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DEPLOYING VICTORY ARCHITECTURE AND SPECIFICATIONS

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ABSTRACT

This paper discusses how programs can leverage VICTORY architecture and specifications in order to achieve interoperability between electronics systems integrated with ground vehicles. It explains the contents of the VICTORY architecture, and the concept of compliance with the VICTORY system and component type specifications. It suggests a model for Army ground vehicle programs to utilize the VICTORY architecture and specifications, and a process called guided self-verification to test components for compliance with VICTORY specifications.

INTRODUCTION

Vehicular Integration for Command, Control, Communications, Computers, Intelligence, Surveillance, and Reconnaissance / Electronic Warfare (C4ISR/EW) Interoperability (VICTORY) is a system engineering initiative sponsored by Program Executive Offices (PEOs) Ground Combat Systems (GCS), Combat Support & Combat Service Support (CS&CSS), Command, Control, and Communications Tactical (C3T), Intelligence, Electronic Warfare & Sensors (IEW&S) and Research Development and Engineering Command (RDECOM). It is developing an architecture and standard specifications that facilitate the integration and deployment of existing and advanced C4ISR/EW equipment onto U.S. Army ground vehicle platforms.

In order to create an environment of open competition, VICTORY defines and matures standard specifications for component and system interfaces. Achieving the goal of interoperability through interface standards requires definition of the concept of compliance, and detailing how compliance with the specifications will be verified. Verification is the process of evaluating compliance of an artifact with the interface specifications by executing a compliance test. In the case of some standards, components and systems are certified as compliant by a third party, meaning the third party organization has evaluated the verification results and certifies the compliance with a certificate or stamp. VICTORY interface standard specifications are defined at the component and system interface level. They are not related to the performance of the component or system, but instead to its interoperability with other components and systems using the standard. Verification of compliance will not affect the performance testing that must be done in order to evaluate the key performance parameters and other acceptability measurements for a vehicle. The value of VICTORY compliance verification is highest during earlier parts of a program, during specification and preliminary design phases, and again during integration of the electronic systems. The specifications can be seen as agreements between organizations for how interfaces to the components and systems will operate, not for how they will perform. Interface standards can be used earlier in the program life cycle to reduce risk, as they nail down parts of the design trade space that are not strongly related to overall performance. They answer how systems will communicate with each other, not as much about how they will perform. Interface standards will enable sharing of hardware interfaces, exchange of data between systems, and will reduce cost of integration, maintenance, and upgrade of the vehicles.

For these reasons, this paper recommends that programs utilize the VICTORY standard interface specifications early in the requirements and specification development phases, and called out in preliminary and critical design phases, as opposed to concentrating on verifying compliance as part of the vehicle performance-testing program. This paper also recommends that instead of setting up a single organization that certifies the compliance of all components, the decision for how components are to be verified against VICTORY standard interface specifications may be tailored for specific Program Executive Office (PEO), Program Managers (PM) or Programs of Record (POR).

BACKGROUND

VICTORY has as its core, the concept that vehicles should include a network to which equipment will be attached and through which the systems will interchange information. This concept can be termed “in-vehicle network” (IVN) integration.

The interfaces currently in the scope of VICTORY have been specified to utilize ubiquitous Ethernet technology for transport of information interchanges between the C4ISR, EW, and platform systems. This is possible because these systems, in most cases, do not require a high level of determinism in the delivery timing of the messages.

Alternatively, systems that are safety critical usually require determinism in their core transport, so standard Ethernet may not be the most appropriate technology. For example, automotive systems that control powertrain components often utilize controller area network (CAN) for message delivery because of its periodic, synchronous timing. Some weapon systems utilize MIL-STD-1553B busses because its timing and fault tolerance properties provide predictable timing and available redundancy. These transports are not necessarily high performance but are real-time transports because of their deterministic behavior. Ethernet is, in most cases, higher performance than these transports, but, in its standard form (IEEE 802.3), does not provide determinism (i.e. is not a real-time transport).

Most of the information systems that are used for functions such as command and control (e.g. mission command), intelligence gathering, surveillance, force protection, and situational awareness do not require a deterministic transport, although they may require high performance. In these cases, transporting data using Ethernet will suffice.

VICTORY has defined a network-based architecture that identifies a set of conceptual building blocks and corresponding interface specifications that can be used to design vehicle networks and interoperable hardware and software components. The architecture identifies system types and component types. The architecture assigns functions to the system and component types, and calls out their interfaces, but does not restrict implementation technologies, interface protocols, or the composition of the types into hardware and software components. The specification describes the system and component type interfaces in detail, including data formats, encoding, messaging protocols, and transport methods. The intent is for the interface specifications to contain enough detail that components developed by different organizations and in different technologies will interoperate via these interfaces, but that the interfaces do not add undue burden in terms of processing resources or implementation difficulty and do not reduce flexibility of the designer in implementing the internal functions of the components.

