained platforms were obliged to cobble together systems from various COTS or custom components with custom me-chanical and thermal structures. VNX+ and QMC (especially leveraging the SOSA Technical Standard) open the door to a standards-based approach to integrating these systems, with comparable high-performance interconnect and flexible mezzanine-based I/O options in a package that is roughly 30% of the volume of 3U VPX on a per-slot basis. Leveraging COTS components offers quicker integration times, and the potential for relatively easy technology refreshes down the road.

However, there are many less-obvious attributes and features of these two standards that make them attractive to base SWaP-constrained autonomous systems on. To highlight this we will dive into a number of the technical details of the standards and how the components based on them can be leveraged to form compact but powerful sensor processing platforms.

BACKGROUND

The Modular Open System Approach (MOSA) to system design has in recent years demonstrated an ability to accelerate complex system integration and improve time to deployment in many domains. The Sensor Open System Architecture, or SOSA® Standard [1] is both a Technical Stand-ard and a Reference Architecture adhering to the MOSA principles, and has been successfully applied to many deployed programs leveraging 3U and 6U OpenVPX Plug-in modules (PIM) and related components based on the standard. However, many uncrewed systems are simply too space, weight, and power (SWaP) constrained to leverage even the smaller 3U OpenVPX components.

To address this, the SOSA Consortium formed the Small Form Factors Subcommittee (SFFSC) in late 2019 to explore options for hardware "physically smaller than 3U VPX" and to draft requirements language for inclusion into the SOSA Technical Standard. Early work in this subcommittee leveraged an earlier standard VITA 74 (VNX) [2] but made substantial changes and improvements to better meet the MOSA requirements. When these efforts had sufficiently matured the effort shifted to the VITA (VME International Trade Association) VSO (VITA Standards Organization) for development into a full industry standard. Given the extensive changes introduced by SOSA, a decision was made to form a new set of standard documents now known as VITA 90, or VNX+. These documents, finalized by the VSO and approved by ANSI in early 2026, are referenced by SOSA as an approved form factor, with rule language governing component implementation details to ensure that key MOSA principles such as interoperability and replaceability are met.

VNX+ OVERVIEW

The VNX+ standard is captured by a set of documents published by the VSO:

- ANSI/VITA 90.0-2026: VNX+ Base Standard [3]
- ANSI/VITA 90.1-2026: VNX+ Profile Tables [4]
- VITA 90.2-2026 VDSTU: VNX+ Optical and Coax Apertures [5]
- ANSI/VITA 90.3-2026: VNX+ Power Supply and Storage Modules [6]
- ANSI/VITA 90.4-2026: VNX+ Cooling and Mounting Systems [7]
- ANSI/VITA 90.7-2026: VNX+ Optical and NanoRF Coax Apertures Standard [8]

All are released and approved by ANSI, except for VITA 90.2 which is currently released by the VSO for trial use (VDSTU – VSO Draft Standard for Trial Use).

VNX+ is a PIM form factor 89mm wide by 78mm deep. The standard defines two board heights, 13mm and 19mm, with double-height PIMs of 27mm and 39mm also captured in the standard. The 13mm and 27mm PIMs have a 200-pin high-speed data connector (HSDC), while the 19mm and 39mm PIMs have three connector configurations (for payloads – power supplies are different): 400-pin, 320-pin with a half-size aperture for optical/coax connector modules, and 240-pin for full-size connector modules. VITA 90.3 defines a set of power supply, power conversion, and power filtering PIMs of various types and specifications.

