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SOSA™ VNX+: Small Form Factor for Ground Vehicle Applications

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ABSTRACT

VNX+ is a new, emerging small form factor computing standard intended to serve severely SWaP-constrained high-performance sensor processing applications. The recent release of the Technical Standard for SOSA™ Reference Architecture, Edition 2.0, Version 2 greatly expanded its coverage of VNX+ over previous releases, and gives suppliers and integrators the basic building blocks to develop SOSA aligned plug-in modules and backplanes using this new form factor.

In this paper we will examine what the Technical Standard for SOSA Reference Architecture, Edition 2.0, Version 2 covers regarding VNX+, and how VNX+ based components can be used to develop sensor processing solutions for SWaP-constrained vehicle-based platforms.

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1. INTRODUCTION

Vehicle electronics have always been constrained by space, weight, and power (SWaP). For high-performance sensor and communications electronics this is especially true given the huge increases in bandwidth and processing demand seen in recent years. 3U OpenVPX has proven to be a rugged, reliable platform for building sensor and communications systems for ground vehicles, but space, weight, and power (SWaP) pressures remain and 3U OpenVPX is sometimes too large for very space-constrained applications. This is a problem for autonomous vehicles, which are often significantly smaller than their crewed counterparts, and require vehicle navigation and control electronics in addition to the sensor payload.

VITA 90, also known as VNX+ offers an alternative form factor for these SWaP-constrained applications. It offers nearly all of the technical features of 3U OpenVPX in a form factor that is roughly 30% of the size on a per-slot basis. In addition, VNX+ has been included as a fully-supported form factor in the latest Sensor Open Systems Architecture™ (SOSA) Technical Standard (TS) snapshot, giving it status as a recognized Modular Open Systems Architecture platform.

In this paper we will examine VNX+ as it is defined in the SOSA TS, and its applicability to military ground vehicle sensor applications.

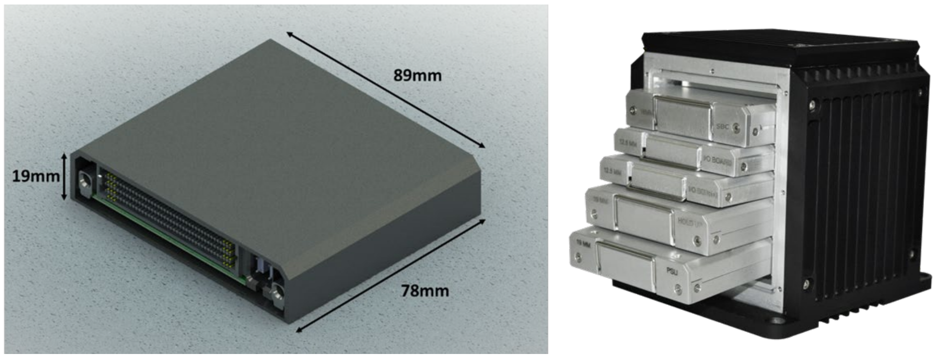


Figure 1. 19mm VNX+ Module Dimensions, and a sample VNX+ System

2. VITA 90: VNX+

The VME International Trade Association VITA 90 set of standard documents define the VNX+ form factor and system infrastructure. The standard consists of seven documents:

- VITA 90.0: VNX+ Base Standard
- VITA 90.1: VNX+ Profile Tables
- VITA 90.2: VNX+ Optical and Coax Apertures
- VITA 90.3: VNX+ Power Supply and Storage Modules
- VITA 90.4: VNX+ Cooling and Mounting Systems
- VITA 90.5: Space VNX+
- VITA 90.7: VNX+ Optical and NanoRF Coax Apertures Standard

The standard defines a plug-in module for payload modules, switch modules, and Position-Navigation-Time (PNT) modules that is 89mm wide by 78mm deep. The module height and connectors are variable:

- 13mm or 27mm, with a 200-pin connector
- 19mm or 39mm, with either a 400-pin, 320-pin, or 240-pin connector

Modules with the 320 or 240-pin connectors may optionally contain a connector module for coaxial and/or optical blind-mate connections (defined by VITA 90.2 and 90.7). VITA 90.1 defines a set of slot profiles and rule language around pin definitions and signals. The standard also includes a definition for power supply and storage modules (VITA 90.3), as well as alternative mounting and cooling mechanical structures (VITA 90.4) and special profiles and considerations regarding VNX+ for space applications (VITA 90.5).