The VICTORY Data Bus

The vehicle network is embodied by the VICTORY Data Bus (VDB). The VDB is a conceptual structure that VICTORY holds and should be built in as part of ground vehicles, and which is essentially an Ethernet network that provides domain specific features. Referring to Figure 1 an instance of a VDB provides network infrastructure functions which transport, route, and deliver data between data sources and sinks with different quality of service levels. In addition to network infrastructure, a VDB also provides shared services (timing, position, orientation, and direction of travel), and shared hardware (HW) devices (processing resources, displays, user interface devices). A VDB also provides data protection functions, which protect the confidentiality of data in transit and data at rest. Access control service functions include authentication of entities and authorization controls to protect the resources. Finally, management services are built into a VDB, which provide interfaces for configuring, controlling, and monitoring the health of the VDB as a whole, as well as the components and systems to which it connects.

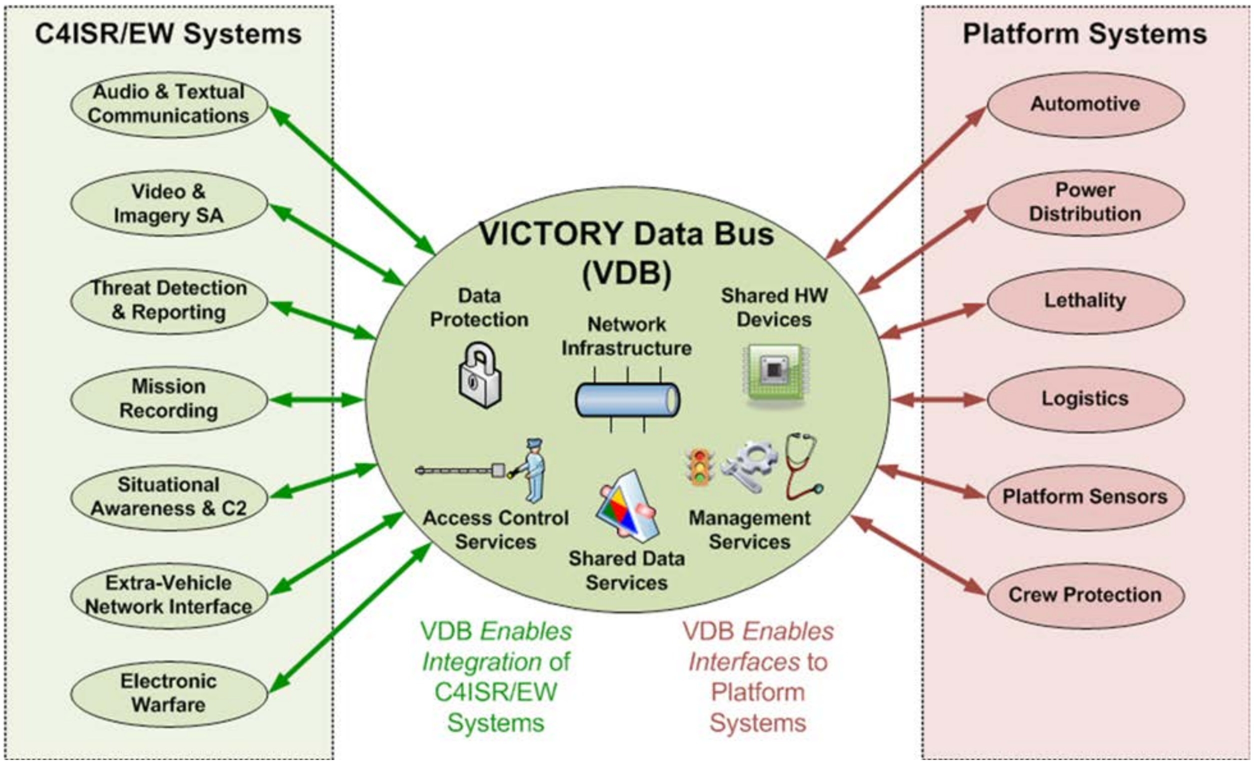

Figure 1. VICTORY Data Bus Context

In the context diagram (Figure 1), the C4ISR and EW systems are shown on the left side. The intent is for those systems to be integrated by the VDB, meaning that their components intercommunicate with each other by passing messages on the VDB network. For these systems, VICTORY identifies and specifies network interfaces at the component and system level. The platform systems group on the right represents systems that are either part of the vehicle platform, or which are tightly integrated with the platform. Examples are weapon systems, and automotive busses. For these systems, VICTORY identifies and specifies network interfaces only at the system level. For example, an automotive system may utilize a CAN network to connect engine and transmission controllers with sensors, and a real-time control algorithm may be tightly integrated with these devices on the CAN network. The VDB is not intended to replace this CAN network. Instead, VICTORY defines an interface between the VDB and the CAN network that can be used as a bridge over which data can be provided to the VDB outside of the tight powertrain control loops. This concept allows for automotive data to be published on the VDB for other uses (e.g. maintenance and other logistics functions) without interfering with the timing of the CAN network. For the platform systems, this is the concept that is used. The VDB interfaces to these systems, but does not provide the main transport for integrating them.