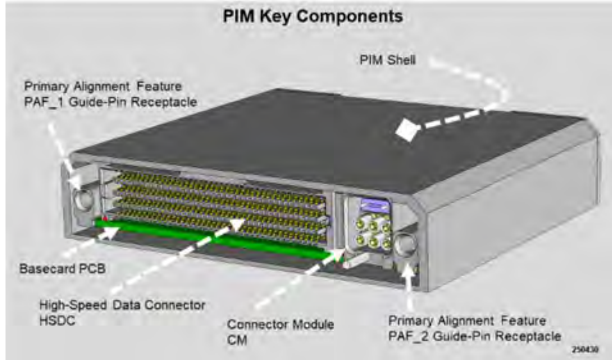

Figure 1: Basic VITA 90 module - key components. From ANSI/VITA 90.0-2026

Since SOSA narrows the module selection to only the 19mm single-height and 39mm Style-B double-height form factors, we will focus on those when we explore the details below in keeping to the topic of MOSA for uncrewed vehicles. Note, however, that much of the detail below also applies to 13mm and 27mm modules and slot profiles.

VITA 90.0 defines the basic PIM form factor defined above. VITA 90.0 PIMs are mounted into a chassis with the three walls of the chassis pressing against the PIMs to form both a retention mechanism as well as a thermal path for cooling the PIMs. Thermal interface material is typically used to absorb any mechanical tolerance between the chassis walls and the PIMs with only modest reductions in thermal efficiency.

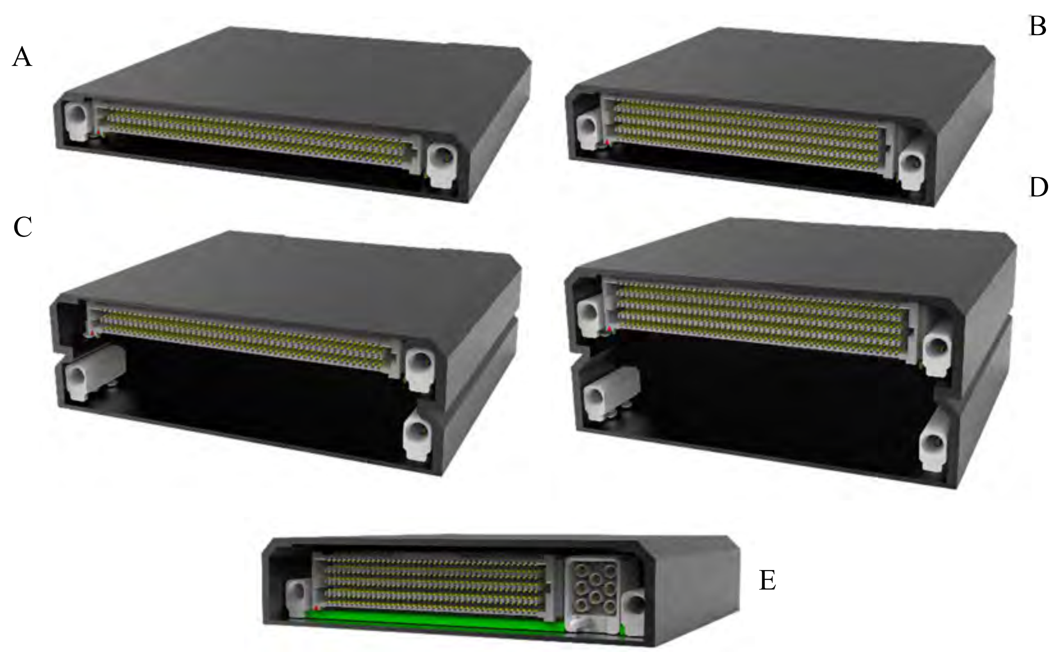

Figure 2: Examples of the VNX+ module types. (A) 13mm, (B) 19mm 400-pin, (C) 13mm double-height Style-B, (D) 19mm 400-pin double-height Style B, (E) 19mm 320-pin with a Style-2D Coax Connector Module.

However, VITA 90.4 defines an alternative module form factor that adds mounting flanges to the base VITA 90.0 external shape. These flanges can be used to mount a wedgelock, or even for mounting to a flat surface such as a bulkhead. The addition of wedgelocks to the base VITA 90.

design greatly eases the task of inserting, securing, and removing a VNX+ plug-in module from a chassis. However, the minimal metal-on-metal contact area between the flange and the chassis rail presents significant thermal resistance when compared to the large three-sided contact area found with the basic VITA 90 design.