Note that at the time of writing the various VITA 90 documents are not yet finalized or available to the general public. However, the technical material contained in them is well vetted and documented, and the SOSA Consortium felt it stable enough for inclusion in the Technical Standard. If at the time of publication any of the documents are yet to be published, they should be published shortly.

3. THE SOSA CONSORTIUM AND THE SOSA TECHNICAL STANDARD

The Sensor Open Systems Architecture (SOSA) Consortium [1] is an organization made up of US Government, industry, and academic organizations with the mission to establish guidelines for Command, Control, Communications, Computers, Cyber, Intelligence, Surveillance and Reconnaissance (C5ISR) systems, as well as other high-performance sensor-based systems for military applications. SOSA is based on the principle of Modular Open Systems Architectures (MOSA), and is driven to meet these core criteria:

- 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

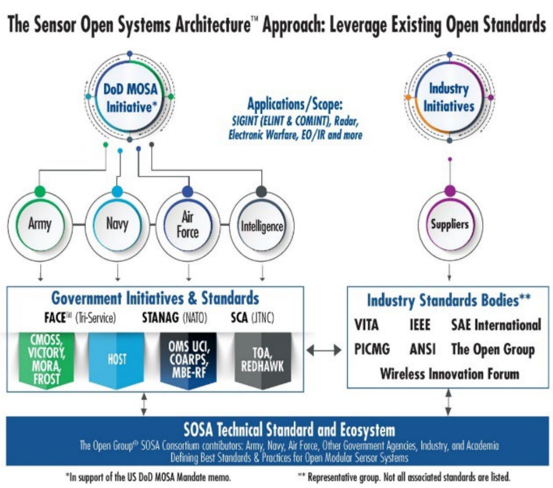


Figure 2. The SOSA(TM) Technical Standard Ecosystem

The primary focus for SOSA is on Radar, Signals Intelligence (SIGINT and other INT modalities), Electronic Warfare (EW), Electro-Optical/Infra-Red (EO/IR), Communications (Comms), and Directed Energy (DE) applications in airborne, subsurface, surface, ground, and space-based environments, but other applications like autonomous vehicle navigation and control may benefit from the consortium's work.

The primary work product of the SOSA consortium is the SOSA Technical Standard (TS). The SOSA TS is a reference architecture addressing both hardware and logical components used to build military sensor-processing platforms. The SOSA TS has undergone several iterations, with the latest being Version 2 Snapshot 2 [2] released in February 2024.

Prior to the Version 1.0 release, hardware elements defined by the technical standard were limited to 3U and 6U OpenVPX. However, there was also interest in applying the technical standard to SWaP constrained 3U OpenVPX platforms. Thus work on VNX+ was initiated and introduced to the standard.

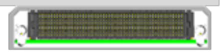
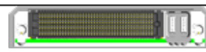
VNX+ content first appeared in September 2021 in the Version 1.0 release [3] and was updated in the August 2022 Version 2 Snapshot 1 release [4] but the material was not complete. The Version 2 Snapshot 2 release greatly expanded the VNX+ content to the point where suppliers and integrators can begin to develop hardware that is in alignment with the technical standard.

Much of the basic technical detail around VNX+ can be found in [5]. The remainder of this paper will examine the details and refinements captured in the Version 2 Snapshot 2 revision [2] of the standard, and how that can be used by integrators for ground vehicle sensor or autonomous platform processing.

