

Network Centric Interoperability – *Using a Variable Message Format (VMF) Based Data-Link to Improve Situational Awareness and Close Air Support (CAS)*

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ABSTRACT

Clearly demonstrated in the recent military deployments in Afghanistan and Iraq, one of the most significant challenges now facing the warfighter is how to seamlessly interface the myriad of disparate stand-alone Situational Awareness (SA) and Close Air Support (CAS) systems into the DoD's Network Centric Warfare (NCW) infrastructure. This point was recently highlighted in the Secretary of Defense's testimony to the Senate Armed Services Committee. Referring to mission critical shortfalls that occurred during the IRAQ deployment, the Secretary discussed the state of the current warfighting environment [1]. Although tremendous progress has been made in the integration of new and emerging technologies and their applications on the battlefield, there is still a significant lack of interoperability between various communication systems.

To address these battlespace management environment issues, Raytheon Technical Services Company's Engineering and Production Support facility underwent a product development effort to provide a Network Centric Interoperability demonstration for CAS. This demonstration utilized various Raytheon-fielded SA and CAS products in a representative CAS scenario interfacing to Variable Message Format (VMF) based data links.

This paper addresses the systems and software issues encountered during this successful demonstration of CAS battlespace connectivity. This presentation will also discuss lessons learned during our product development from both a systems and a software engineering perspective.

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BACKGROUND

Lack of CAS Interoperability in the Field

Warfighters are currently facing a Close Air Support (CAS) environment undergoing an unprecedented level of transformation. Unfortunately, this transformation involves an interoperability gap that can be characterized by an overall lack of real-time shared battlespace knowledge; limitations in voice communications; and significant lags in reaction-response times to changes in mission plans, execution checklists, and the enemy threat.

Even with advances in technology, CAS "call for fire" actions still rely, to a high degree, on passing critical data through radio-based voice communications. Further complicating the situation is the disparate radio-based voice communication nets that often require multiple links or gateways to provide a complete path between the point of origin and the destination. In addition to creating information overload for users, the potential for lost, misinterpreted, or misdirected data produces an inefficient and potentially dangerous situation.

Limitations of the current CAS management environment include the following:

- Continued reliance on voice communication/human transcription of CAS targets
- Manual transcription errors – lack of automation
- Lack of appropriate situational awareness – "Blue Force" knowledge
- Incorrect interpretation of voice-transmitted data or incorrect actions taken
- Lengthy process time for call-for-fire actions
- Need for greater access to battlefield situation awareness data

