WHITEPAPER

Local Situational Awareness Design and Military and Machine Vision Standards

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Introduction

Video is playing an increasingly important role in a growing range of military local situational analysis (LSA) applications to help improve surveillance and intelligence of possible threats while keeping troops out of harm's way.

Supporting Military Design Objectives with Ethernet

Modernization: Stream video from previously isolated imaging source sources over a multicast network

SWaP: Off -the-shelf, small footprint, lower power computing and cabling

COTS: Standards-based, enables use of commercial computing and networking technologies

Usability: Multicast high-bandwidth video to processing and display units in real-time

Specific to vision system design, military LSA systems allow multiple video sources to share data with multiple endpoints — including computing platforms used for processing and analysis and display panels for human observation — over a common infrastructure. In the first phases of this modernization, military designers often relied on proprietary or legacy analog point-to-point interfaces to connect images sources to computers and displays.

Increasingly, digital video based systems are becoming the technology of choice in both retrofit and new designs in order to better share video across an integrated Ethernet network, meet cost and size, weight, and power (SWaP) demands, support future scalability, and simplify usability.

As part of this migration to Ethernet-based digital video systems, military designers are adopting an open architecture approach to help reduce costs and promote compatibility in multi-vendor applications. This paper discusses how the GigE Vision standard, widely adopted in the machine vision and industrial automation market, aligns with military standards that outline the mechanisms and protocols for distributing digital video over Ethernet infrastructure. This includes an overview on the GigE Vision standard and its interoperability with the British Ministry of Defense (MoD) Vetronics Infrastructure for Video over Ethernet (VIVOE) Defence Standard (Def Stan 00-82) and the U.S. Department of Defense Vehicular Integration for C4ISR/EW Interoperability (VICTORY) initiative.

Modern Networking Approach

Traditionally, military vision systems have used point-to-point interfaces to connect sensors and cameras to displays or computers. These umbilical connections, based on interfaces such as analog, Camera Link, or Low-Voltage Differential Signaling (LVDS) standards, require a dedicated cable between each camera/sensor and its endpoint, whether that be a display or computer.

In applications with numerous cameras/sensors and displays, such as a vehicle electronics (vetronics) system, the cabling becomes costly, complex, heavy, and difficult to manage and scale. In addition, these interfaces require a PCI frame grabber at each endpoint to capture data, driving up cost.

Ultimately, these legacy interfaces complicate design. They limit component choice, increase costs, and result in more complex systems. To address these issues, military vision system designers are migrating to digital video distribution systems.

Military Standards for Digital Video

As designers migrate from a legacy or proprietary approach to an open system for video distribution, a number of standards are now in place that guide performance and component choice. A full review of these standards is beyond the scope of this paper, but manufacturers designing video distribution systems must understand the UK Ministry of Defense (MOD) Vetronics Infrastructure for Video over Ethernet (VIVOE) standard the U.S. Department of Defense Vehicular Integration for C4ISR/EW Interoperability (VICTORY) initiative.

VIVOE Def Stan 00-82 is a comprehensive standard published by the British MOD that outlines the required mechanisms and protocols to be employed when distributing digital video within an Ethernet-based vetronics system. This standard does not define any new protocols, and instead relies on open, widely used network standards from the telecommunications industry.

Def Stan 00-82 outlines how multiple cameras and image sources and displays and processing platforms should distribute and receive information using the same network infrastructure. The underlying transport mechanism is real-time transport protocol (RTP), which supports both uncompressed and compressed video using a variety of different formats. The standard also facilitates the distribution of data over the same network.

What is GigE Vision?

GigE Vision is a global standard for video transfer and device control over Ethernet networks, including GigE, 10 GigE, and 802.11 wireless networks. Since the ratifi cation of the standard in May 2006, most of the world's leading hardware and software vendors for industrial video have unveiled GigE Vision-compliant products. These products – frame grabbers, embedded hardware interfaces, cameras, video servers, video receivers, control applications, and management entities – all interoperate seamlessly over the Ethernet platform.

The overarching goal of Def Stan 00-82 is to define an architecture that helps lower costs and improve performance for end-users. With an architecture based on open standards and protocols, multi-vendor solutions can be more easily integrated into a system, the same technology can be more easily redeployed across multiple platforms (for example, different vehicle types), and the system can be upgraded with more advanced sensors, displays, or processing systems. Video sources and display endpoints may have an integrated Ethernet interface, or interface modules can be used to convert legacy connections into Ethernet.

