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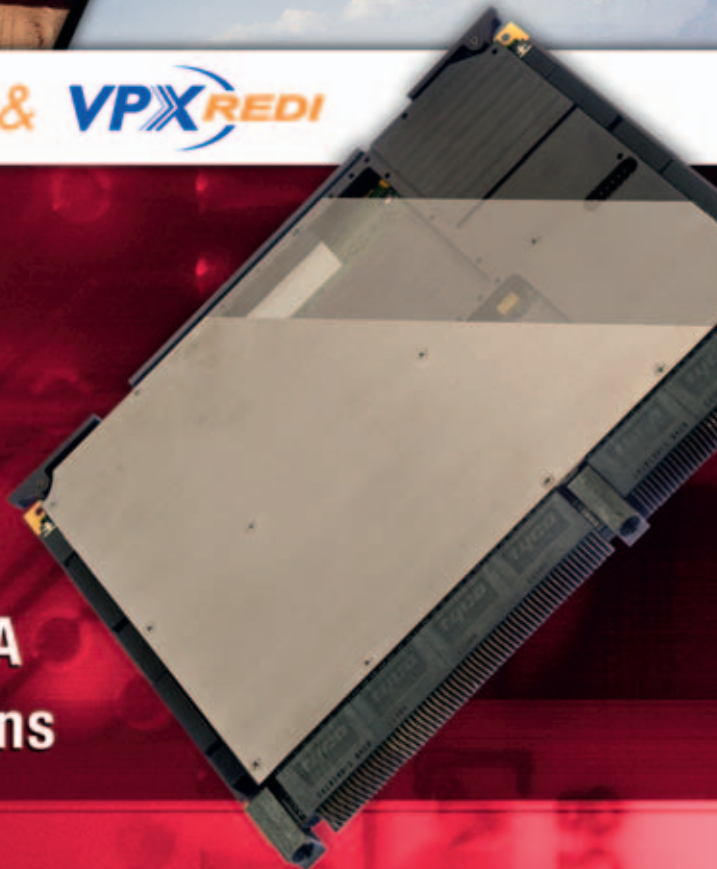
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COVER
STORY

Line Replaceable Module (LRM) Approach
SLASHES Sparing Costs and
SPEEDS Battlefield Maintenance



Line-replaceable modules speed field maintenance

By Mike Macpherson, Curtiss-Wright Controls Embedded Computing

Compared with traditional three-level maintenance, the new approach of two-level maintenance using LRMs provides more cost-effective field maintenance for warfighting systems.



■ A significant part of the cost of sustaining deployed complex weapons system over their lifetime is the cost of repairs, including both the actual repair operations and the logistics tail of mobile repair shops and spares holdings. With the 30- to 50-year life expectancy of typical military platforms such as airplanes, helicopters, armored vehicles, and ships, through-life cost has become a much more critical factor than the initial capital procurement expenditure. The high cost of sustaining deployed systems is behind a growing demand for line-replaceable modules (LRMs) with protective metal covers and ESD protection in the defense and aerospace (D&A) market.

The demand for LRMs is driven by the military desire to implement a two-level maintenance methodology, which significantly reduces costs and logistics complexity by enabling in-the-field replacement of module level components. Today's more common approach entails the removal and replacement of an entire line-replaceable unit (LRU) or subsystem, including the chassis, modules, power supply and disk drives, with the faulty system transported to a remote repair depot. Integrators and end-users have identified that operational and support costs could be reduced by 50 to 70 percent by streamlining the traditional maintenance models and adopting the simpler and more cost-effective 2-level maintenance using LRMs. In

addition, LRMs also enable increased commonality due to the ability to use common modules across multiple electronics racks within the platform. This helps improve logistics by reducing the number of spare parts that must be managed, since a single part number can be used to satisfy the field maintenance of a variety of functional modules via location-specific configuration management.

Traditional VMEbus and other COTS-based embedded computing solutions were initially designed to complement the LRU-based three-level maintenance concept (table 1). In comparison, two-level maintenance using LRMs provides a faster, more efficient and cost-effective way to maintain and upgrade today's

warfighting systems in the field. LRM technology solves a fundamental problem. When a standard unprotected system module is improperly handled or inadvertently exposed to electro-static discharge (ESD) its sensitive electronics can be easily damaged.