4. SOSA VNX+ PLUG-IN CARDS AND SLOT PROFILES

In order to maximize the interoperability and replaceability, the SOSA TS specifies that Plug-in Cards (PICs) are limited to 19mm or double-sized 39mm module heights, and a limited set of slot profiles. Table 1 shows the connection options supported by the SOSA TS. Slot profiles defined by the standard include:

Table 1. SOSA VNX+ Connector Types

Connector/Aperture Combination	Connector Type	Aperture Fill Config	Image
VNX+ Connector Only	400-pin	None	
VNX+ w/ Half Aperture	320-pin	2x MT	
VNX+ w/ Half Aperture	320-pin	1x MT 6x RF	
VNX+ w/ Full Aperture (limited to coaxial switch applications)	240-pin	2x MT 20x RF	

- 400 Pin Payload
- 320 Pin Payload
  - Half-aperture for blind mate connector modules
- 240 Pin Payload (limited to coaxial switch functionality)
  - Full-aperture for blind mate connector modules
- 400 Pin Network Switch
  - 7x Data Plane, 8x Control Plane
- 320 Pin Network Switch
  - 5x Data Plane, 5x Control Plane
  - Dual MT Optical blind-mate connector module
- 7-Slot 320 pin Radial Clock
  - Based on the Payload Template
  - 7x REF_CLK/AUX_CLK pairs
  - Half-aperture for coaxial clock or GPS inputs
- High-density 320 pin Radial Clock
  - Not based on the template
  - 22x REF_CLK/AUX_CLK pairs
  - Half-aperture for coaxial clock or GPS inputs

In addition, there are two Space VNX+ profiles captured in the standard. Details on those profiles are outside the scope of this article.

Except for the network switches and the High-Density Radial Clock, all slot profiles are based on a Profile Template defined by VITA 90.0. This maximizes design reuse in both PIC and backplane designs. This common Profile Template captures the whole of the S0 Utility Segment, along with the arrangement of ports in the S1 Communications segment. The S2 Overlay Segment instances are defined by each slot profile.

The SOSA TS also limits the blind-mate connector module options to a minimum set. Table 1 outlines these options.

Two additional variable features found in the S0 Utility Segment of VNX+ which are limited within the SOSA TS are System Management pins and the Unique External I/O (UEIO) pins. In VITA 90.1, the System Management pins [SM0:3] can be configured in one of five ways:

- Mode 0: SM_A = IPMB_A, SM_B = IPMB_B
- Mode 1: SM_A = IPMB_A, SM_B = NC
- Mode 2: SM_A = IPMB_A, SM_B = I2C
- Mode 3: SM_A = I2C, SM_B = I2C
- Mode 4: SM_A = NC (no connect), SM_B = I2C

In the SOSA TS only mode 0 is supported. It should be noted that the SOSA technical standard requires VITA 46.11 support on these pins, including all Tier-3 commands along with a number of other optional commands, including payload mode sensors and firewall commands.

The UEIO features are intended to connect to components outside of the PICs or backplane such as port expanders, lower-speed I/O converters, or device control elements which are commonly found on small form factor computing platforms. VITA 90.1 defines six different combinations of I2C and SPI interfaces, but SOSA limits modules to a single configuration:

- 1x I2C and 1x SPI with 1x-3x SPI Selects

Additional details of each slot profile are defined in the following sections.

4.1. 400-Pin Payload Profile

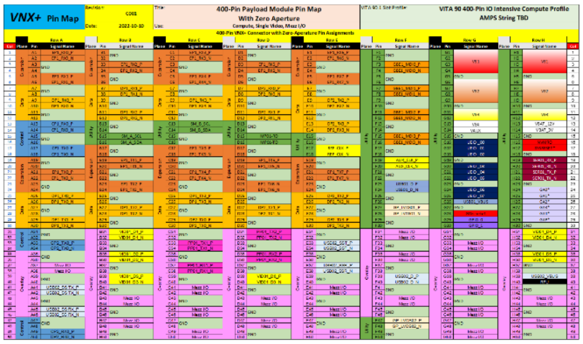


Figure 3. 400-Pin Payload Profile

The 400-pin Payload Profile (shown in Figure 3) is characterized by the following features:

- 2x Data Plane ports (Orange)
- 2x Control Plane ports (Blue)
- 8 lanes of Expansion Plane (Amber)
- USB 3 port (with power) (Pale Blue)
- Video port (Yellow)
- Peripheral port (Purple)
- 21 lanes (42 pins) for mezzanine mapped I/O (Lilac)

4.2. 320-Pin Payload Profile

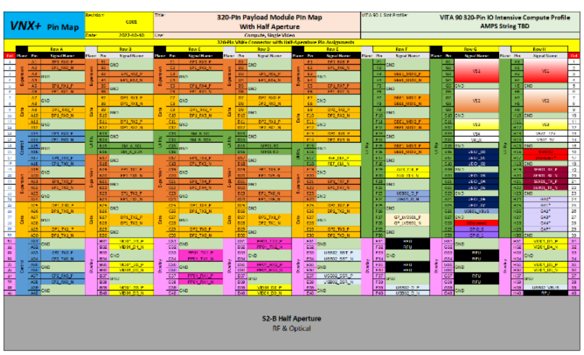


Figure 4. 320-pin Payload Profile

The 320-pin Payload Profile (shown in Figure 4) is characterized by the following features:

- 2x Data Plane ports (Orange)
- 2x Control Plane ports (Blue)
- 8 lanes of Expansion Plane (Amber)
- Additional pins to extend USB01 to USB 3 speeds (with power) (Pale Blue)
- Video port (Yellow)
- Peripheral port (Purple)

4.3. 240-Pin Payload Profile

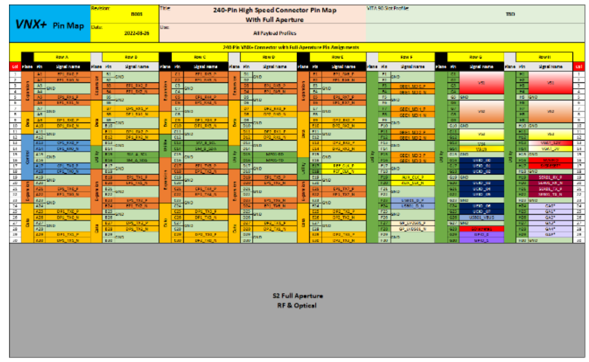


Figure 5. 240-pin Payload Profile

The 240-pin Payload Profile (shown in Figure 5) is characterized by the following features:

- 2x Data Plane ports (Orange)
- 1x Control Plane ports (Blue)
- 8 lanes of Expansion Plane (Amber)

Note that the 240-pin Payload Profile is limited to coaxial switch applications.

4.4. 400-Pin Network Switch Profile

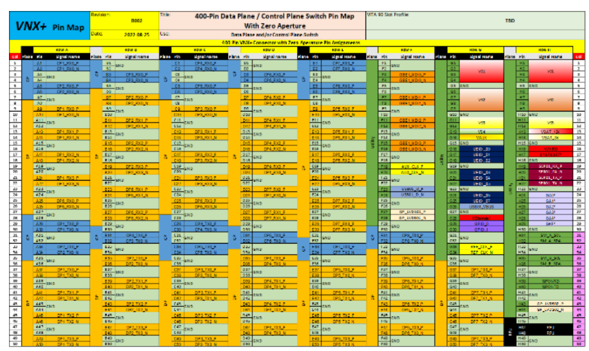


Figure 6. 400-pin Network Switch Profile

The 400-pin Network Switch Profile (shown in Figure 6) is the mechanism for forming Data Plane and Control Plane switch networks on a backplane. It is characterized by the following features:

- 7x Data Plane ports (Orange)
- 8x Control Plane ports (Blue)