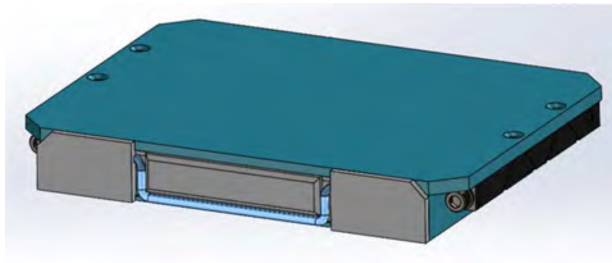

Figure 3: Wedgelock version of a VITA 90 module.

Another thing that VITA 90.0 defines is common pin assignments and payload card regions of the connector. All VNX+ modules have a region known as the S1 Utility Segment, which is where utility functionality such as power, resets, chassis management bus (IPMB), and other signals such as NVMRO (non-volatile memory read only) reside. Most profiles have these pins in the same location on the connector, although some have this region slightly rearranged. It should be noted that the S1 Utility Segment includes all of the same utility functionality found in OpenVPX (and then some), ensuring a commonality in architecture elements between the two form factors. This is important for the MOSA approach to system design.

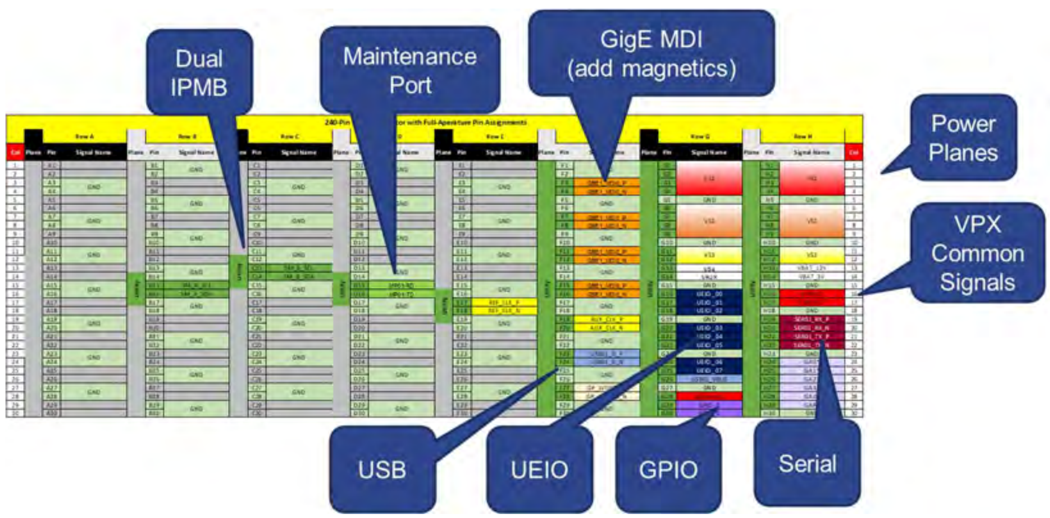

Figure 4: S0 Utility Segment based on the profile template.

One important port defined in Payload profiles S1 Utility Segment is known as the Unique External I/O (or UEIO) port. This port, not found in OpenVPX, consists of eight pins and can be defined in various ways implementing I2C and/or SPI interfaces which are useful in smaller VNX+ based systems for talking to port expanders, low-speed protocol ports, LCD displays, and similar devices often found in small systems. There are six configurations defined in VITA 90.0:

- 1x to 4x I2C
- 1x to 2x SPI
- 2x I2C and 1x SPI
- 1x I2C and 1x SPI with 1x-3x SPI Selects
- 1x SPI with 1x-5x SPI Selects
- 2x SPI with 1x SPI Select each

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Additionally, the S1 Utility Segment in payload profiles defines a set of commonly used I/O ports, including:

- Maintenance Port (RS-232 console port using LVCMOS voltage levels)
- 1000BASE-T (MDI, with no magnetics. Magnetics are to be implemented external to the PIMs)
- RS-232/422/485
- USB2
- GPIO and LVDS-GPIO

In this way these common ports can be found in the same place in any payload they are implemented on.