VICTORY System and Component Types

As described in [1], "VICTORY Architecture - Version A1", 16 January 2012, the VICTORY architecture is made up of a set of types that can be instantiated and integrated to create designs. The set includes system types, component types, and their interfaces. The architecture also identifies a structure called the VDB, which is a conceptual entity that provides functions and interfaces as a composite, and which is made up of other component types.

Figure 2, Figure 3, and Figure 4 provide hierarchical breakdowns of the types for the VDB components, C4ISR/EW systems, and Platform systems.

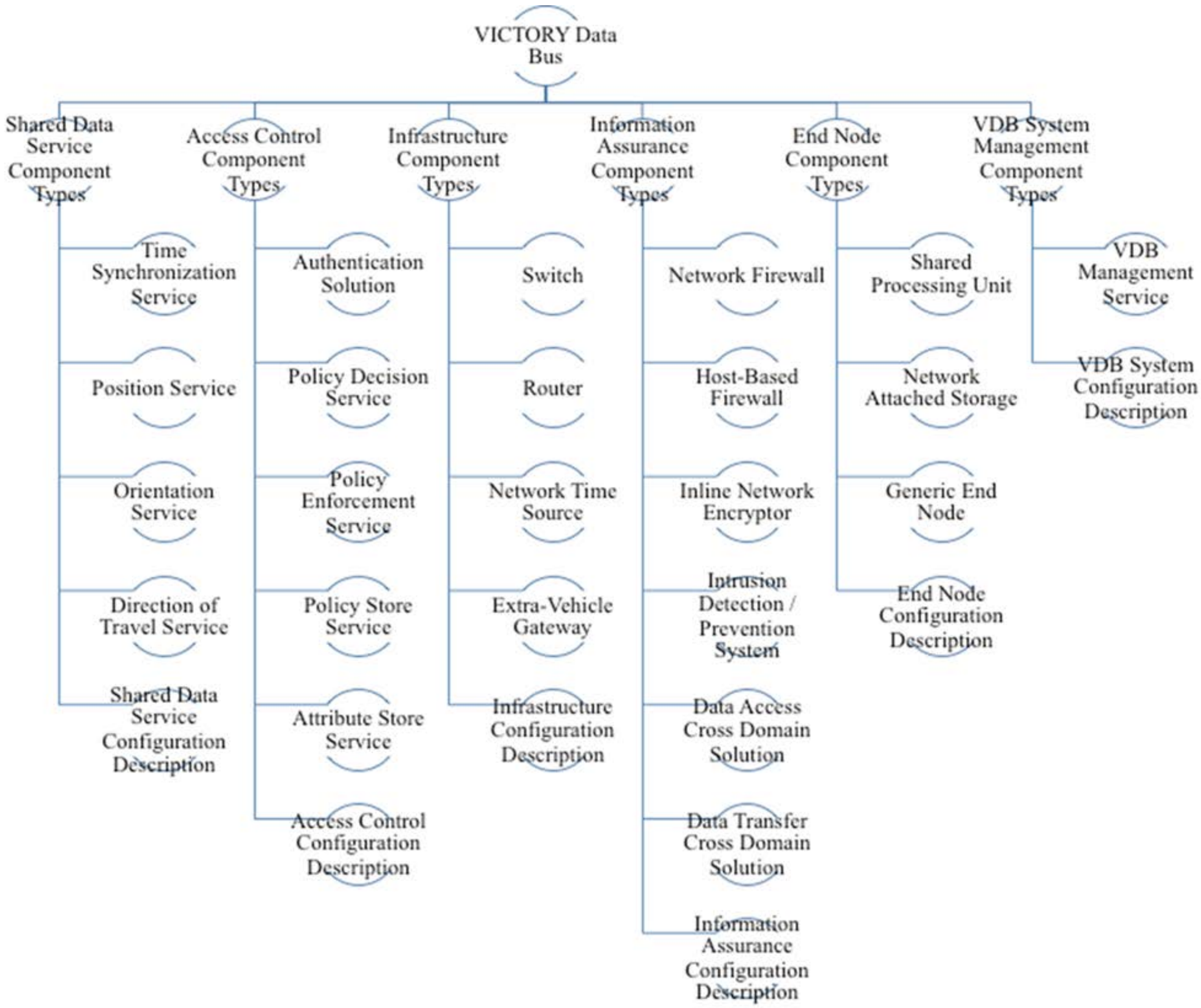

Figure 2. Hierarchical Breakdown of VICTORY Data Bus Component Types

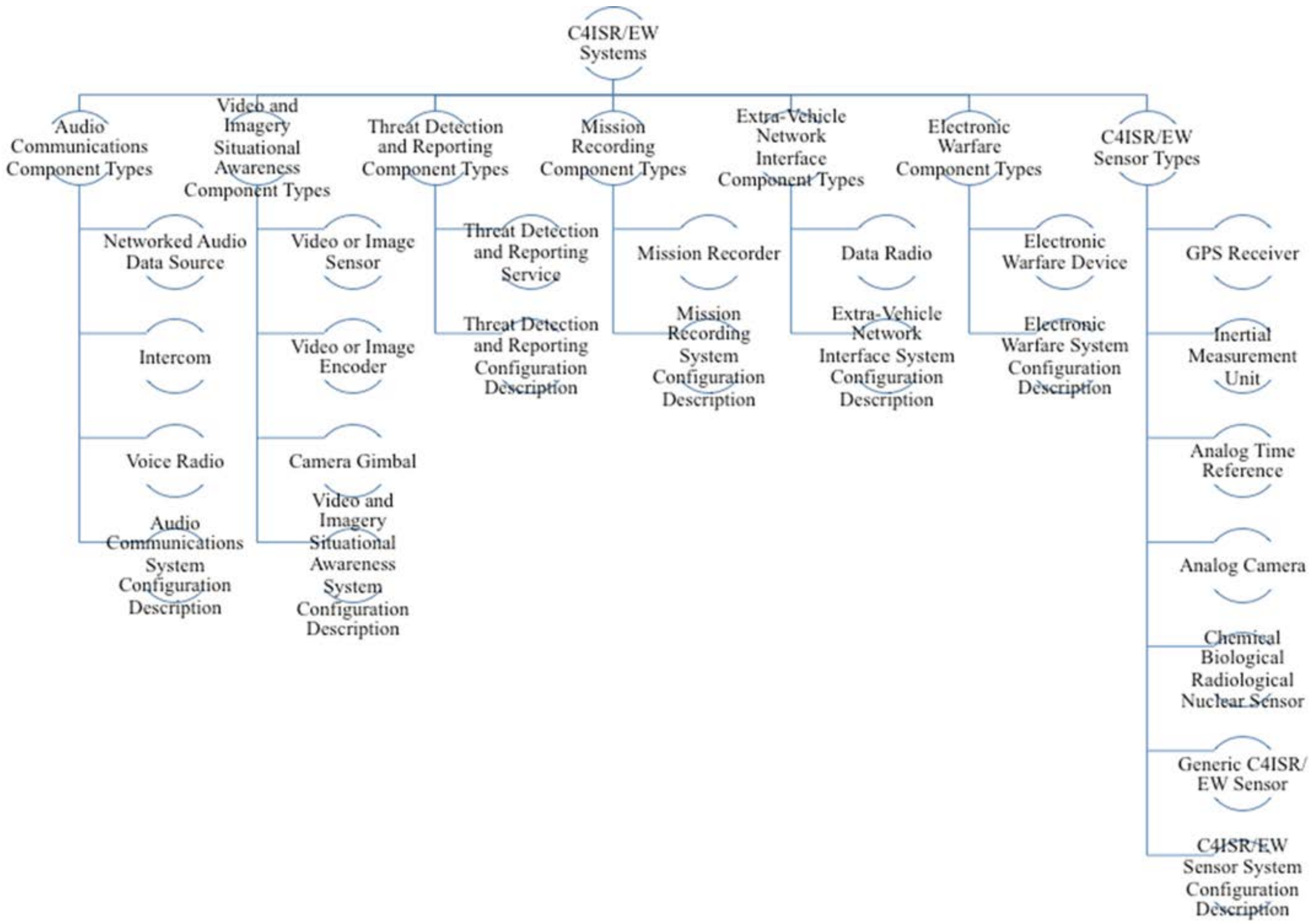

Figure 3. Hierarchical Breakdown of C4ISR/EW System Types

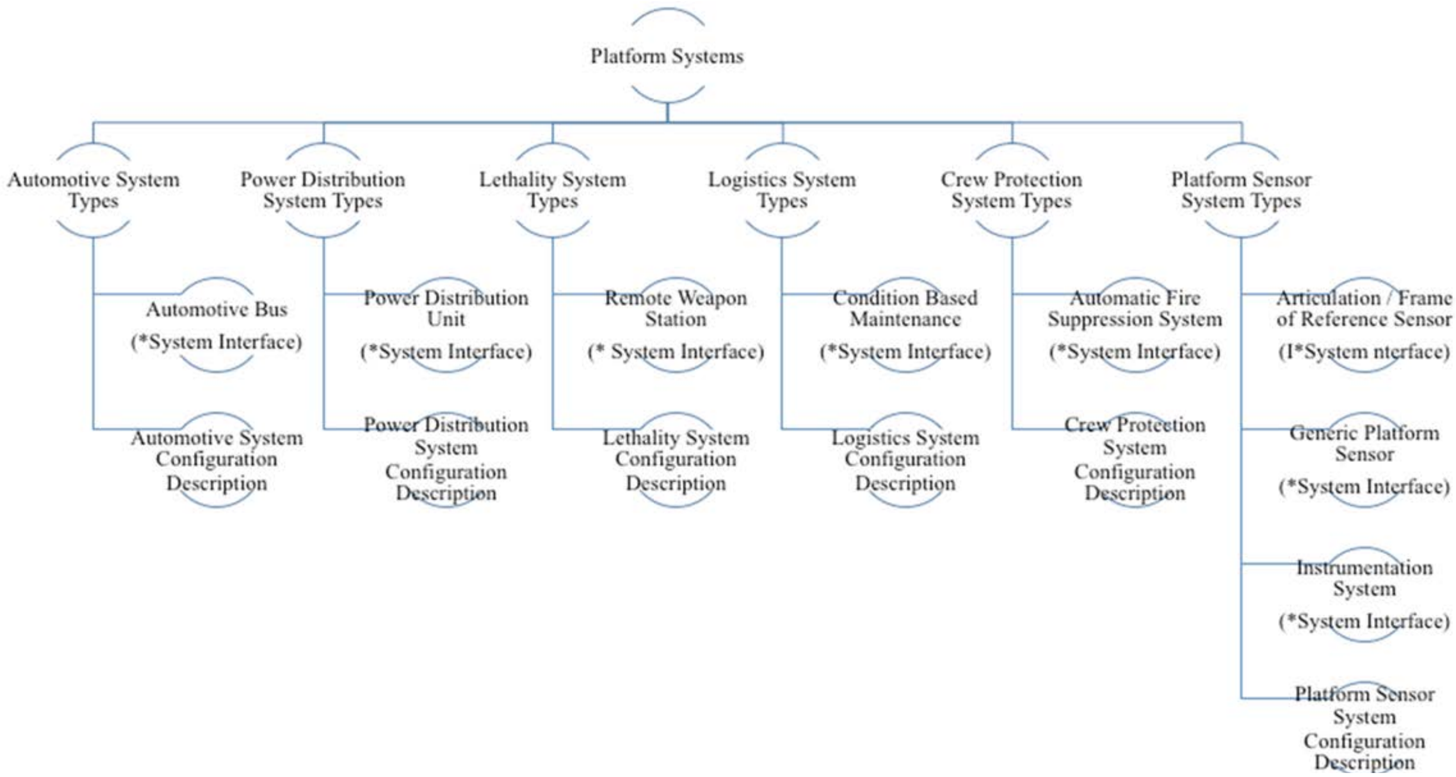

Figure 4. Hierarchical Breakdown of Platform System Types