For end-users, the system must support complex multicast transmission of the full range of video formats and resolutions and metadata, with flexible control mechanisms to distribute images and data to processing units and display panels without reconfiguring hardware or software. For example, uncompressed video used by the driver to navigate the vehicle can be shared with crew members for surveillance and observation and compressed for archiving purposes.

Diagram 1 below outlines a video distribution network for a vetronics system, with navigation and targeting systems distributing and accessed Def Stan 00-82 compliant video over a Gigabit Ethernet (GigE) architecture. In this system, video from legacy analog image sources and newer HD-SDI or GigE cameras is streamed to a rugged Ethernet switch and multiplexed over a 10G Ethernet switch interconnect. The platform's centralized image processing accesses the video from the multiplexed streams and performs image fusion, stabilization, enhancement, or stitching as required. Processed images are then fed back to appropriate displays and workstations in the vehicle.

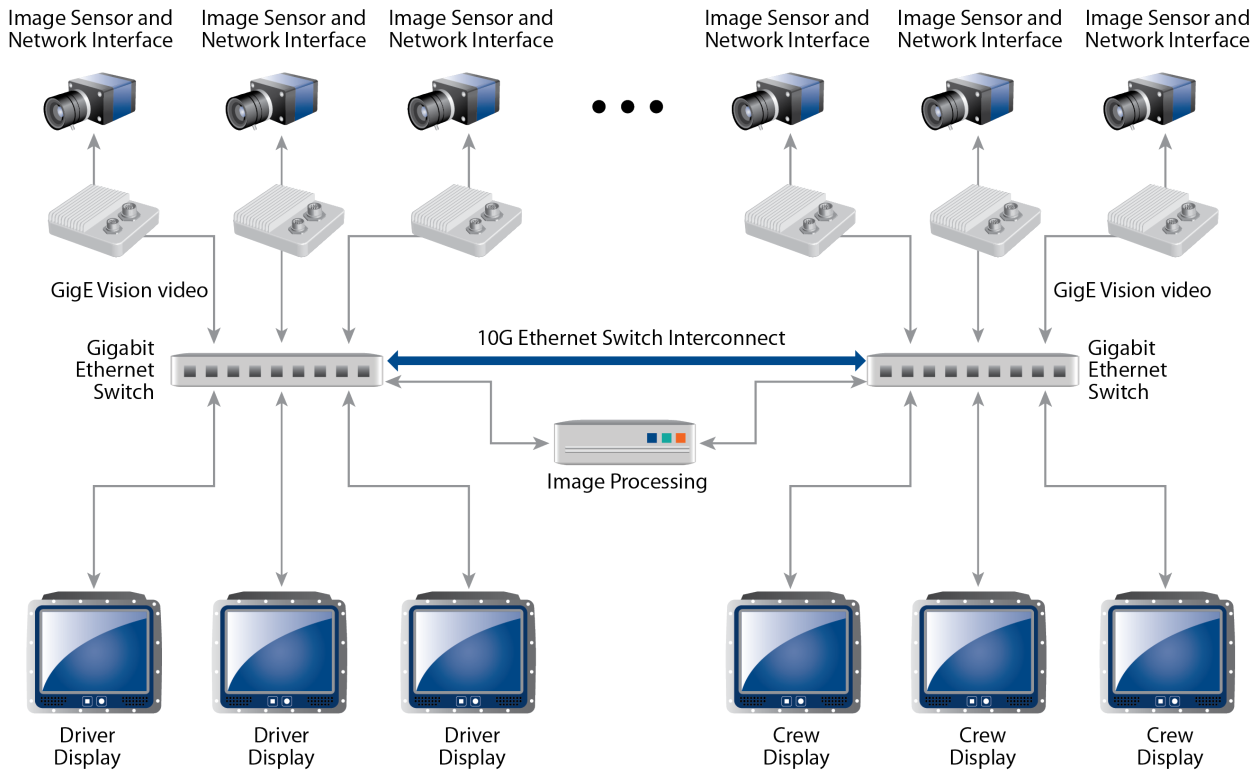

Diagram 1: Video distribution network for a vetronics system

By using an open standard for video transportation, designers eliminate the need to translate different protocols. This simplifies control of multi-vendor imaging equipment, and eliminates latency related to protocol conversion. The common infrastructure approach also eliminates the need for multiple cables within the space-constrained vehicle; video, control data, and power can be transmitted over a single, light-weight, longer reach Ethernet cable.