While the LRM concept is not new, it is only recently that significant advances have been made in defining an open standard approach. Previously, fielding LRMs has required costly closed-architecture systems. These proprietary systems inherently suffer from high development costs, high sustainment costs, and limited support options. The lack of an open standards solution for LRMs left the military with the costly and complex logistics inherent

- 1) Organisational Level (O-level):** Carried out as expeditiously as possible between missions of operational equipment and includes assessment of battle damage, preventive maintenance, and inspections. Repair of electronic equipment is by Line-Replaceable Unit (LRU), equivalent to complete box level replacement.
- 2) Intermediate Level (I-level):** Normally at a fixed facility allowing modules to be replaced and the LRUs to be fully tested before being returned to O-level. Modules are sent to the next lower level for repair.
- 3) Depot Level (D-level):** A specialised facility where individual modules can be repaired. In many cases, particularly for COTS products, the module's manufacturer provides D-level repair.

Table 1. Description of the LRU-based three-level maintenance model for the US Air Forces

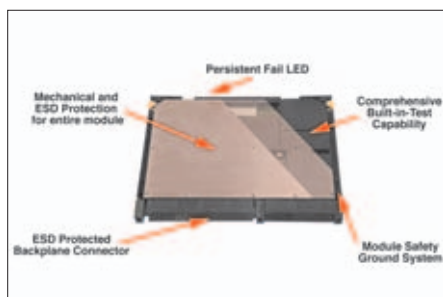


Figure 1. LRMs employ characteristics to provide enhanced mechanical and electronic protection and diagnostics support.

in the status quo subsystem-level LRU replacement strategy. The good news is that in recent years, Curtiss-Wright Controls Embedded Computing, prime military integrators and other COTS industry leaders have come together to collaboratively tackle the urgent military need for LRM-based systems, and have responded with new open standards, technology, and products that now make LRM a practical reality. The benefits of LRM are now available from open standard COTS vendors. Today's new LRM modules and LRM-based

systems are designed using VPX-REDI (VITA 48), the first open standard that defines enhanced ruggedisation using top and bottom metal covers, built-in ESD protection and fault isolation down to the module/card level. VPX-REDI LRMs enable the deployment of COTS circuit boards that can be quickly and easily removed and replaced in the field without special training or tools. Key to VPX-REDI's innovative use of protective metal covers shields the circuit board from the environment, while also providing enhanced stiffening against the shock and vibration typical of harsh battlefield conditions. The new standard also specifies the use of the new high-bandwidth connector, the MultiGig RT-2 that provides built-in ESD protection by routing static discharge away from sensitive electronics. The MultiGig connectors are designed to withstand a discharge of 15 kV (per ANSI/VITA 47).

LRMs are generally similar in size and function to traditional 6U and 3U embedded electronics products, such as the long-popular VME and CompactPCI open standard boards. But LRMs go beyond these standard board types in

the way that they employ additional characteristics to provide enhanced mechanical and electronic protection and diagnostics support (figure 1). These enhancements include top and bottom protective metal covers, rugged and keyed connectors and latches. LRMs for military applications have a number of desirable characteristics that are built around the strengths of COTS and the popular 6U and 3U form factors (table 2). The benefits of LRMs include: mechanical and ESD protection on module, ESD-protected backplane connector, safety ground system, comprehensive built-in-test capability, and persistent fail LED.

The VPX-REDI (VITA 48) standard was designed to inherently support the need for COTS LRMs. VPX-REDI is aimed at A&D applications which need to operate in harsh environments including conduction-cooled environments, and where a high value is placed on backplane I/O. VPX-REDI is strongly supported by the major military systems integrators and COTS suppliers. The standard retains many of the popular features of the VME ecosystem, the most widely-implement-