Note that hardware or software products will likely be designed to implement several system and component types. A product will implement the interfaces of each of the component types it represents. For instance, a vendor may design a device that implements the shared processing unit, position service, orientation service, time synchronization service, global positioning system (GPS) receiver, inertial measurement unit, and VDB management service component types. In this case, the developer must reference the component type tables and implement at least the union of the interfaces required by those component type specifications.

Such a device would be said to be compliant with the shared processing unit, position service, orientation service, time synchronization service, GPS receiver, and inertial measurement unit component types. It must then implement at least the set of interfaces that are required of those component types. A compliance test must evaluate the compliance of each of the required interfaces, and document the results. This document must describe the compliance for each function of each interface, including which of the optional and recommended interfaces are implemented.

Minimal VDB Configuration

The minimal VDB configuration is a representative of the smallest set of physical and logical components required to have any level of compliance with the VICTORY component and system type specifications. The minimal VDB is necessary for a design to be compliant with any of the VICTORY component or system types. It provides the possibility through software modifications to implement additional standard interface specifications for C4ISR/EW and Platform systems that may later be connected to the VDB.The minimal VDB consists of components that provide the functions of the following component types:

- Switch
- Shared processing unit (could be headless)
- Shared position service
- Time synchronization service

In addition to these component types, it is recommended that any VDB also implement VDB management service. The minimal VDB may also provide connections to C4ISR/EW and platform systems on the vehicles, even if they do not implement VICTORY-compliant interfaces.

