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GPS Signal Distribution Approaching VICTORY

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ABSTRACT

The VICTORY initiative has been broadly adopted across the US Defense ground vehicle community. Last year, PEO GCS generated Acquisition Decision Memorandums (ADM) guiding the Platform community to incorporate VICTORY architecture in many vehicle modernization efforts, as well as new start vehicle programs. The community can generally agree that VICTORY is driving the vehicle architecture in a positive direction, providing a much more efficient architecture to enable current, and future, technology integration. A major component of the VICTORY standards addresses the distribution of GPS-supplied information for position, heading, elevation, and timing. The vast majority of major subsystems on today's military ground vehicles utilize GPS data in some form. These systems include fire control computers, navigation and blue force tracking equipment, ISR assets, electronic warfare devices, personal navigation equipment, laser range finders, command & control (C2) computers, UAV's, and much more.

As the joint industry, academic, and Government VICTORY effort matures over the next two to five years in an era of significant budget constraints, how can we as a community ensure a cost effective transition occurs from today's technology to a full blown "data on the wire" architecture that VICTORY will enable? Hardware and software solutions requiring GPS information are being invested in today by major vehicle programs that will be a part of the vehicle architecture for years to come. How do we ensure these solutions continue to be available for cost effective fielding and sustainment? How do we ensure our key international partners can leverage the architecture and technology today and tomorrow to effectively partner in supporting global conflicts?

The objective of this paper is to discuss a realistic & cost effective vehicle electronics & architecture strategy leading up to full scale VICTORY adoption for major military ground vehicle programs. It will discuss the short term technical issues related to efficient distribution of the GPS frequencies and IS-GPS-153 message formats, as well as potential & current methodologies in support of today's ground vehicle fleet. It will identify the major issues Industry partners will face as a concerted transition is made from non-VICTORY architecture to the efficient and mandated VICTORY architecture. What are the short term steps integrators and OEM's can take to ensure a seamless transition and prepare vehicles and subsystems to maximize the value of VICTORY? The conclusion supported shall be that a cost effective strategy can be adopted by a joint industry/Government team for the implementation of VICTORY architecture. Key steps to bridge these architectures shall be identified for consideration by Government and industry participants.

INTRODUCTION

Global Positioning System (GPS) technology is arguably the most important technology available to the Warfighter on the battlefield. Technology in the hands of our Soldiers, Airmen, Marines, and Seamen have become heavily reliant on the position, heading, elevation, and timing information available from the GPS constellation of satellite vehicles. Equipment including blue force tracking, DAGR, vehicle

and handheld computers, tactical radios, fire control solutions, precision weapons, and aerial delivery equipment are now dependent on the information provided by the GPS constellation to enable its full functionality, improving the lethality and survivability of our brave Warfighters. Without GPS, missiles don't hit targets, MEDEVAC teams can't find and save injured personnel on the battlefield, and tactical communications channels are broken.

Not surprising, systems integrated to, and used within, our fleet of military ground vehicles are similarly reliant on the receipt of the L1 and L2 GPS frequencies to function as intended. This reliance has generated interest in identifying efficiencies with distribution of GPS and other critical infrastructure and information. This legacy equipment will continue to be fielded for years to come.

Within the military ground vehicle community, an evolving initiative, the Vehicular Integration for C4ISR/EW Interoperability (VICTORY) effort, has matured over the past four years to develop a generally accepted framework for the distribution of information within a vehicle, including the critical GPS information. As stated on the VICTORY Portal website, this framework includes:

1. An architecture, which defines common terminology, systems, components, and interfaces;
2. A set of standard specifications, that provide technical specifications for the items identified in the architecture, and
3. A set of reference designs

The concept is simple and logical; a "data bus-centric" pipeline of information should be made available to any "sensor" on the vehicle network, sharing resources and information with the intent of saving size, weight, and power at the system level. Information available from GPS will be a major component distributed on this network. The objective is to eliminate the "bolt on" paradigm today where individual systems are integrated to a vehicle with their own information gathering hardware and capabilities. In a classic example of this paradigm, FBCB2 is integrated to a HMWWV with an organic computing capability, display, DAGR, and GPS antenna.

The benefits of incorporating shared GPS information through VICTORY in this application makes total sense. In this same HMMWV example, a single GPS antenna can provide position, heading, and timing information to any number of devices on board a ground vehicle platform, including FBCB2. A DAGR, display, CPU, and GPS antenna can potentially be eliminated from the vehicle architecture with the correct implementation of VICTORY. VICTORY is designed to standardize how that GPS information is provided on the network and how sensors may request and utilize this information, supporting shared use of all available information, computing resources, and displays. This paradigm assumes each device is capable of communicating on the data-bus.