Payload profiles (as opposed to more specialized profiles such as switch and radial clocks) fol-low a template which in addition to the S1 Utility Segment also includes an S2 Communications Segment and an S3 Overlay Segment. The S2 Communications Segment is where the Data Plane (DP), Control Plane (CP), and Expansion Plane (EP) ports reside, which form the primary inter-module communications pathways in VNX+ systems.

The S3 Overlay Segment is a region composed of copper pins (in 400-pin profiles), an aperture for coax and/or optical (in 240-pin profiles), or a split copper/aperture region (in 320-pin profiles). The S3 Overlay Segment is where slot profiles differentiate by providing different arrays of com-munications ports or capabilities.

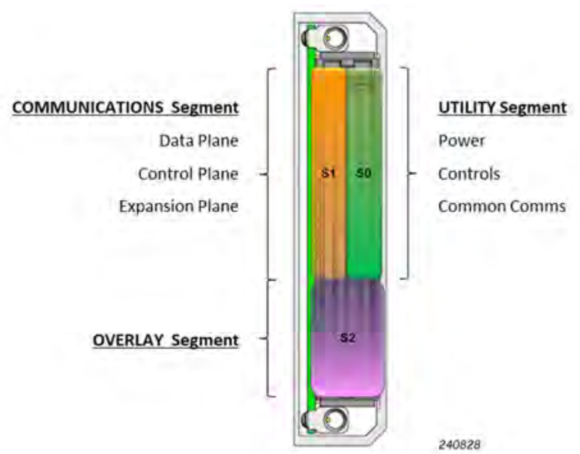

Figure 5: Rough mapping of the segments to a 19mm VITA 90 connector. Note that 13mm connector has a similar template. From ANSI/VITA 90.0-2026.

It should be noted that the VNX+ architecture closely matches the latest editions and profiles of VITA 65/OpenVPX. This was a deliberate choice by the standards committees to promote and leverage the MOSA principles found in SOSA. This commonality includes critical S0 Utility Segment signals such as NVMRO and GDiscrete1, as well as the DP/CP/EP structure for inter-module communications. Like OpenVPX, these planes have general (although not mandated) functionality in high-performance embedded systems:

- Data Plane: Fat Pipes (FP – four bidirectional lanes) for high-speed streaming data. This is where the primary application data is exchanged between PIMs, and sometimes where incoming data passes as it is sent to PIMs for processing.
- Control Plane: Ultra-Thin Pipes (UTP – single bidirectional lanes) for exchanging command and control messages. The CP is separate from the DP so to not interfere with the high-speed streaming data.
- Expansion Plane: A series of lanes that can be flexibly utilized for more closely-coupled links between PIMs. Typical uses include PCI Express between PIMs (GPU expansion, I/O, etc.) or dense FPGA-to-FPGA links. EP can also be used for direct LVDS links providing extremely low-latency channels (critical for many applications including EW and Radar).