The minimal VDB configuration provides a small, cost-constrained implementation targeted at non-combat vehicles with the lightest electronics implementation. This configuration would be applicable for vehicle variants with minimal C4ISR systems, but onto which additional systems may be integrated in the future for enhanced capability.

VICTORY PRODUCTS

The U.S. Government has ownership of all the products generated from the VICTORY initiative, including:

1) The *101 Educational Material* is an introduction of VICTORY for new participants. It provides a background of the initiative, the latest architecture, the capability plan and release schedule, and the process overview for standard development, validation, and verification.
2) The *Standards Development and Maturation Plan* details the process that the VICTORY Standards Support Office (VSSO) adopted to develop and mature the VICTORY specifications.
3) The *Architecture Document* provides the framework for integrating with C4ISR and EW systems and interfacing with vehicle systems. [1]
4) The *Standard Specifications Document* provides the technical details of the systems, components, and interfaces outlined in the architecture document. [4]
5) The *Standard Specifications Appendices* provides XML Schemas, web services description language (WSDL) files, and tables to accompany the specifications document.
6) The *Reference Design Documents* describe a set of example designs that demonstrate how systems can be designed using the VICTORY types. One type of reference designs is to describe how implementers can scale the architecture to provide various levels of capability.
7) The *Initial Validation Artifacts* include the documentation, data, and software developed to perform the initial validation experiment on each VICTORY specification.
8) The *Reference Software Library* provides an example instantiation of the VICTORY specifications in a digital and executable form.
9) The *Verification Toolkit (VTK)* consists of software tools, and verification document templates and guidelines for users to conduct guided self-verification testing.
10) The *Compliance Document* outlines the requirements for ground platforms and mission equipment systems to be compliant with VICTORY specifications.

How will a Program Manager use the VICTORY Products?

The *101 Educational Materials* provide an introduction of how the VICTORY initiative has evolved since 2006 when the initial concept was established, an overview of the specification development process, VICTORY architecture and capabilities being standardized, and samples of reference designs demonstrating how to utilize VICTORY specifications for providing various levels of system capability. In addition, the Standards Development and Maturation Plan provide introduction to the process adopted for developing and maturing the VICTORY standard specifications. These two products are great introductory material for new VICTORY participants.

The *Architecture*, the *Standard Specifications* (including all the appendices) and the *Reference Design* documents are the three key products applicable for a PM to use at the early stage of implementing VICTORY. The acquiring PM who adopts VICTORY specifications is responsible for identifying and selecting the VICTORY specifications that are relevant to their program capabilities. The PM will then include these specifications into their program's performance specification and contractual language for product acquisition. The awarded contractor will use the required VICTORY specifications along with other required standards and performance specifications to design and develop the end product. Prior to delivering the end product to the acquiring PM, the contractor will test the end product and generate test reports to prove that it meets all the performance requirements, as well as compliance with the required VICTORY specifications and any other required standards (e.g. MIL-STD).

This concept is very similar to the Lego® building block system. An individual component type and its specification describe a base "block type." The *Architecture* and *Standard Specifications* documents are the "catalogs" with all the block types available to be used. The *Reference Design* documents provide "build instruction manuals" for constructing example designs, showing how to use the available "blocks" to build various types of end products. Assuming that we know the required end form, function, and performance of the end product, we identify and select the relevant types of "blocks" using the "catalogs" and "build instruction manuals." The identified "blocks" and the end product requirements will be announced to the competitors to design and build. The interested competitors will use the given "blocks" to design and build the prototype per directions from the contract and the PM. Prior to delivery, the competitor will test to make sure that the prototype has used all the required "blocks" appropriately.

The initial validation artifacts and the reference software library are tools available to help the competitors build their implementation of the prototype. The VTK is a tool available to help the competitors in verifying and testing their implementation.

VICTORY COMPLIANCE

The "C" in VICTORY stands for "C4ISR/EW," which means that VICTORY covers a majority, if not all, of C4ISR/EW systems to be integrated into a vehicle platform. Therefore, it is not feasible and practical for any single program to implement all VICTORY specifications for one single system or platform. In addition, VICTORY specifications are at the component interface level, not at a system level. In summary, a claim of "VICTORY Compliance" is not enough information and is meaningless. The accurate claim is:

> "*Widget X (a mythical component) makes compliance claims that it provides (implements the service side of) the following VICTORY specifications: (e.g. shared processing unit, VDB management service, switch, position service, and time synchronization service component types) and uses (implements the client side of) the following VICTORY specifications: (e.g. automotive bus system interface system type and electronic warfare device component type).*"

The PM will include their selected VICTORY specifications into their program's performance specification and contractual language for product acquisition. As part of the contractual binding, test reports are one of the mandatory Contract Data Requirements Lists (CDRLs) for defense acquisition contracts. Testing is a built-in cost for any defense acquisition development contract. The test reports will include the test plans, test performed, data collected, test results, and other applicable information proving that the delivered end product meets all the performance requirements, as well as compliance with the required VICTORY specifications and any other required standards (e.g. military standards). As part of the test reports, the contractor should specify all the VICTORY components with which the delivered end product is compliant and provide the respective evidence justifying the claim. The PM is responsible for evaluating and assessing the test reports to ensure that the delivered end product meets all the performance requirements, as well as compliance with the required VICTORY specifications and any other required standards.