Desirable LRM Characteristics	Rationale	Compatibility with VME
ESD protection	An LRM will be handled by a maintainer in the same way as a complete boxed system, without the use of any ESD precautions.	Although a number of proprietary solutions have been offered, current connectors offer no ESD protection during handling. New VPX (VITA 46) connectors will provide ESD protection. Top and bottom covers are standardised in VPX-REDI (VITA 48) to protect the complete assembly.
Mechanical protection	Exposed components are vulnerable to damage and must be protected against handling.	Some manufacturers already offer conduction-cooled VMEbus modules with covers for protection, to special order. VITA 48 will enhance VPX modules to include covers.
Fault diagnosis/Isolation	Unambiguous fault diagnosis required to speed the repair process at 0-level.	Many COTS manufacturers already offer comprehensive Built-in-Test (BIT) and fault isolation in their military product ranges.
LRM insertion and replacement	Should be accomplished with the minimum of skills and special tools.	Conduction-cooled VME already meets this requirement. VPX enhances its capability with positive location during connector mating plus keying to ensure correct placement.
Cooling	LRMs must offer adequate cooling using current and future techniques. Future performance requirements suggest that 300 W/LRM may be required for many compute-intensive applications.	VITA 48 will offer interfaces to both conduction and liquid cooling. Liquid-cooling connectors have been tried and tested in many applications already.
Handling sensitive data	Any LRM returned to its manufacturer for repair should be free of any sensitive data.	Some COTS manufacturers now recognise this need and provide declassification functions to scrub any sensitive data stored in flash EPROM.

Table 2. LRMs are based on COTS and 3U/6U form factors

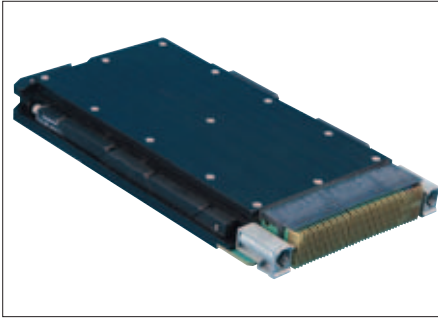


Figure 2. The VPX3-125 3U SBC is an example of a VPX-REDI module.

ed format in military applications. It goes beyond VME and CompactPCI though, providing an evolutionary roadmap for VME users that enables them to leverage the broad spectrum of high-speed interconnect technologies, such as Serial Rapid I/O (SRIO) and PCI Express (PCIe). Because VPX-REDI was designed to provide compatibility with VMEbus electrical, software and selected mechanics it enables heterogeneous architectures, which preserve existing investments in COTS-based systems. It maintains the familiar 6U form factor made popular by VME, but also defines a rear-I/O 3U version that offers the higher bandwidth Multi-Gig RT2 connector and the LRM metal covers and ESD protection.

System management has emerged as an important aspect of improving the maintenance of fielded COTS systems. A standard to define system level management has been proposed through the VMEbus International Trade Association/Standards Organisation (VITA/VSO). Curtiss-Wright has enhanced its VPX-REDI LRMs with standard features to support System Management. These features include: built-in-test, 3.3V auxiliary power supply, and built-in system management connectivity. In addition, Curtiss-Wright has extended its software support to meet the unique needs of LRMs. This software support includes drivers for PCI devices and switched fabric nodes including enumeration, memory mapping and interrupt processing. BIT (built-in-test) framework and routines are provided so that customers can extend BIT to add new or modified tests including application-specific system level BIT functions that are portable between Curtiss-Wright products supported by its COTS Continuum interoperability initiative. And firmware features such as board initialisation and access to recovery mode boot images. Recovery mode refers to an alternate boot process to recover from an application accidentally over-writing the primary boot code of the board. A device driver programming interface speeds device driver development and makes devices drivers highly portable across differing product lines. Leading A&D COTS vendors are helping to drive the move toward LRM main-

tenance through their leadership role in bringing rugged, ESD-protected VPX-REDI modules to the embedded COTS market. Curtiss-Wright has already introduced several COTS single-board computers that support LRM maintenance requirements and is taking a leading role in bringing VPX-based LRMs to the military COTS market. The industry's first VPX-REDI single board computer, the VPX6-185, and DSP engine, the CHAMP-AV6, were introduced last year. This year the VPX6-684 FireBlade Gigabit Ethernet switch/router board, the CHAMP-FX2 Dual FPGA card, and the VPX3-125 3U SBC and VPX3-215 ExpressReach 3U I/O expansion card have been introduced. The Freescale 8641 single/dual-core PowerPC-based 6U VPX6-185 delivers a nominal backplane bandwidth of 8 GB/sec via four Advanced Switching Interconnect (ASI) ports and features two PCI Express VITA 42 XMC/PMC sites, Gigabit Ethernet (GbE), serial ports, and mass storage interface options. The CHAMP-AV6 features quad PowerPC 8641 processors. These boards are built to the Level 300 ruggedisation level, which includes VPX/VPX-REDI features plus additional enhancements to support LRM 2LM. A sample VPX-REDI module, the VPX3-125 3U SBC, is shown in figure 2. ■