Similarly, the US Department of Defense VICTORY initiative was first introduced to avoid interoperability and scalability issues during "bolt on" retrofit upgrades of tactical land-based vehicles. Today, VICTORY guidelines also encompass new situational awareness system design.

One of the guiding principles of the VICTORY initiative is to encourage the use of commercial off-the-shelf (COTS) products and technologies to enable multi-vendor integration and avoid vendor lock-in. Of equal importance, the initiative stresses careful component selection to help reduce SWaP in space-constrained vehicles.

VICTORY provides designers and manufacturers with a framework for integrating Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance and Electronic Warfare (C4ISR/EW) and other electronic mission equipment on ground platforms. The overall technical approach includes:

- A "data bus-centric" design;
- Sharable hardware components;
- Open standard physical and logical interfaces
- A set of shared data bus services;
- Shared hardware and software information assurance components to enable systems integrators to build security designs that protect and control access to information.

Considering the requirements for both VIVOE and VICTORY, as well as similar component and design guidelines established by military departments in other countries such as the NATO Generic Vehicle Architecture (NGVA), manufacturers are increasingly adopting the GigE Vision standard.

GigE Vision and Military Design

GigE Vision is an open standard originally developed by the machine vision industry for industrial applications requiring high-bandwidth, real-time video for automated analysis, including quality inspection, package sorting, and transportation monitoring.

The GigE Vision standard was initiated in 2004 by industry leaders from the vision market, ratified in 2006, and is today managed by the Automated Imaging Association (AIA). GigE Vision is now the most widely deployed standard in the vision industry, and has allowed manufacturers to lower costs and enhance performance by leveraging the inherent cabling, networking, and multicasting advantages of Ethernet.

GigE Vision is an open framework for deterministic, continuous transfer of imaging data and control signals between cameras and computing platforms or displays over standard Gigabit Ethernet networks at up to 10 Gb/s. The standard does not impose any limits on image size, image format, and data rate. Images and data are streamed directly to an Ethernet port on a processing platforms, enabling the use of lower-cost and smaller form factor computers for real-time processing and analysis. Multiple endpoints can be networked using off-the-shelf, cost-effective Ethernet LAN equipment.

GigE Vision meets the military's most important requirements: low latency, support for uncompressed and compressed video, interoperability with legacy equipment, and full multicast support.

Latency requirements for LSA applications are easily met in any GigE Vision systems built from quality components. The low, predictable, end-to-end latency is less than 80 milliseconds. GigE Vision supports both compressed and uncompressed streams. The standard promotes interoperability between compliant hardware and software from different vendors, and allows for addition of sensors, displays, and processing resources without requiring changes to the underlying protocol.

Designers should note that the GigE Vision standard does not define any performance metrics. Although GigE Vision can transmit up to 10 Gb/s, a high-performance, end-to-end solution requires high-quality hardware and software components throughout the signal chain and quality implementation.

GigE Vision and Military Standards

The GigE Vision standard aligns with leading military design standards to help ensure manufacturers can more easily design compliant systems.

Considering the basic objectives of VIVOE, VICTORY, and NGVA, GigE Vision and Def Stan 00-82 both allow existing Ethernet-based imaging products to interoperate in a fully networked, multi-vendor environment. Designers can leverage the performance benefits of Ethernet, including lighter and longer reach cabling, networking flexibility, and full-duplex connections. The standard supports the use of COTS technologies, including networking equipment, PCs, laptops, and displays, with a scalable architecture that enables future addition of new imaging sources displays, and processing technologies.

Specific to the requirements around video distribution, both Def Stan 00-82 and GigE Vision use a variety of well-known networking standards. In their design, both standards rely heavily on IETF and IEEE standards in layers 1 through 7 of the OSI model. Both standards support uncompressed and compressed video transmission, sit on top of UDP, and are transparent to the physical layer.