4.5. 320-Pin Network Switch Profile

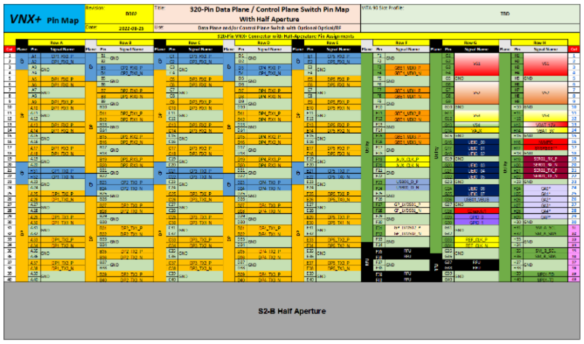


Figure 7. 320-pin Network Switch Profile

The 320-pin Network Switch Profile (shown in Figure 7) is the mechanism for forming Data Plane and Control Plane switch networks on a backplane. It is characterized by the following features:

- 5x Data Plane ports (Orange)
- 5x Control Plane ports (Blue)
- Aperture for a dual-MT Connector Module

4.6. 320-Pin Payload with Radial Clock Profile

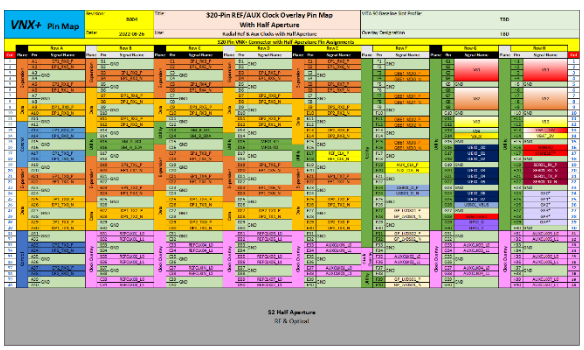


Figure 8. 320-pin Payload with Radial Clock Profile

The 320-pin Payload with Radial Clock Profile (shown in Figure 8) can be thought of as a basic Payload profile with radial clock ports added to the S2 Overlay Segment. As a result, a developer may implement this profile as a single board computer (SBC) with the added feature of a radial clock source.

This profile is characterized by the following features:

- 2x Data Plane ports (Orange)
- 2x Control Plane ports (Blue)
- 8 lanes of Expansion Plane (Amber)
- 7x REF_CLK/AUX_CLK pairs (Lilac)

4.7. High Density 320-Pin Radial Clock Profile

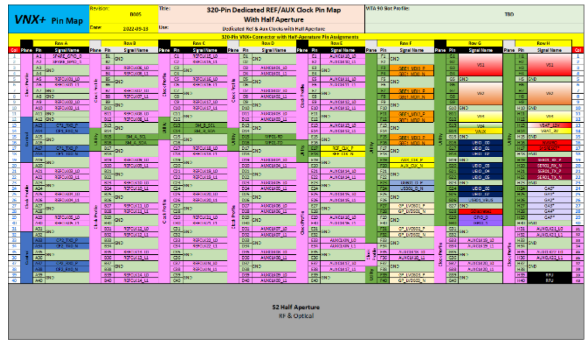


Figure 9. High-Density 320-pin Radial Clock Profile

Unlike the 320-pin Payload with Radial Clock Profile, the High-Density 320-pin Radial Clock Profile (shown in Figure 9) is much more of a pure radial clock. This profile is characterized by the following features:

- 2x Control Plane ports (Blue)
- 22x REF_CLK/AUX_CLK pairs (Lilac)

Note that while 22 pairs of REF_CLK and AUX_CLK may seem excessive for what is considered a small form factor, systems may be both space constrained but require many slots. Imagine a long tube-shaped sensor pod the size of a missile body, too narrow for 3U OpenVPX but packed with computation.

