# VPX-Aligned Small Footprint General-Purpose Computing for Naval and Maritime Applications

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## Abstract

Naval and maritime demand for increasingly advanced computational capabilities continues to grow with the higher volumes of data from sensors, cameras and other systems, and the decision-making tools that are used for command and control purposes. Intelligent electronic devices with embedded computing capability are widely deployed to tackle the increased data processing needs. These systems are generally designed for their dedicated purpose, which results in vendor-specific computing hardware and relatively closed operating system and software applications. Managing spares for maintenance and repairs, often in remote locations, can be very costly and logistically challenging.

An alternative approach is to provide a networked general-purpose computing environment that can support many software applications across a range of operating systems, taking advantage of the many virtualization and containerization tools that have been developed for land-based cloud computing systems. When based on the OpenVPX VITA65 standards that have been developed and adopted by the defense and aerospace sectors, a miniaturized general-purpose computing solution presents an ideal architecture for shipboard and land-based deployments where size, weight, power, cooling and ruggedness are critical considerations. Further benefits accrue from significantly reduced power and cooling requirements when compared to conventional equipment designed for data centres, and the resulting 80% reduction in operational footprint and 90% reduction in GHG emissions over the lifetime of the systems.

## Naval and Maritime Computing

As demand for advanced computing resources trends inexorably upwards, for both shipboard and land-based systems, the need for space, power and cooling becomes a limiting factor.

In addition to the dramatic increase in data volumes from more complex sensors, digital signal processing and vision systems, applications and the operating systems they run have become more complex and computationally intensive to operate.

Conventional system vendors often approach this challenge using increasingly capable embedded computers in proprietary system designs.

Figure 1 illustrates a number of benefits of leveraging more powerful centralized, shared computing resources through virtualization and containerization in Cloud Computing, but this leads to additional layers of complexity, and large shipboard data centers that demand increasingly scarce resources.

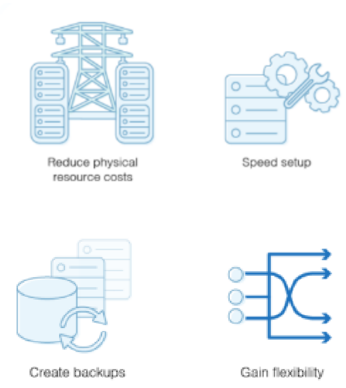


Figure 1. Advantages of Virtualization in Cloud Computing[i]

## SWaP/C for Rugged Shipboard IT Systems

Naval and maritime shipboard deployments of IT equipment are challenging due to space limitations and the need to minimize weight. Generating adequate electricity to power the equipment and keep it cool adds to the complexity of shipboard systems. Not only are size, weight, power and cooling (SWaP or SWaP/C) key challenges, but the ability to withstand vibration, shock, wide temperature fluctuations and humidity generally present significantly higher challenges than land-based deployments.

When a dedicated IT system is supplied by a vendor to address a specific purpose, a common approach is to ruggedize the IT components to handle the environment where they are used; rugged computers are widespread.

Dozens or hundreds of dedicated, but disparate, single-purpose systems creates another level of difficulty for maintenance and repairs, managing spares and upgrades, and providing suitable mounting for varied shapes and sizes of equipment, bulkhead, and equipment spaces.

The standardized 19-inch rack mount approach is widely used but does not generally address vibration and shock, and does not address the need to minimize space. In large data centers, these are usually deployed half empty in anticipation of expanded demand over time, as seen in Figure 2.

In a large modern warship, the need for dozens of 19-inch racks, containing hundreds of servers, and their corresponding space, weight, power and cooling demands has become problematic.

Figure 2. 19-inch racks and cabinets commonly used in data centers[ii]

In September 2021 the US Airforce, Army and Navy ratified the adoption of VITA65/OpenVPX and numerous other ANSI/VITA VPX standards, by releasing the first version (v1.0) of the Sensor Open Systems Architecture (SOSA) for widespread defense adoption. SOSA and other modular defense technology standards, such as MOSA and FACE, all embrace rugged, modular and compact architectures, in particular VPX.  These standards elegantly address the need for an IT hardware architecture that can handle the challenges of shipboard systems and other deployments that require low SWaP/C, ruggedness, modularity, and cost-efficient upgradeability.