DEF STAN 00-82 Elements

Element	Description
Session Announcement Protocol (SAP)	• Used to broadcast multicast session information • Experimental protocol based on UDP
Simple Network Management Protocol (SNMP)	• Used for collecting and organizing information about managed devices on IP networks and for modifying that infor-mation to change device behaviour
Session Description Protocol (SDP)	• Format for describing streaming media initialization parameters • Used in conjunction with Real-Time Protocol
Real-Time Transport Protocol (RTP)	• Network protocol for delivering audio and video (compressed/ uncompressed) over IP networks • Typically based on UDP
Management Information Base (MIB)	• Hierarchal database used for managing the entities in a IP network • Each entity addressed through an object identifier (OID)

GigE Elements

Element	Description
Device Discovery	Defines how compliant devices obtain IP addresses and are identified on the network
GigE Vision Control Protocol (GVCP)	Defines how to specify stream channels and control and configure compliant devices
GigE Vision Stream Protocol (GVSP)	Defines how compliant devices obtain IP addresses and are identified on the network
XML Camera Description File	• Computer-readable datasheet of features in compliant devices • Based on schema in EMVA's GenICam™ standard

Above: Key Elements of the GigE Vision Standard
At Left: Key Elements of Def Stan 00-82

With respect to device discovery, GigE Vision defines a protocol based on UDP while GigE Vision 2.0 also permits use of multicast domain name system (mDNS). UDP was selected for its simplicity, low overhead, and multicast support. It is ideally suited for low-latency networked video, but does not guarantee data delivery.

To address this limitation, the standard includes an optional mechanism that allows video sources to resend undelivered data to video receivers. This mechanism can also be turned off if resending data is not required for the application. In a properly architected in-vehicle network, where the constant bandwidth of uncompressed video has been taken into consideration, packets will rarely if ever be dropped.

For device control, GigE Vision mandates use of the EMVA's GenICam standard, which defines a generic interface for the computer control of digital cameras and other imaging products that transmit video. GenICam allows designers to use the same interface to program applications for any compliant camera or imaging transmission product, regardless of its vendor, implementation details, feature set, or interface technology.

GenICam defines the format of an Extensible Mark-up Language (XML) file that captures and specifies how to access and control the features of a compliant camera or other imaging product. The XML files encode information about coercion (if the value of X changes, here's how the value of Y changes) and invalidation (if the value of X changes, then the cached values of Y and Z must be discarded and recalculated). The GigE Vision Control Protocol (GVCP) is then used to read/write the registers.

Def Stan 00-82 mandates use of the Simple Network Management Protocol (SNMP) widely used in telecom applications to control all devices on the network, including cameras. The Management Information Database (MIB) files provide a means to configure features (or objects), and the SNMP reads/writes the features through the objects defined in the MIB.

	GigE Vision	DEF STAN 00-82
Discovery	Discovery Protocol	SAP
Control	GVCP	SNMP
Streaming	GVSP	SDP + RTP
Register Access	GenICam XML File	MIB

Table 1: GigE Vision and Def Stan 00-82 Comparison

In GigE Vision, the description of the stream is contained in a GenICam XML file while Def Stan 00-82 uses the Session Announcement Protocol/ Session Description Protocol (SAP/SDP). It should be noted that SAP is not standardized by the IETF, and it does not support the Dynamic Host Configuration Protocol (DHCP).

To deliver video, GigE Vision uses the GigE Vision Streaming Protocol (GVSP). This ensures there are no restrictions on resolution and provides support for an exhaustive list of pixel formats. Packet resend capability is standardized, and by allowing jumbo frame streaming designers can increase imaging system performance.

A jumbo frame carries a much larger payload, typically about 9,000 bytes compared with a standard frame of 1,500 bytes. At six times the size, its overhead is just 0.55%, compared with 4% for standard frames — a significant amount considering approximately 13,800 jumbo packets per second can be sent at maximum throughput over a 1 GigE link. The use of jumbo frames has a positive effect on throughput, as well as CPU usage as each frame is processed and copied on arrival.

A high CPU load will inevitably result in processing delays in the host PC, as well as a reduced image processing capability. The use of jumbo frames clearly diminishes the number of interrupts, lowering the CPU burden accordingly, and increasing the processing bandwidth. GigE Vision filter, stack and performance drivers can further reduce the burden. Such drivers, for example, transfer the larger video packets directly to the application software, freeing the CPU of a considerable processing load.

In comparison, Def Stan 00-82 uses RTP/UDP to deliver video. Pixel formats and resolutions are limited to those used in broadcast standards, plus a small number of non-standard types. There is no support for packet resend, and the payload is limited to 1500 byte frames.

GigE Vision Implementation in a Ground-Based Vehicle

With GigE Vision-compliant video interfaces, designers can easily upgrade vision systems for military ground vehicles to integrate different types of cameras, displays, and processing computers into a single, all-digital, real-time video network.