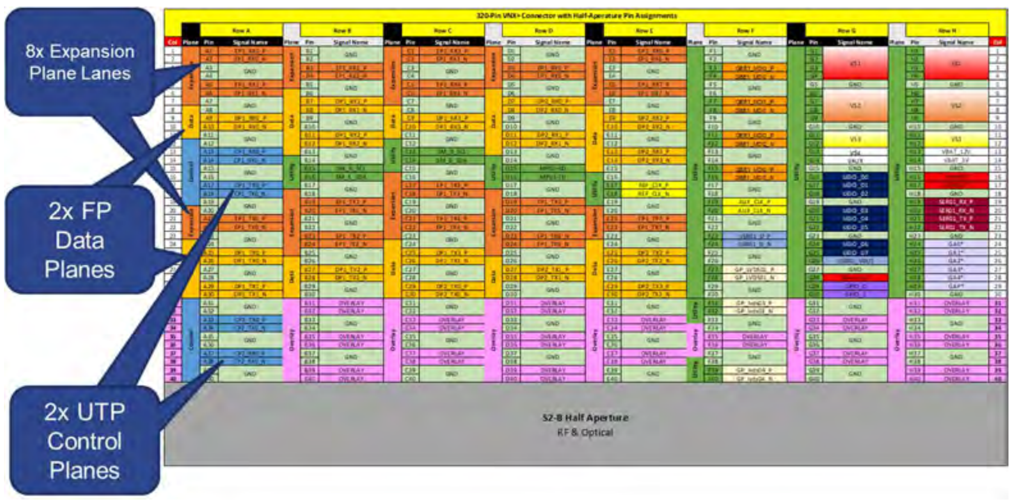

Figure 6: 320 pin profile S2 Communications Segment based on the profile template.

VITA 90.3 defines a set of power supply module profiles (PSU), along with a set of power conditioning modules (PCM), including power conversion (PCU), energy storage (ESU), and power filter units (PFU). Power subsystem modules are limited to 19mm and 39mm module heights, and the connectors are position keyed to prevent incompatible modules from mating with the backplane, or accidental insertion of a payload module into a power supply slot. VITA 90.3 modules use the same mechanical retention and cooling as VITA 90.0 and 90.4.

VITA 90.3 PSU modules also have a set of five power output profiles. These five profiles define different ratios of the four output voltages VS1 through VS4. These output profiles were defined in order to encourage payload cards to follow one of the profiles in their power consumptions, thus aligning the loads the payloads put on the PSUs with the power output by the PSU.

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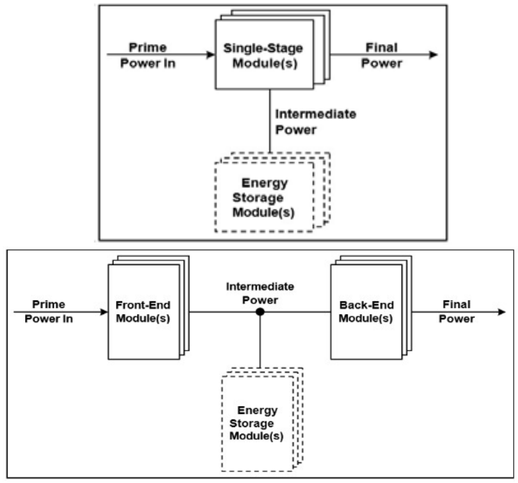

Figure 7: VNX+ Power Module architectures for single-stage and two-stage power subsystems. From ANSI/VITA 90.3-2026.

VNX+ AND SOSA

SOSA is a standard (and a reference architecture) intended to promote MOSA in building components and systems for high-performance sensor platforms such as EO/IR, Electronic Warfare, Radar, SIGINT (and other 'INTs), Communications, and Directed Energy. SOSA is designed around a set of fundamental principles to achieve its MOSA goals:

- Modular
- Interoperable
- Replaceable
- Securable
- Portable
- Plug-and-Play
- Scalable
- Resilient
- Vendor Agnostic
- Royalty Free
- Protection of IP
- Extensible and Evolvable
- Simple through complex systems
- Small through large systems

VNX+ has many options, such as different slot profiles, I/O protocols, power settings, etc. To promote the various MOSA attributes such as interoperability and replaceability, SOSA has reduced these options to a minimum set. In the following sections we will review this minimum set and describe the reasoning for the choices made in SOSA.