5. PROTOCOLS

The protocols defined for VNX+ in the SOSA TS are the same as those defined for OpenVPX (non-Space):

- Data Plane: Ethernet (10/40/100GBASE-KX, PCIe Gen2/3/4)
- Control Plane: Ethernet (1/10GBASE-KX)
- Expansion Plane (PCIe Gen2/3/4, Serial-FPDP, Aurora, LVDS)
- Peripheral port (PCIe/NVMe, SATA, ARINC-818)

6. GROUND VEHICLE APPLICATIONS AND VNX+: CONCLUSIONS

Due to its small size, scalability, high-performance connectivity, and natural ruggedness, SOSA aligned VNX+ components are an attractive solution path for many ground vehicle applications. Table 2 below lists many of the features of VNX+ and their benefits:

Table 2. Features and Benefits of VNX+ for Ground Vehicle Applications

Feature	Benefit
S0: Common utility signals with OpenVPX (NVMRO, SYSRESET, radial clocks, etc.)	System design patterns established with OpenVPX can be replicated with VNX+. Also, software designed for VPX platforms can run with little or no change on VNX+ hardware.
S0: Common I/O (Ethernet, Serial, GPIO/GP_LVDS, etc.)	Common I/O ports in predictable locations in the payload profiles increases design reuse.
S0: VITA 46.11 System Management	Out-of-band system management is a key element in SOSA based systems. It provides a reliable mechanism for hard monitoring and control, as well as diagnostic/prognostic capabilities.
S0: UEIO	Ideal for port expansion, low-speed interfaces (i.e. CANBus), device control (relays, LEDs, etc.).
S1: Data Plane	Primary inter-PIC data path. Based on Ethernet. Identical to OpenVPX. Easily integrated into the VICTORY architecture.
S1: Control Plane	Command/data inter-PIC path, separate from the Data Plane. Based on Ethernet. Identical to OpenVPX. Easily integrated into the VICTORY architecture.
S1: Expansion Plane	Wide path for board-to-board communications, GPUs, FPGAs, etc.
S2: Copper ports (Video, USB, Peripheral port)	Interfaces commonly found on single-board computers.
S2: Mezzanine-mapped I/O	Supports expansion through mezzanine cards with I/O mapped to the backplane. VITA 93 QMC is under development in VITA and will utilize these pins.
S2: Apertures	Provides high-performance coaxial or MT-based optical (or both) for out-of-box connectivity to sensor heads, other systems, upstream networks, etc.

While VNX+ brings many of the same features and benefits of 3U OpenVPX in a package that is less than 1/3 of the size, the small size does have a drawback with respect to power and performance densities. 3U VPX can often support payloads in the 65-85 Watts/slot range when operating at high temperatures (typically up to 85°C card edge) with conventional conduction cooling (higher power density is possible with air or liquid flow through cooling techniques). VNX+ is more limited, with power more typically in the 35W range for conduction cooling (although there is opportunity for higher densities using more innovative chassis designs and cooling approaches). In addition, the larger CPUs, GPUs, and FPGAs available today will often be physically too large to fit inside the tight VNX+ packaging. As a result, processing performance will be somewhat limited in VNX+ PICs when compared to 3U OpenVPX.

VNX+ is expected to be applied to ground vehicle applications in the coming years – most especially in the autonomous ground vehicle applications where vehicles will be much more compact and space-constrained. Applications such as 360° situational awareness systems, active protection systems, SIGINT/EW, software defined radios, and network processors are all good candidates for VNX+ implementations.

7. REFERENCES

[1]https://www.opengroup.org/sosa

[2]"Technical Standard for SOSA™ Reference Architecture, Edition 2.0, Version 2", The Open Group standard, 2024. https://publications.opengroup.org/standards/sosa/s241

[3]"Technical Standard for SOSA™ Reference Architecture, Edition 1.0", The Open Group standard, 2024. https://publications.opengroup.org/standards/sosa/c212

[4]"Technical Standard for SOSA™ Reference Architecture, Edition 2.0, Version 1", The Open Group standard, 2024. https://publications.opengroup.org/standards/sosa/s221

[5]M. Littlefield, "VNX+: A Modular, Scalable Computing Architecture For Autonomous Vehicles" in AUVSI XPONENTIAL 2023.