In a LSA application (Diagram 2), real-time video from analog and digital cameras and sensors is transmitted to display panels for crew members to navigate the windowless vehicle and survey surroundings. Video from analog cameras is converted to GigE Vision and streamed uncompressed over the multicast Ethernet network to displays and processing equipment at various points within the vehicle. Video, control data, and power are transmitted over the single cable; lowering component costs, simplifying installation and maintenance, and reducing "cable clutter" in the vehicle.

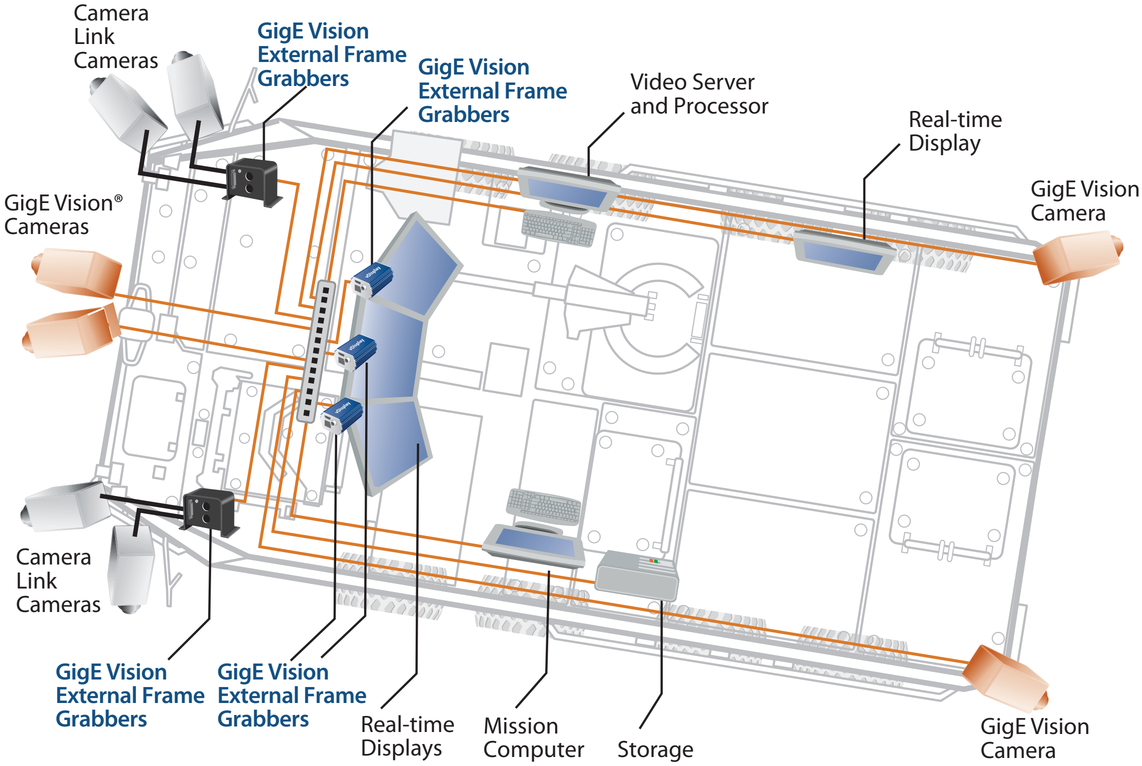

Diagram 2: Video is converted to GigE Vision by an external frame grabber and streamed over the multicast Ethernet network to displays and processing equipment at various points within the vehicle

All computers used for processing and mission control connect to the network via their standard Ethernet port, eliminating the need for a computing platform with an available peripheral card slot. Instead, system designers can employ ruggedized laptops, embedded PCs, or single-board computers for image analysis and control to help lower costs, improve reliability, and meet SWaP objectives.

Pleora and Military Imaging

Global military manufacturers rely on our products, systems insight, and standards expertise to bypass development and integration complexities in high-performance imaging systems. Our products have been designed into situational awareness, sighting, targeting for vehicles, vessels, airframes, standalone systems.

With all devices connected to a common infrastructure and straightforward network switching, multiple streams of video can be transmitted easily to any combination of mission computers and displays. Troops can decide "on the fly" which video streams they need to see, without any changes to cabling or software configurations, or use the on-board mission computer to combine images for use by others in the vehicle. For example, the video feed from visible light cameras can be converted to GigE and blended with video from a native GigE thermal camera to provide more detail on a region of interest.

Beyond LSA systems, GigE Vision-compliant video interface solutions are ideal for vision systems for sighting, threat detection, weapons targeting, and surveillance in naval vessels, manned and unmanned airframes, and standalone systems for persistent surveillance.

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