SLOT PROFILES

Arguably the most important rules in the SOSA Technical Standard involving VNX+ are the permitted slot profiles. There are six slot profiles defined within SOSA (excluding space-specific profiles):

- 400 Pin Payload: VNX.PL-1-HH.400-7.2.1.1-<General Payload>
    - Includes pins designated for mezzanine-mapped I/O
- 320 Pin Payload: VNX.PL-1-HH.320-8.2.2.1-<General Payload>
    - Half-size aperture for coax and optical

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- 400 Pin Switch: VNX.SW-1-HH.400-7.4.1.1-<7DP/8CP Switch>
    - 7x Data Plane, 8x Control Plane
- 320 Pin Switch: VNX.SW-1-HH.320-7.4.2.1-<5DP/5CP Switch>
    - 5x Data Plane, 5x Control Plane
    - Dual MT Optical
- 7-Slot 320-pin Radial Clock: VNX.RC-1-HH.320-7.5.2.2-<7REFCLK/7AUXCLK Overlay>
    - Based on the Payload Template
    - 7x REF_CLK/AUX_CLK pairs
    - Half-size aperture for coax
- High-density 320 pin Radial Clock: VNX.RC-1-HH.320-7.5.2.1-<22REFCLK/22AUXCLK>
    - Not based on the template
    - 22x REF_CLK/AUX_CLK pairs
    - Half-size aperture for coax

While this at first glance may seem like a lot of options, each was in fact carefully chosen to address specific needs within the SOSA application space:

- 400 Pin Profile: General SBC-type of payload, with an assortment of I/O and pins for QMC I/O
- 320 Pin Profile: Similar to the 400 Pin Profile, but with a reduced set of I/O, no mezzanine mapped I/O for QMCs, but a half-size aperture for coax and/or optical connections
- 400 Pin Switch: Maximum switch matrix ports
- 320 Pin Switch: Reduced switch matrix ports, but a half-size aperture for optical connections
- 7-Slot Radial Clock: A highly accurate clock source is a common requirement for SOSA systems. This profile implements seven slots of REFCLK/AUXCLK pairs in the S2 Overlay Segment region, preserving the S1 Communications Segment, allowing a full payload card's worth of Data Plane, Control Plane, and Expansion Plane I/O.
- 22-Slot: Replaces most of the S1 Communications Segment with REFCLK/AUXCLK pairs to support systems with large node counts.

PROTOCOLS

SOSA limits the protocols permitted on the Data Plane, Control Plane, and Expansion Plane to the following:

Data Plane	1000BASE-KX 10GBASE-KX4 10GBASE-KR 40GBASE-KR4 25GBASE-KR 100GBASE-KR4
Control Plane	1000BASE-KX 10GBASE-KR
Expansion Plane	PCIe Gen2/3/4 Serial FPDP 10/25 LVDS

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The Peripheral Port is currently limited to SATA Gen 1/2/3, but that is likely to change as the market begins to find uses for this new port.

UTILITY SEGMENT: UEIO

As mentioned previously, it is not uncommon for small systems to have the need to talk to port expanders (RS-232/422/485, GPIO, etc.), low-speed protocols (like CANBus), or specialized devices or displays. These sorts of functions are often implemented using I2C or SPI based devices. To address this, VITA 90.0 added a special port not found in OpenVPX slot profiles – the Unique External I/O port.

Again, as mentioned above, in VITA 90.0 there are six possible configurations that the UEIO pins. To improve replaceability, SOSA reduces this to one:

- 1x I2C and 1x SPI with 1x-2x SPI Selects

In this way, a payload module designer can implement I2C and/or SPI in a predictable way to enable easy reconfiguration or technology upgrades in the future.

THE IMPORTANCE OF QMC TO VNX+

Many OpenVPX cards are able to adjust their functionality by adding XMC I/O mezzanine cards. These cards have two connectors – one that connects to the host (usually via PCIe) and a second with pins that are mapped to pins on the backplane connector for custom I/O. The backplane is then designed to map those pins to sensors or other I/O channels typically outside of the OpenVPX chassis. This gives OpenVPX an important flexibility to interface to many different types of I/O channels. This is especially important for SOSA with its limited number of slot profiles for OpenVPX with a limited selection of I/O to choose from.