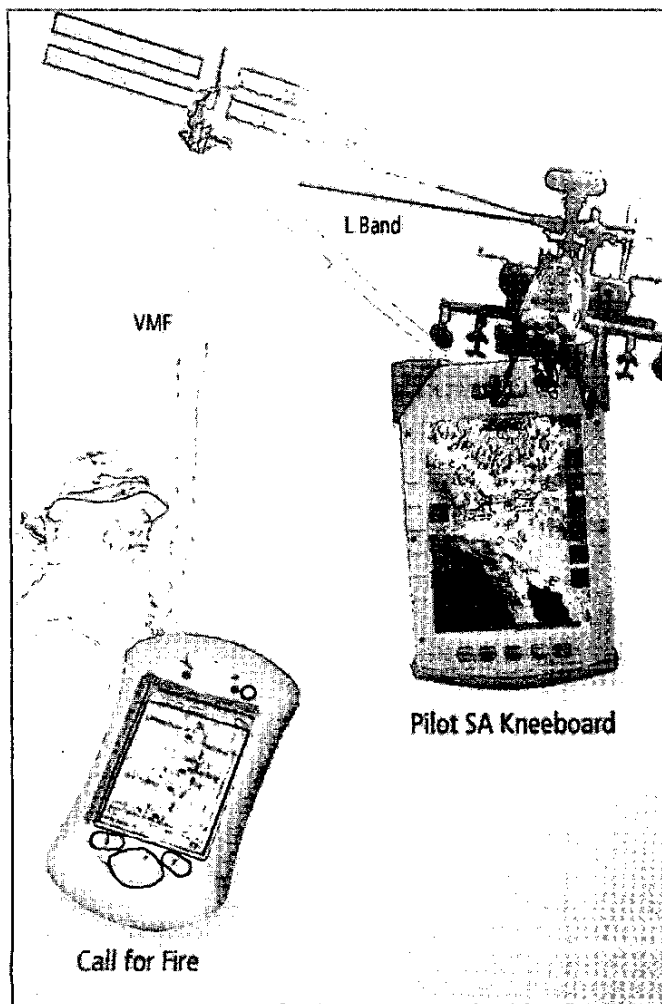


Fig. 1. Handheld Products for VMF Connectivity

- Lack of standardized combat I.D. integration systems (7 different systems fielded in Iraq)
- Lack of portability of large legacy CAS workstations
- Limited data-link connectivity for handhelds, electronic tablets, and laptops deployed in the battlefield since most systems did not have Satellite Communication (SATCOM) or Line-of-Site (LOS) connectivity
- Lack of “rugged” hardware.

Fratricide Incidents

Tightly coupled with this lack of interoperability has been an unacceptably high increase in the percentage of deaths attributed to fratricide, or “Death by Friendly Fire,” which has taken a more visible role since Operation DESERT STORM.

The lack of interoperability (i.e., “target locations incorrectly transmitted or received” [2]) has been cited as the cause of several fratricide incidents in the last two major DoD deployments in Afghanistan and Iraq.

Desire for Mobile Systems

The Afghanistan and Iraq deployments have highlighted the need for fielding lighter, more mobile units to accommodate the vast open terrain as well as the urban environment. Likewise, the warfighter is becoming more mobile by using handhelds, tablets, and laptops instead of traditional “man portable” systems. Additionally, the lower cost and reduced development time of the handheld solutions make them an even more desirable alternative. However, as these systems have been deployed, significant limitations have been noted in the ability to seamlessly integrate mobile hardware into the DoD’s NCW infrastructure. In many cases, the concurrent development of the NCW infrastructure and the necessary C4I components that integrate into it further complicates the challenge.

Tactical Data Links

DoD has placed great emphasis on replacing existing radio nets with a digital data-exchange capability using tactical data links. This migration has shown a significant increase in combat effectiveness. For example, the USAF saw an increase of over 100% in combat effectiveness by adding Joint Tactical Information Distribution Systems (JTIDS) tactical data link capability to F-15C aircraft. Data collected by the USAF from over 12,000 sorties showed that JTIDS-equipped F-15C aircraft had significantly higher kill ratios (by a factor of 2.6) than those with only voice-data communications [3].

VMF – DoD’s Message Standard for Fire Support Interoperability

The Army and Marine Corps have jointly developed the necessary communications protocol, message protocols, and fire-support messages to promote interoperability for the fire-support community. This effort has resulted in the development of three separate standards: VMF for the messages, MIL-STD-188-220 for the lower communication layers (Transportation, Network, Data Link, and Physical), and MIL-STD-2045-47001 for the upper layer (Application). The DoD has mandated VMF as the single message standard for US tactical fire-support data systems as part of DoD’s Joint Vision 2010, Joint Vision 2020, and Joint Technical Architecture (JTA) interoperability initiatives.

As a result, all DoD services have been driven toward implementing VMF. As legacy systems become obsolete, they are replaced by VMF-compliant replacements. Likewise, existing systems are being enhanced to support VMF in an effort to eliminate not only legacy protocols and architectures, but also extra equipment that only provide gateways between different protocols. This also allows these systems to take advantage of available capability that is provided by other VMF-based systems.

OUR APPROACH

To address these CAS interoperability issues, Raytheon undertook an internally funded product-development effort. The goal was to enhance existing fire-support and situational awareness systems, creating an integrated "system of systems" that provides desired CAS interoperability. This effort focused on replacing the current voice-based "call for fire" CAS radio environment with a well-integrated, automated replacement that allows the warfighter in the field to easily transmit a "call for fire" from a handheld computer. This is accomplished via a tactical data link to a CAS pilot's SA electronics knee board (Figure 1).

For this effort, Raytheon formed a CAS Interoperability Integrated Product Team (IPT) made up of experts with backgrounds in CAS operations, CAS software designs, VMF data, radios, data links, rugged/mobile computing hardware, and Situational Awareness. This IPT was tasked with enhancing several of our existing products to develop an integrated "system of systems" approach that would meet the demanding requirements of a representative CAS scenario. Major undertakings of this effort included the following:

- Rehosting existing fire-control software from large UNIX workstations to handheld computers
- Adding VMF data-link capability to fire-control and situational-awareness products
- Ruggedizing handheld computer hardware to support the harsh military environment
- Ensuring compatibility with DoD interoperability and symbology standards
- Enhancing existing situational awareness software through data-fusion techniques
- Providing necessary network connectivity via tactical data links.