## VITA65 OpenVPX

In 2003, the VMEbus International Trade Association (VITA) launched the VITA 46 working group to develop a new module standard to address the challenges of high performance when constrained by SWaP/C. Now known as the VPX standard[iii], it has led to the development of rugged commercial-off-the-shelf (COTS) modules, with high-speed serial interfaces, within the defense and aerospace industries.

More recently ratified in 2010, VITA65 (OpenVPX) is a system-level specification that defines how VPX modules are connected through a backplane in a number of standard system topologies, known as profiles[iv], providing vendor-neutral architectural guidelines for designers and integrators.

**VPX-aligned COTS general purpose computing systems**

Since the advent of large data centers, the trend toward increasingly powerful computational abilities in the cloud have spawned the growth of very capable systems that efficiently share centralized resources. The migration of data and processing from on-premises data centers to networked data centers continues for a wide range of commercial, industrial and government organizations.

For security, technical, operational, and economic reasons, the processing of data generated in naval and maritime environments is generally not practical or suitable for cloud-based processing when ships are at sea. Maintaining shipboard or on-premises land-based facilities with a logical air gap that segregates and protects network-connected digital assets can be beneficial and will generally be preferred. This approach, which is known as Edge Computing, is evolving and expanding rapidly today in order to solve the need for local, uninterrupted, real-time data processing in environments subject to SWaP/C constraints, low (or no) bandwidth, and which require low-latency response times (such as tactical or navigational response).

Bringing together interconnected systems that are aligned to the OpenVPX standard, and that can offer the computational flexibility of on-premises rack-based computing, delivers immediate advantages to the naval & maritime environment.

Figure 3. Compact VPX-aligned computing pod in a 10-inch cube chassis

Designed to be installed in a compact computing pod, such as the example shown in Figure 3, these palm-sized 3U OpenVPX-aligned servers are 90% smaller and lighter than conventional blade and rack-mount servers. Spares are easier to source, send to site, store on site, remove and install – this is extremely important for shipboard use where the need for replacement may be far from home port. The modular and standardized general purpose design of VPX servers allows all computing in a shipboard environment to be conducted on a single, interchangeable VPX server type, thus greatly simplifying cost, user complexity, and logistical complexity.

Using 75% less power and cooling can have a substantial impact on the design of the power system and cooling plant. This is especially relevant for shipboard systems and their related fuel consumption, but can also have a meaningful impact on land-based deployments where reliable shore power may be limited or costly.

Integrated networking on the VPX backplane eliminates wiring errors and connector failures that may be caused by ship vibrations, defense operations, or user error.

The current state of the art for advanced computing architecture that is used in VPX-aligned servers will feature Intel XEON or AMD Epyc, enterprise-class CPUs, or Nvidia Jetson GPUs if intensive video analytics or AI processing is required. On-board memory to 64GB (DDR4) and storage memory to 16TB per hand-sized VPX Server (NVMe) is currently available.

Long term archival data storage is commonplace in cloud data centers and this need can be essential for air-gapped shipboard systems that may be deployed far from home port for weeks or months. The ability to share storage between multiple servers using easily replaced solid state storage modules (32TB or more) within the computing pod is a highly desirable feature.

Communications interfaces to shipboard or land-based networks using wireless, wired, or fiber optic networking is a minimal requirement for any VPX-aligned computing pod. Additional I/O capability to provide interfacing to monitoring and control systems is commonplace.

### Modularity Reduces Risk

Easy replacement of compact computing components will increase operational resilience of shipboard and land-based systems, but the small size and modularity can be leveraged to reduced operational risk on board warships in other ways.

Starting with the overall design of the ship, architects have been faced with few alternatives to ever-increasingly large data center spaces and centralization of computing resources, with the corresponding need for additional power and cooling.