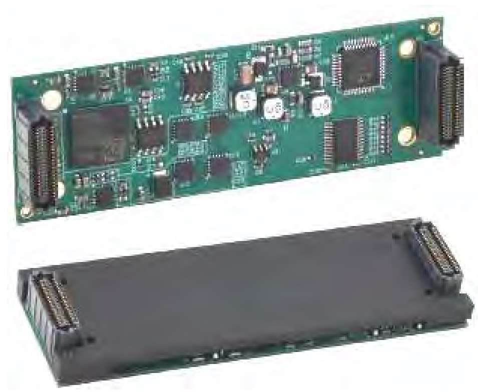

Figure 8: QMC (VITA 93) is a new small form factor mezzanine for I/O expansion.

VNX+ has the same basic need. However, XMC is too large to fit inside of a VNX+ module. After studying the I/O mezzanine market and not finding a suitable standards-based I/O mezzanine with the features needed for VNX+ I/O expansion, VITA started the VITA 93, or QMC standard effort. Now ratified and approved by ANSI [9], QMC defines a small 78.25mm x 26mm module (with single, double, triple, and quad-width options) with two connections, one for PCIe connection to the carrier, and a second for custom I/O to be mapped by the carrier to the backplane. QMC also defines

defines a conduction cooling interface that QMCs and carriers (that require conduction cooling) must adhere to, thus ensuring an "any QMC, any carrier" compatibility (see Figure 8 above). By leveraging QMC and a suitable carrier, VNX+ system integrators can add interfaces ranging from system busses such as CANBus and MIL-STD-1553, to specialized sensor interfaces such as CSI, AS6135, ARINC 818, or CameraLink.

Figure 9: The compact size of QMC is evident when we compare it to the much-larger XMC (VITA 42 and 66) standard.

THE VALUE OF SCALABLE OPEN ARCHITECTURE-BASED SOLUTIONS BASED ON VNX+

There are numerous elements and attributes of VNX+ and QMC that integrators of autonomous systems will find of particular value, ranging from specific technical features to the general value of adopting a MOSA approach to system design.

Beyond its standards-based small size, VNX+ and QMC offer a number of other features that make them an attractive form factor and architecture for SWAP-constrained autonomous systems, including:

- High-bandwidth inter-node communications fabrics: supporting links up to 10/40GBASE-KX and PCIe Gen4, with the potential for even higher-speed links. This is critical for advanced sensor processing functions such as EW, SIGINT, Radar, EOIR, etc.
- UEIO: It is not uncommon for small SWAP-constrained system to need direct actuator control or I/O port expansion. VNX+ included UEIO for this very reason, eliminating the need for external intelligent nodes to perform these tasks.
- Fiber optic and coaxial links: bringing these critical I/Os directly to the module without external conversion hardware.
- Out-of-band system management: Providing a critical health monitoring and system management functionality based on the industry standard VITA 46.11. Also introduces the potential for advanced prognostics and even in situ upgrades.
- Beyond its useful features, basing a platform on a SOSA aligned VNX+/QMC architecture brings with it the well-identified advantages of MOSA, including:
    - Rapid component integration, which translates to faster time-to-deployment.
    - The potential for deploying multifunctional systems, combining vehicle control with sensor processing, or even multiple sensor and communications functions in one package.
    - The potential for rapidly changing a platform's mission set by quickly replacing modular I/O and/or processing modules.
    - Enabling rapid system upgrades and technology insertions, ensuring that the platform can remain relevant by tracking the pace of technological innovation.

By leveraging VNX+ and QMC, platforms which in the past were too SWaP-constrained for form factors such as OpenVPX can now reap the benefits of MOSA using commercial off-the-shelf standards-based components.

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