HARDWARE SOLUTIONS

The IPT first looked at the background of the issues. Considering CAS system requirements, users expressed a strong desire for lighter and more powerful systems. They also indicated a strong preference for handheld computers for CAS technical fire direction, first and foremost because of portability. They want a much lighter system to take with them whenever they parachute from their helicopters or planes. The warfighter in the battlefield can validate potential solutions through computing the options on a handheld computer, and can also obtain an independent verification of the firing solutions being computed by the larger systems. The users also want to have stand-alone capabilities with handheld computers to retain calculation capability when the larger systems are

unavailable, such as initial entry into the drop zone or a loss-of-power scenario.

Both the Afghanistan and Iraq deployments demonstrated that "out of the box" COTS handhelds and tablets are not suitable for rugged combat conditions where they have to withstand extreme temperatures, blowing dust and sand, water, etc. In both deployments, there were many examples of the "next best thing" being deployed on "out of the box" COTS that could not survive military environmental conditions. In order to perform the warfighter's mission, hardware has to meet stringent environmental, logistics, and human factors criteria.

As part of the Raytheon product-development effort, a survey was conducted on COTS handheld and tablet computers to evaluate their suitability for a military environment. This survey identified the following conditions that distinguish the warfighter's needs from the typical "out of the box" COTS user: temperature extremes, shock/drops, vibration, altitude, moisture, humidity, sand/dust, EMI/EMC, ability to operate wearing biological/chemical warfare MOPP-IV gear, anti-fungal growth, salt fog, etc.

Providing effective, fieldable COTS solutions that meet the warfighter's needs and operational requirements presented challenges. In fact, ruggedization in general is a challenge. Most systems are required to be qualified or at least MIL-STD-461-compliant. Night Vision Goggle (NVG) compatibility (or more often NVG non-interference) can be required for systems used primarily for night-time operations. In direct competition to the NVG requirement, sunlight-readable displays may be required. Frequently, a system must be both NVG-compatible and sunlight-readable. The matter is further complicated when the unit has dismounted operations requiring extended operation only from battery power. And, while meeting all of the above requirements, the unit must also be more powerful, smaller, lighter, and cheaper than existing systems.

Extended Environment Hardware Solutions

To address this need to provide highly reliable handhelds and tablets for rugged combat conditions, the IPT used two Raytheon products for this product development – the Agama Handheld Computer and the Electronic Data Manager (EDM) shown in Figure 2. Both products are part of Raytheon's extended-environment, commercial-off-the-shelf (E2COTS™) rugged computer products customized for the global military, heavy industrial, and niche markets. Customers in these markets need products that can withstand adverse environmental conditions such as extreme temperatures, severe shock, vibration, and humidity.

Agama Handheld Computer

The Agama is a handheld computer, based on a Hewlett Packard iPAQ, that Raytheon has repackaged to withstand extreme environmental conditions required for military and industrial use. The Agama was chosen for this product development to host CAS fire-control software for a spotter deployed on the ground.

The Agama provides a rugged, compact and lightweight unit suitable for a military environment. By running the Windows 2002 Pocket PC operating system, the Agama supports the running of many COTS and military handheld software applications.

Electronic Data Manager

The EDM is a ruggedized handheld computer for use as a pilot's electronic kneeboard. Raytheon has repackaged it to withstand extreme environmental conditions required for military use. For this product development, the EDM will be used as the SA kneeboard for a CAS pilot.

Highlights of the EDM are as follows:

- Provides an Electronic Notes capability for the user to quickly enter data with a stylus
- Graphical GPS tracking of the aircraft's current location using an attached GPS receiver or aircraft GPS
- Qualified to tailored MIL-STD-461/704/810
- Weighs less than 3 pounds.

SOFTWARE SOLUTIONS

Enhanced CAS Situational Awareness

Using feedback from users of Raytheon's fielded SA software (Figure 3), we made enhancements as part of this product development to further extend the ability of our software to optimize the quality and speed of the warfighter in making CAS decisions.

Our product development effort extended existing data-fusion techniques in order to make our software more capable of meeting the concepts of the "OODA Loop" and providing a more complete Common Operational Picture.