Despite the positive progression that VICTORY has made standardizing this information for distribution, the ground vehicle community is not in position to completely adopt this shared-information paradigm today. A number of key questions are raised when considering the transition from today's vehicle integration scheme to tomorrow's VICTORY architecture. Is the hardware ready? Can we truly afford a single leap to the VICTORY standard? Can we better leverage today's technology in a progressive implementation of VICTORY? Have we identified and managed the risks inherent to this significant transition? What is the process to support progression of our NATO and international partners to full VICTORY compliance?

The objective of this paper to open dialogue within the ground vehicle community on realistic & cost effective vehicle electronics & architecture strategies, specific to GPS signal distribution, leading up to full scale VICTORY adoption for major military ground vehicle programs. It will discuss a number of key short term technical issues related to efficient distribution of the GPS frequencies and IS-GPS-153 message formats, as well as potential & current methodologies in support of today's ground vehicle fleet. It will identify the major issues industry partners will face as a concerted transition is made from non-VICTORY architecture to the efficient and mandated VICTORY architecture. What are the short term steps integrators and OEM's can take to ensure a seamless transition and prepare vehicles and subsystems to maximize the value of VICTORY? The conclusion supported shall be that a cost effective strategy can be adopted by a joint industry/Government team for the implementation of VICTORY architecture. Key steps to bridge these architectures shall be identified for consideration by Government and industry participants.

TODAY'S GPS PARADIGM

Let's briefly discuss the paradigm used for the distribution of the GPS signals in today's military ground vehicle architecture. Many systems incorporated into a U.S. military vehicle today require GPS in some form. FBCB2, for example, requires an IS-GPS-153 formatted message from a DAGR J2 serial port, which is connected to a GPS antenna on the roof of the vehicle to obtain position and timing information. The US Army's PEO C3T provides all the equipment to the platform for installation, including GPS receivers, cables, system hardware, etc. Similarly, command and control (C2) computers require a GPS signal, which is typically fed directly from a dedicated GPS antenna, or supplied via RF splitter from a single shared GPS antenna.

In some cases, second, third, or fourth DAGR devices are installed in the vehicle each feeding secure GPS messages to individual equipment. Fire control computers, tactical radios, electronic warfare devices, laser range finders, target engagement equipment, UAVs, soldier modernization equipment, and a host of other devices requiring GPS have all been utilized aboard military platforms over the past decade of persistent conflict. These types of devices have become the standard in the hands of our Warfighters. The key point in this discussion is that each device has its own GPS receiver and signal distribution infrastructure and manipulates the information modulated on the GPS frequencies to meet its inherent needs.

It is important to understand, however, that these devices have not necessarily been integrated or installed with other "kits" in mind, causing significant interference and reduction in space inside the vehicle. In some cases, installation of a piece of equipment may have been directly in support of an urgent requirement or threat from theater. In these instances, systems engineering took a back seat to speed and fielding with the intent of saving lives. For example, if the device required GPS, it typically was installed with its own GPS signal distribution hardware and GPS receiver.

Gaining efficiencies in Size, Weight, & Power (SWaP) back from this decade of unsystematic integration is the core objective of VICTORY. GPS signal distribution is a core component of this effort.

VICTORY DEFINED

In order to engage in honest dialogue regarding successful implementation of the VICTORY standards, one must first pause to fully understand the scope of the VICTORY initiative and the broad support it has received from the ground vehicle industry.

By definition and referenced from the VICTORY Portal, the initiative was started, "*as a way to correct the problems created by the "bolt on" approach to fielding equipment on US Army vehicles. Implementation of VICTORY allows tactical wheeled vehicles and ground combat systems to recover lost space while reducing weight and saving power. Additionally, implementation allows platform systems to share information and provide an integrated picture to the crews. Finally, implementation provides an open architecture that will allow platforms to accept future technologies without the need for significant re-design. Under the initiative, a framework for integration of C4ISR/EW and other electronic mission equipment on ground platforms continues to be developed*."

The VICTORY framework incorporates an architecture and set of terminology, a set of standards for that architecture, and a reference design from which integrators can base their vehicle-specific architecture. The overall VICTORY technical approach includes a "data bus-centric" design that will allow for sharable components at the system level, enabling shared computing, display, and storage resources along with a coherent information assurance plan.

Most importantly, at its core, the VICTORY standard specifications are jointly developed by Government, Industry, and Academic members and participants. These standards are independent of specific hardware or software designs, ensuring a workable solution across all ground vehicle families and their support community.