The alternative is to deploy decentralized and redundant computing pods throughout the ship, that can operate closer to where the computing power is needed, and greatly reducing risk during warfighting scenarios.

### Miniaturization Benefits to the Environment

In addition to the obvious benefits of reduced SWaP/C and increased ruggedness that can be attained using a VPX-aligned computing pod, such deployments will result in a meaningful reduction in greenhouse gas (GHG) emissions when compared to conventional technology that is common in land-based facilities.


Figure 4. GHG emissions by source[v]

Scope 1 GHG emissions are directly related to the fuel consumption of the ship's propulsion system, electricity generation system, and cooling infrastructure. Reducing the demand for electricity and cooling (by using more compact, lighter, and lower power computing pods) is directly linked to reduced fuel consumption and lower Scope 1 emissions.

Scope 2 GHG emissions are the indirect emissions that relate to fuel consumption that is used to generate the electricity consumed over the lifetime of the computing pods. For shipboard systems, the Scope 2 emissions may already be included in the Scope 1 emissions previously discussed or can be determined as a portion of the overall fuel consumption. For land-based naval and maritime facilities that do not have propulsion systems, the generating and cooling load must be met by the local electrical grid or microgrid, which generally includes some level of fossil fuel consumption. A compact VPX-aligned computing pod can attain 80% reduction in operating costs and in Scope 2 emissions, when compared to conventional 19-inch rack-mounted IT equipment. Using solar or wind power may also be an option.

Scope 3 emissions include all other sources of GHGs, from manufacturing to logistics (shipping and handling) and installation, to decommissions and recycling or disposal at end of life. A compact VPX-aligned computing pod contains far less material and requires far less energy to manufacture than a conventional 19-inch rack full of IT equipment. It also needs far less energy for shipping and handling, installation, upgrades and disposal. Scope 3 GHG emissions can be reduced by as much as 90%.

## Conclusions

The VITA 65 (OpenVPX) standard offers a robust architecture for the design of IT systems that are suitable for naval and maritime deployments. Due to the non-stationary nature of shipboard systems, these deployments have, until now, been largely unable to take advantage of the significant developments in cloud and on-premise cloud-like advanced computing environments, without significant commitment to the requirements for size, weight, power and cooling (Swap/C).

By aligning a compact computing pod with OpenVPX design principles, it is now possible to deploy compact, highly capable, multi-server systems that meet the ruggedness and SWaP/C requirements of naval and maritime applications.

## About the Authors

Jeff MacMillan received his Bachelor of Electrical Engineering at Royal Military College in Kingston ON and is a decorated ex-Naval Engineering Officer. He is the inventor of several patented innovations around cyber-security & edge computing technology, and sole founder of KeyNexus, a VC-funded cyber-security start-up that was acquired in 2020. CEO and co-founder of Green Edge Computing Corp, Jeff has an ongoing passion for technologies that can have an impact on naval and maritime operations, and society overall.

Rudi Carolsfeld received his Master of Electrical and Computer Engineering degree from University of Victoria in Victoria BC. He has over 25 years of experience with measuring systems, industrial controls & networking. Rudi has held senior executive roles in product management (including a co-invention patent), marketing and sales from early growth through acquisition of two significant Canadian technology companies: Power Measurement (to Schneider Electric) and RuggedCom (to Siemens). As Chief Revenue Officer and Co-founder of Green Edge Computing Corp, Rudi strives to bring game-changing technology to clients that need more capable edge computing with a smaller environmental footprint. Rudi has been a member of the IEEE since 1983.

[i] https://www.dnsstuff.com/benefits-of-server-virtualization
[ii] http://green-data.blogspot.com/2019/08/how-to-choose-data-center-racks-cabinets.html
[iii] https://en.wikipedia.org/wiki/VPX
[iv] ANSI/VITA 65.1-2021, OpenVPX™ System Standard – Profile Tables; October 4, 2021
[v] https://www.diligent.com/insights/esg/scope-1-2-3-emissions/