"OODA Loop"

The "OODA Loop" (Observation, Orientation, Decision, Action), popularized by Col. John Boyd of the USAF, was developed by Boyd to explain how US fighter pilots were able to win a sizeable majority of air-to-air engagements in the Korean War despite the fact that, at the time, the enemy possessed superior air technology in the Mig-15. Boyd attributed the success of the US fighters to their training, which allowed the US pilots to perform the "OODA Loop" faster than their adversaries. The "OODA Loop" has been demonstrated as an effective model to identify how raw data can be processed by warfighters to their tactical advantage [4].

Common Operational Picture (COP)

In order to provide similar tactical advantages to our users, we have applied data-fusion techniques to our SA software to provide the required Common Operational Picture (COP) required for CAS. This COP needs to provide the warfighter

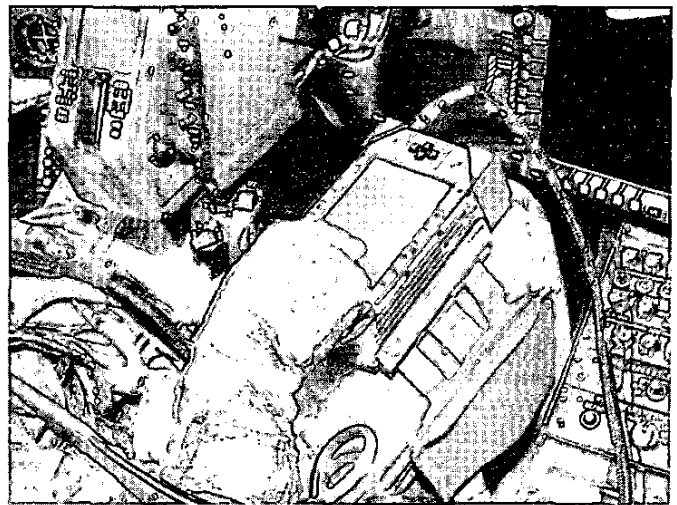


Fig. 2. Electronic Data Manager (EDM)

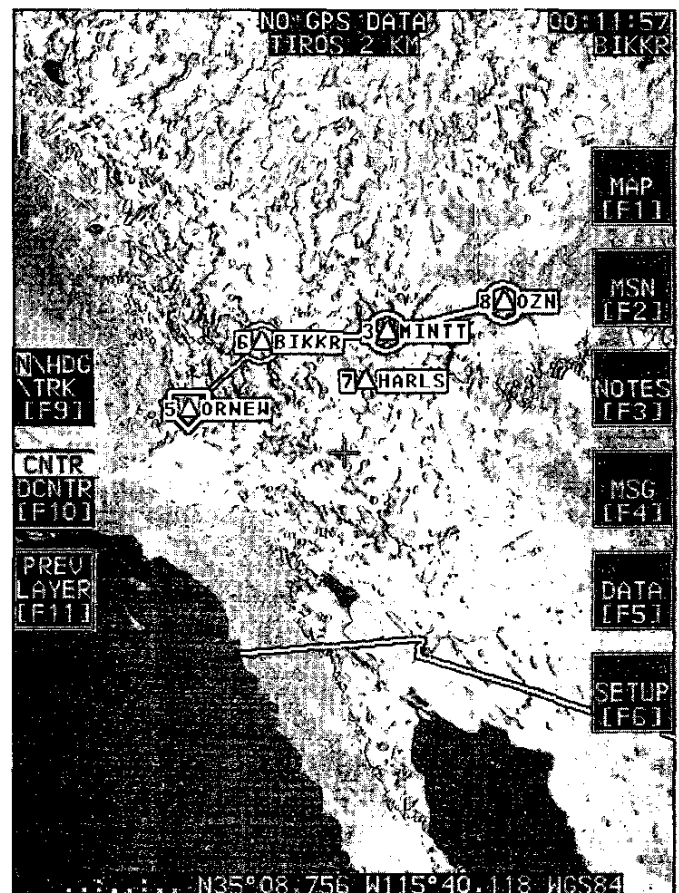


Fig. 3. SA Software

with dominant battlefield awareness. These data-fusion techniques allow the collection and correlation of raw data from multiple CAS sources and provides the effective filtering of this data to present information to the user in a manner intended to avoid information overload. As part of this product development effort, we extended the existing data-fusion

capability of our existing SA software by adding a MIL-STD-2525B-compliant overlay capability that enhanced the following COP capabilities of our SA software:

- Timely and accurate situation awareness and assessment
- Threat/impact assessment
- Classification and identification of battlespace elements
- Correlation of threat data
- Optimization of the quality and speed of decision making
- Quick reaction response time to "Deltas" in Mission, Enemy, Terrain, or Troops.