Guided Self-Verification

Guided self-verification is a concept in the standards arena that describes the process by which the implementation of a component, in the case of VICTORY, can measure and assert compliance with the specification. In the VICTORY guided self-verification model, the claimant runs a series of tests that exercise the interfaces, executed by the VTK, and captures the test results. These results, if they all indicate "passed," are submitted to the PM, or prime contractor in the case of a second-tier supplier or below, to claim compliance. The "guided" adjective refers to the fact that the compliance effort has guidance provided in the documentation for the VTK to tell the claimant how to perform the self-verification. The "self-verification" concept indicates that the claimant is the one who performs the tests and gathers the results and evidence, as opposed to an independent third party testing and verifying the implementation.

Verification Tool Kit

The Verification Toolkit (VTK) is a set of software owned by the U.S. Government that is designed to exercise the VICTORY standard interfaces for a given VICTORY component type. The goal of the VTK is to give implementers a standard set of test code to run against their implementation to investigate the areas of the specification with which they are compliant. The VTK can be used as part of a guided self-verification compliance testing effort performed by the claimant. This toolkit will be made available to all VICTORY implementers for use in testing VICTORY compliance with any specific component type.

The VTK is implemented as a Virtual Machine (VM) to facilitate the adoption of, and use of, the software by contractors, government labs, and other potential users. In order to use the VTK, the user must simply boot the VM using a VM Manager (VMM), load a VICTORY Configuration Language (VCL) instance document that describes the system under test, and initiate the automated tests. The automated tests will utilize VICTORY standard interfaces to interrogate the component type(s) being verified and produce detailed results. These test results can be used at early stages of integration and development to troubleshoot components before integration testing. Also, in some cases as described in earlier sections, the test results generated by the VTK can be used as evidence to a PM that the component under review is compliant with a given VICTORY component type interface. The test results can also be used by second-tier vendors to claim compliance for their subsystem, which can be used by prime contractors as acceptance criteria.

The initial release of the VTK is 30 June 2012. This initial VTK release has the capability to test the compliance of the following component types to the VICTORY 1.1 specification: Position, Orientation, Direction of Travel, Threat Detection and Reporting, and Automotive. Semi-annual releases of VTK are scheduled for additional VICTORY specifications.

COMPLIANCE PERSPECTIVES

How does a PM verify that the delivered end product by his contractor is indeed compliant with the VICTORY components as claimed in the test reports? Is the use of the guided self-verification process, and the test results from the VTK, sufficient enough to prove compliance? Is there a need for third party independent verification tests in addition to the use of VTK? Is there a need for establishing and maintaining a formal entity to certify compliance of VICTORY specifications and to mandate compliance certification? Many VICTORY specification implementers have been asking these questions.

As described in the Validation paper [2], the VSSO has conducted and documented due diligent experiments through a thorough validation process prior to releasing VICTORY specifications for implementation. The objective of conducting these initial validation experiments is to mature the VICTORY specifications from the Experimental to the Proposed maturity level and to reduce implementation risks. This effort distinguishes the VICTORY Standards Body from other standards bodies (e.g. IEEE, OpenGroup). Up to this point, there have been significant due diligent steps performed and data captured for the released VICTORY specifications.

In addition, the VSSO has adopted the industry's best practices and recommended a more efficient and cost effective approach to verify VICTORY specification compliance, which is codified in the guided self-verification method described in previous sections. This concept has been widely accepted by the industry. The VSSO adopted the "adopt, adapt and author" methodology for development of VICTORY specifications. Most specifications in VICTORY adopt existing industry or military standard specifications and then refine them using more details on how to use the specification in a VICTORY-specific manner, including communicating the data within the vehicle VDB. VICTORY specifications focus on defining on-the-wire interfaces and data messaging between interfaces. Therefore, the compliance tests should be focused on testing whether implementations have the correct on-the-wire interfaces and correct communication protocols as required by the VICTORY specifications. It should not focus on testing the adapted industry or military standard specifications because they are well adopted and implemented by the community (e.g. Ethernet, GPS). In addition, it is not the job of a compliance test to verify whether or not the data in the on-the-wire datagrams is accurate; for instance, whether or not the vehicle is actually at a specific set of GPS coordinates. Rather, it is within scope to test that the GPS coordinates are within the proper bounds.