It is important to acknowledge that GPS is not the only set of data available on the VICTORY data bus. Any information related to system performance, shot detection, vehicle health, etc can be standardized and available on the network. This paper, however, has focused on the niche application of GPS signal distribution.

RISKS AND THREATS

Adoption of the VICTORY standards by the military ground vehicle community has matured significantly over the past 3-4 years. Support for the initiative at the Program Executive Office (PEO) level is strong with Acquisition Decision Memorandums (ADM) circulated in FY12 requiring the implementation of VICTORY-compliant architecture by vehicle modernization efforts and new start vehicle programs. The early adopter of VICTORY was the joint service Joint Light Tactical Vehicle (JLTV). The Stryker and Bradley Engineering Change Proposal (ECP) efforts have also embraced the standards and are seeking their own VICTORY compliant data bus-centric solutions.

There is no question, joint work by the VICTORY team should continue, refining and maturing the architecture, standards, and reference design. However, as these individual solutions continue in their maturity and engineering design, a number of important questions are raised regarding the implementation of such architecture. This section will discuss these questions and how the risks and threats associated may impact ground vehicle programs and overall acquisition strategy.

Current Investment & Divestment

A war footing over the past 10-12 years has resulted in rapid procurement of equipment deemed critical to the Soldier's safety and survivability. A perfect example of such rapid acquisition program is the joint Mine Resistant Ambush Protected (MRAP) family of vehicles. Identified to counter the improvised explosive device (IED) threat first experienced in Operation Iraqi Freedom (OIF), MRAPs have become a part of the DoD inventory of military ground vehicles and a staple of the Brigade Combat Team (BCT). A large amount of equipment procured in this same rapid manner has been pushed to the field during this timeframe. Examples include tactical radios, electronic warfare devices, and more. Much of this equipment is critical to our

communications infrastructure and networks. At the same time, much of this equipment is reliant on a DAGR device feeding IS-GPS-153 messages, or has an embedded SAASM GPS receiver to reduce susceptibility to jamming and spoofing.

A major risk is raised when considering this legacy equipment and the VICTORY modernization effort; how will this equipment be integrated with the VICTORY architecture? Is this equipment going to be shelved or will it find a home within some level of vehicle-specific VICTORY design? Is an interface device necessary to support integration to VICTORY, and how much will that device cost? Will a separate GPS signal distribution solution be required in the short term to support this legacy equipment?

To complicate this risk, one must assess whether the industry is ready for full scale adoption and government lifecycle managers prepared for the impacts of VICTORY on their fielded GPS-reliant equipment. Who will test these existing systems and products against the VICTORY architecture for compliance? As new versions of fielded equipment mature, has anyone considered their integration to the VICTORY paradigm?

The Current Fielding Paradigm

As discussed previously, a mature paradigm exists today for the incorporation of hardware requiring GPS into a military ground vehicle. For example, one Government program office owns tactical radios, another program office owns target engagement equipment, and yet another program office manages the vehicle platform and automotive infrastructure. To further complicate this paradigm, in some instances, contractors own technical data packages of key equipment.

Progression towards a VICTORY architecture requires moving away from this paradigm and this "change" will present challenges. Will all hardware lifecycle managers identify a strategy to modify their devices to the VICTORY standard and architecture? Who will own the data bus technology and implementation? How will program schedules and modernization budgets align?

"Cultural change" is rarely a simple undertaking, especially when dealing with large diverse organizations in private industry and the public sector. Significant risk exists in identifying and agreeing upon a strategy to integrate the current technology into the new VICTORY paradigm.

International Support

Operations, primarily in Iraq and Afghanistan over the last decade, have been supported heavily by US international allies such as the UK, Australia, Canada, Poland, France, and others. In many cases, such operations are led by a Joint Task Force element comprised of two, three, and sometimes more countries operating together and cohesively. In other cases, one nation may operate security in a province or city in the Area of Operations (AOR), with smaller joint multi-national operations occurring within this "territory." In these instances, communication between multi-national forces is critical. This communication goes well beyond language, and dives into equipment and networks operated by each force and nation.

A major question is raised when considering these multi-national operations and theater command; will our international allies be modernizing their communications and signal distribution equipment to match that of the US for VICTORY compliance? Will secondary impacts of the US modernization plan be felt by these partners who may not have the same financial or logistics resources to modernize today? How will other GNSS frequencies such as GLONASS, Galileo, and BeiDou affect joint efforts and interoperability?