Fire Control Software Rehost to Handheld

In order to provide a handheld solution, a portion of our existing fire-control software needed to be ported to the Windows CE environment. This legacy fire-control software runs on large UNIX-based systems, which allows it the freedom to present much greater amounts of data on each screen. Therefore, one of the challenges facing this effort was how to provide the same information in a meaningful manner on the handheld screen. The first inclination was to just shrink the screens. That resulted in handheld prototype screens that required the user to scroll up and down and back and forth just to see the information. This approach was soon discarded in lieu of a hierarchical approach to presenting data and information consistent with the look and feel of typical COTS handheld software.

VMF Parser

VMF transfer-and-receive capability was implemented as part of this effort through our development of a generic VMF parser. Our design approach was to implement a socket-based interface that allowed the parser to communicate with user applications and communication interfaces. We designed this parser to be flexible by using an Interface Control Document (ICD) defined database that can be easily updated to add additional VMF messages. As part of this product development, the full VMF message set has been implemented and a demonstration was made of 22 different message types. Additional VMF message types can easily be implemented by adding new data to the database.

VMF Integration

Integral to providing an interoperable CAS-based solution is the flexibility to support existing communication data links. For CAS applications, there is a need to support both Line-of-Site (LOS) and Satellite Communication (SATCOM)-based radios. Due to the increasing tendency for

troops to quickly deploy out of LOS communication range, LOS-based radios have increasingly lost favor with the warfighter, creating an increased demand for SATCOM-based communication hardware. However, there are two major deployment issues associated with SATCOM data-link connectivity:

- Limited availability of SATCOM-based radios
- Limited satellite bandwidth availability to support the CAS NCW infrastructure.

Despite the increasing trend toward SATCOM-based radios, there is still a very large base of LOS-based radios currently being fielded. Therefore, a CAS-based software application needs to have enough flexibility to support both SATCOM and LOS-based data links.

In our product development, we developed systems that were capable of supporting either satellite or LOS-based communications utilizing VMF. In the first phase of this effort, we concentrated on LOS. To accomplish this we leveraged off our previous experience in providing VMF Link 16/J series data link connectivity for the F/A-18. For this phase, we successfully integrated our applications with LOS-based ARC-210 RT-radios that were configured in MIL-STD-188-220A (Transportation, Network, Data Link, and Physical Layers) and MIL-STD-2045-47001B (Application) compliant configurations for VMF-based digital messaging.

To provide SATCOM-based communications, we pursued a second phase of this product development that focused on utilizing a SATCOM-based data link by integrating with a SINCGARS radio. This effort required our development of the necessary SP-TCIM modem drivers for use on Windows CE. Based on the successes of these VMF integration efforts, we have integrated our SA software with the Blue Force Tracker L-Band satellite data links utilizing a Raytheon-developed mini-router.

LESSONS LEARNED

Our experience in performing this product development has generated some valuable lessons learned for NCW CAS interoperability. They have been incorporated into production efforts subsequently funded by various DoD customers for deployed versions of these systems. A high-level summary of relevant lessons learned from our successful efforts to provide NCW CAS interoperability utilizing VMF based data links is listed below:

- Need to provide flexibility of system architecture to support LOS and satellite-based data links
- Need to provide an integrated COP for CAS SA
- Recognize the value of data-fusion techniques to support warfighter's COP

- Need to address the OODA Loop when designing CAS SA software
- Need to provide a “system of systems” solution versus integrating disparate applications with “interoperability glue”
- Need to repackage portable COTS hardware for rugged military applications
- Acknowledge the value of database-based generic VMF parser (versus hard-coding).

SUMMARY

VMF is, by far, the predominant standard used by ground forces for network centric CAS interoperability. As more and more engagements are exercised as joint operations, both within the US Armed Services as well as forces abroad, it is apparent that communicating through VMF is becoming mandatory to engage in an efficient, agile manner while protecting the warfighter from friendly fire. Similarly, as more ground engagements rely on close air support and precision

strike capability, the need for the air community to interoperate with ground forces’ VMF-based networks is further demanded. It is the challenge of systems integrators to design effective VMF-based solutions that will allow both air and ground forces to effectively communicate with the CAS NCW infrastructure being deployed by the DoD.

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