PM's Role in Compliance

As mentioned before, it is the acquiring PM's responsibility to evaluate and assess the test reports to ensure that the delivered end product is indeed meeting all the performance requirements, as well as the claims of compliance with the required VICTORY specifications and any other required standards. One key point to be noted: the contractor-submitted test reports do not replace the formal program tests that are documented in the program's Test and Evaluation Master Plan (TEMP). The program's performance tests will be conducted by various groups of the Army Test and Evaluation Command (ATEC) depending on which milestone the program is at currently. Once the acquiring PM accepts the end product delivered by the contractor, respective development tests (DTs) and operational tests (OTs) will be conducted in accordance with the approved TEMP.

Third Party Verification and Certification

However, prior to conducting any formal DTs and OTs, the acquiring PMs could, at their discretion, have another organization perform additional independent verification tests ensuring the end product is compliant with the VICTORY specifications as claimed by the contractor. This is the acquiring PM's choice and decision. There are government lab facilities being established to provide this type of service, which are outside the purview of the VICTORY effort and the VSSO. One option for these entities is to utilize a fee-for-service structure for independent verification testing.

Besides the fee-for-service type of independent verification tests, is there a need for establishing and maintaining a formal entity to certify compliance of VICTORY specifications and to mandate compliance certification? In order to answer that question, it is useful to look back at the history of how some other standards bodies have attempted formal compliance certification in the past. One great example is the GPS receiver specification compliance and certification [3]. The concept of certifying commercial GPS receivers started more than 20 years ago. The GPS industry and the U.S. Air Force made several attempts to formalize the certification process for GPS receivers. However, for reasons of timeliness, resource constraints, and the legalities associated with certification, several voluntary initiatives proved unsatisfactory and unworkable for both the industry and the U.S. Air Force.

Prior to mandating formal compliance certification, there are several key factors that must be considered. Identifying a neutral party that has in-depth knowledge of specifications and systems that are being certified is the first key factor. VICTORY crosses the entire C4ISR/EW spectrum for the vehicle platforms. What are the candidate organizations that can perform this function? What are the responsibilities for which the certifying organization is responsible? What authority will this certifying organization have, and how legitimate will this certification be with respect to the overall acquisition process?

The next key factor is identifying the cost associated with formalizing the certification process and identifying the origin of the resources. Establishing a formal neutral certification organization, training the personnel to understand the VICTORY specification and all the systems being certified, laboratory equipment, and other related costs can be a large cost. In addition, the sustainment cost of this organization can be another large cost. How will this be resourced from the government perspective and industry perspective?

The third key factor is the level of complexity for certification and the timeliness of the overall certification process. Since the VICTORY specifications focus at the component level, will the certification be at the component level, the subsystem level, the system level, or the platform level? How timely can the certification test be accomplished? What will be the overall impact to the deployment schedule for which the PM is responsible? Technology changes rapidly, especially in the C4ISR/EW arena. If the certification process takes too long, the certified technology will be obsolete by the time it is deployed.

The last, but not least, key factor is what level of risk reduction the formal compliance certification process will mitigate for the PMs. Each VICTORY component specification has been validated prior to implementation. The implementer, prior to acceptance and integration, will test each component. Does this combination of solid specifications and verification of a component against those specifications reduce risk for a PM? Further complicating matters, what if a second-tier vendor delivers a subcomponent to the prime contractor for acceptance and integration with the respective VICTORY compliance verification evidence? Does the system integrator then have to perform a higher level of compliance verification in order to reduce system risk? These questions do not have a "one size fits all" answer because it depends on the role of the components in the system, and the overall risk plan for the PM's program. In general, compliance verification at multiple levels at the earlier stages of a program reduces risk for a PM because it increases the chance that components will interoperate. It also helps reduce integration testing effort because the interfaces are already proven to work well.

These key factors and questions are key lessons learned from the GPS receiver compliance certification efforts. And they must be addressed and well thought out prior to mandating a formal compliance certification for VICTORY specifications.

RECOMMENDED PATH FORWARD

Industry and PMs cannot, and should not, wait for the open ended questions presented in this paper to be fully addressed before they implement VICTORY specifications. The recommendation for PMs is as follows:

1) Develop in-house technical expertise in understanding and fully knowing how to use the VICTORY products effectively.
2) Ensure the test report CDRLs in POR contracts specifically require verification test results for proving compliance with VICTORY component and system type specifications.
3) Distribute the VTK and encourage usage of the VTK for verification tests at various development and integration stages.
4) Have the right technical staff to evaluate and assess delivered test reports.
5) Seek fee for service type of third party independent verification tests as necessary.
6) Do not mandate formal compliance certification until the key factors and questions identified in this paper are fully addressed.

REFERENCES

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