As we dive deeper on this issue, Foreign Military Sales (FMS) are an important component of current industry revenue driven by defense hardware. How will investment towards VICTORY compliance affect viability of this hardware for international sale? Will differing versions of each product be required to support FMS activities by defense contractors?

Current Budget Environment

"Sequestration" is the dirty word when considering the US federal budget status. Impacts stretching from DoD budgeting and acquisition to state & local support are being felt across the United States as a result of the sequester. When laid over the plan considered by the ground vehicle community for implementation of VICTORY, conflict is unavoidable. True impacts of sequestration are being identified on a daily basis and it doesn't take an advanced degree to predict that change in the defense industry is upon us.

How does sequestration and reduced defense budgets impact DoD plans to implement VICTORY architecture within JLTV, Stryker, MRAP, GCV, and other ground vehicle programs? VICTORY compliance means investment in hardware and infrastructure. Will these programs stay funded or will they fall victim to the budgeting process and priorities in Congress and the Pentagon? Is there an interim and responsible step the military ground vehicle community can take to make the implementation of VICTORY more affordable over a longer period of time?

An excellent example of this risk applied to GPS signal distribution was the FY11 decision to move away from DAGR-fed equipment mounted in vehicles, moving towards an embedded solution. With over 600,000 DAGR devices fielded around the world, Army leadership decided enough

systems were available and they would no longer budget for the acquisition of new hardware.

RISK MITIGATION & PATH FORWARD

The risks and threats to full scale VICTORY adoption presented in this paper are simply a small cross section of the total environment faced by those supporting the military ground vehicle industry. It is not difficult to identify additional and ever growing risks associated with the implementation of a data bus-centric architecture to support our Warfighters.

However, identifying these risks, discussing the threats, and working together to plot a path forward to support implementation of the VICTORY architecture will ensure longevity and success of the plan.

The path forward for implementation of GPS signals inside military vehicles is a critical step forward in the maturity of SWaP efficiencies provided to our Warfighters, and eventually adoption of VICTORY architecture. It is the recommendation of this author that key steps are taken in the immediate future to support a successful long term strategy for adoption of VICTORY. These short term steps are designed to mitigate some of the key risks related to GPS signal distribution, identified in this paper and ensure success in the long term.

Ground Vehicle GPS Signal Distribution Strategy

To mitigate a majority of the threats and risks facing VICTORY implementation of GPS signal distribution, this author recommends a short term GPS Signal Distribution Strategy that will allow for a cost effective progression towards VICTORY adoption across the fleet. Such stepwise progression improves the chances of affordability, addresses technology risk, ensures our international partners are able to maintain technological progression, and provides industry with achievable milestones.

The short term strategy should address both a timeline as well as priorities to achieve long term success. It is intended to provide guidance to industry for development of new technologies that can support the Government's longer term desires to achieve the efficiencies identified by VICTORY for GPS signal distribution.

Suggested components of this short term strategy are as follows:

1) **Establish a Ground Vehicle GPS Users Group**. As a starting point, bring together the Army's GPS User community to discuss specific strategy of GPS signal distribution and define a path forward that benefits the majority of military GPS users. This recommendation requires a Government "Champion" and willing participants. It should include a voice for all program offices that own and manage hardware lifecycles requiring GPS aboard a military ground vehicle. The voice of platform managers and industry partners should also be heard. The objective of this User's Group is to help develop the short term steps to change the current GPS signal distribution paradigm. A great example of an organization who is capable of managing such a user community is PEO IEW&S's Product Director for Position, Navigation, & Timing (PD PNT).
2) **Establish Priorities & Timelines**: This User Group should define what capabilities brought forth by VICTORY are most critical and a timeline of when these capabilities should be implemented. Careful consideration regarding cost and threats should be discussed and documented with inputs from platform managers, budgeteers, and end users. A key question that needs to be addressed through these priorities & timelines is; does a disruptive paradigm shift for the distribution of GPS need to occur now?
3) **Establish a Plan That Leverages Recent Investments**: Priorities and timelines should consider recent technology investments and identify low risk technology integration plans can best leverage those investments. Considering the current budget environment, a plan should focus on how legacy equipment can best be rolled into the VICTORY architecture with the focus on transition from today's GPS signal distribution paradigm to tomorrow's VICTORY paradigm.

Holistically or by individual components, execution of the above recommendations can only assist in the objective of this paper; to engage industry and government stakeholders in dialogue supporting a seamless transition from the GPS signal distribution paradigm today into a VICTORY architecture of tomorrow. Multiple paths exist to enable legacy equipment in the VICTORY model, however, the risks presented can create an uncomfortable or unaffordable path that can be mitigated with the right input.

A great example of such progression within a short term strategy is a program managed by the US Army's Product Director for PNT; the DAGR Distributed Device (D3) program. Historically the DoD's DAGR lifecycle manager, PD PNT recognized the need to move secure GPS signal distribution technology forward due to the sheer number of devices requiring interface with SAASM based GPS receivers. Dwindling acquisition budgets for new DAGR production units made a transition plan necessary. Limited O&M budgets prohibited purchase and integration of GB-GRAM modules to support existing equipment. Furthermore, multiple DAGR devices had found their way into military vehicles, demonstrating to PD PNT the need to move towards a VICTORY-like architecture to gain volumetric and electrical efficiencies. An affordable

"evolutionary" transition had to occur, versus a giant "revolutionary" step.

The key question persisted; how could PD PNT ensure legacy equipment could continue functioning with the necessary IS-GPS-153 messages in vehicles, while supporting dismounted requirements for DAGR devices? All of the above requirements had to be met under the current budget environment.

In July 2013, GPS Source was awarded a contract by PD PNT to supply GLI-FLO*TM* to meet the requirements of the D3 program. A COTS solution designed as a central vehicle "GPS hub," GLI-FLO embeds a GB-GRAM SAASM card and provides a single point of secure GPS signal distribution to up to eight devices on board the military ground vehicle. Although short of communicating GPS position, heading, or timing information onto a central vehicle Ethernet data bus, GLI-FLO is an affordable investment approaching VICTORY-like goals by eliminating multiple DAGR devices, antennas, and cabling from the vehicle architecture while providing a single point of GPS signal distribution.

With PD PNT's D3 solution, vehicle power draw and weight are reduced while volume inside the vehicle is improved. A short term priority was addressed while progressing towards a VICTORY architecture for the distribution of GPS signals. Further, a current investment in vehicle hardware was leveraged towards this common goal, ensuring long term viability for existing systems.

When considering this example, the key question becomes, can the ground vehicle community continue leveraging this strategy to achieve the long term goal? Why "throw away" legacy technology, when it can be leveraged to further progress vehicle architecture to tomorrow's VICTORY design?

Although a short term solution to address existing issues, D3 has the potential to offer a path towards VICTORY compliance by modernizing around this technology. Today's GPS-reliant infrastructure can continue to operate in the current paradigm, while transitional technology, such as D3, can support progression to the VICTORY architecture. D3 is not a threat to VICTORY, it is a single step towards achieving success with the VICTORY architecture.

If executed, a short term strategy can support the community in building priorities and timelines that make sense financially and with the available technology. For example, with GPS now centrally distributed on a military vehicle, an affordable tool expanding D3 can be implemented, making IS-GPS-153 messages available on the Ethernet data bus *in addition* to raw GPS frequencies available for legacy equipment. By understanding priorities and timelines, industry and Government together can progress towards a VICTORY architecture in an affordable way.

An Approach to Risk Mitigation

These stepwise progressions in the vehicle architecture address the vast majority of the risks identified within this paper. If implemented in a conscious manner, a cultural paradigm shift can be achieved over time in the manner technology is implemented on military ground vehicles. Investments can be made within the context of a smart strategy, short term goals can be built into *real* budgets in the current fiscal environment.

Similarly, international allies will have affordable stepping stones in which to invest, ensuring compatibility in vehicle architecture and communications technology for joint operations, all while providing an outlet for defense contractors via FMS and international sales. Contractors then have the capital to reinvest, further developing technology and products which can progress the GPS signal distribution strategy. The investments made yesterday can be leveraged over the horizon, but all within the progression towards full blown VICTORY compliance.

CONCLUSION

In conclusion, the progression towards VICTORY compliant vehicle architectures is a generally agreed upon path within the ground vehicle community. However, a broad step forward to achieve this architecture raises a series of risks that may derail the effort and extend the timeline for implementation, especially when considering the niche of GPS signal distribution and today's paradigm.

This paper highlights a number of key risks and threats, and provides a suggested framework for the community to jointly develop a short term strategy that can achieve the long term goal of VICTORY implementation. A prime example of evolutionary progression in ground vehicle GPS signal distribution that can support the longer term objectives was provided; the Army's DAGR Distributed Device (D3) program.

Taking smart steps together can, and will, mitigate many of these risks and establish an affordable and sustainable long term vehicle architecture solution.

REFERENCES

[1] http://129.162.104.103/. VICTORY Standards Public Website.

[2] "Acquisition Decision Memorandum (ADM)." PEO Ground Combat Systems, US Army. 2012.