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Guideline on Integration of Crew Station Components into Vetronics Architectures

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Defence R&D Canada

Technical Memorandum

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Abstract

The interface requirements for generic crew station components within an AFV are discussed to identify existing commercial interface standards that could be used to interconnect components to meet these requirements. The focus is not on the crew station or its components in themselves, but rather the electrical and data communication standards that the components of a crew station might use to communicate with the other vehicle systems. A limited number of commercial standards are discussed as possible options to meet the requirements identified.

Résumé

L'examen des besoins concernant l'interface des composants des postes d'équipage génériques à l'intérieur d'un véhicule blindé de combat (VBC) ont amené à identifier les normes existantes des interfaces commerciales pouvant être utilisées pour interconnecter les composants et répondre ainsi aux impératifs des interfaces de VBC. L'étude ne porte pas tant sur le poste d'équipage et les composants eux-mêmes mais plutôt sur les normes de communication des systèmes électriques et de données que les composants d'un poste d'équipage utiliseraient pour communiquer avec d'autres systèmes de véhicules. Un nombre limité de normes commerciales est étudié comme étant des options potentielles pouvant répondre aux besoins identifiés.

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Executive summary

The proliferation of electronic systems in AFVs requires the development of more complex crew workstations to allow the crew to manage and control these systems and to fully exploit the information that they can provide. The integration of the electronic systems will benefit from standardization of interfaces and protocols (vetronics) to allow more rapid technology insertion and lower life cycle costs. The crew station itself can also exploit vetronics principles.

A vetronics based crew station provides the flexibility to extend a common crew station design to multiple types of vehicles, mission specific equipment within a particular vehicle, or to have multiple modes of an interface for differing roles or types of operations. A vetronics based vehicle moves the crew station design from traditional human machine interface ergonomics to much more of a human computer interface. This introduces a significant challenge to acquisition staff and system designers. They must recognize that the flexibility of the computer interface can easily be stretched to exceed the flexibility, or cognitive capacity of the user, especially if the user is in a highly stressful environment. The physical performance of the operator can also be limited by cold, protective equipment or merely by the motion of the vehicle in ways that preclude interface concepts that are commonplace for office environments.

The computer industry has numerous interface standards that may be applicable to AFV vetronics, but few have been designed for mission critical environments or validated in the hostile operational environment of an armoured vehicle. The automotive industry has some current and emerging standards that may be sufficiently robust, but which lack protocols to support the requirements of an AFV. Additional work is required to select and customize commercial standards for military applications. In the absence of specified national or NATO standards supporting crew workstation integration, system developers will have to select and adapt commercial standards on an ad hoc basis. This may result in effective solutions for a single vehicle acquisition but will increase support costs and reduce the potential cost savings associated with the introduction of common sub-subsystems on a fleet wide basis.

Chesney, R.H., 2001. Guideline on Integration of Crew Station Components into Vetronics Architectures. TM 2001-190. Defence Research Establishment Suffield.

Sommaire

La prolifération des systèmes électroniques dans les VBC exige que des postes d'équipage plus complexes soient mis au point, permettant ainsi à l'équipage de gérer et de contrôler ces systèmes et d'exploiter pleinement l'information qui en résulte. La normalisation des interfaces et des protocoles (vétronique) amélioreront l'intégration des systèmes électroniques en permettant une insertion plus rapide des nouvelles technologies et en réduisant les coûts de cycle de vie du matériel. Les principes de la vétronique peuvent être exploités dans le poste d'équipage lui-même.

Un poste d'équipage à base vétronique permet plus de flexibilité si le concept d'un poste d'équipage commun s'étend à des types multiples de véhicules, d'équipement spécifique à une mission à l'intérieur d'un véhicule particulier ou permet d'avoir des modes multiples d'interface pour différents rôles et types d'opérations. Un véhicule à base vétronique transforme le concept traditionnel de l'ergonomie du poste d'équipage comme machine humaine en une interface informatique beaucoup plus humaine. Ceci pose un problème important pour le personnel des acquisitions et les analystes-programmeurs qui doivent être conscients que la flexibilité d'une interface informatique peut facilement être étendue et excéder la flexibilité ou les capacités cognitives de l'utilisateur, surtout si ce dernier fonctionne dans un environnement très stressant. La performance physique d'un opérateur peut aussi être limitée par un équipement protecteur froid ou simplement par le mouvement interdisant les commodités d'interface qui sont usuelles dans un bureau.

L'industrie informatique possède de nombreuses normes d'interfaces pouvant s'appliquer à la vétronique des VBC mais peu d'entre elles ont été conçues pour des environnements critiques de mission ou ont été validées pour l'environnement opérationnel hostile d'un véhicule blindé. L'industrie automobile possède quelques normes courantes et nouvelles, suffisamment robustes mais qui manquent de protocoles soutenant les besoins des VBC. Il sera nécessaire de continuer les travaux pour sélectionner et individualiser les normes commerciales pour les applications militaires. Dans l'absence de normes spécifiées par l'OTAN ou les nations qui favoriseraient l'intégration des postes d'équipage, les développeurs de systèmes devront sélectionner et adapter les normes commerciales sur une base empirique. Des solutions efficaces pourront en résulter à l'acquisition d'un seul véhicule mais augmentera les coûts de soutien et réduira le potentiel d'une économie d'échelle, associée à l'introduction de sous-systèmes communs, au niveau d'une flotte entière.

Chesney, R.H., 2001. Guideline on Integration of Crew Station Components into Vetronics Architectures. TM 2001-190. Defence Research Establishment Suffield

Table of contents

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Acknowledgements

This document is the original version of a document delivered to NATO Land Group 2 (LG2) as a component of supporting a Working Group on Vetronics established under the Land Group (LG2.WG1). The NATO version of the document will be revised in time to reflect technological change and any changes in requirements identified.

This document is the second version of the NATO document written on the same topic. The original version was written by Mr. Art Rofe of the United States Army's Tank Automotive and Armaments Command (TACOM). The current paper draws on some of the material and concepts introduced in the previous version, however the specific content of the current document is solely the responsibility of the current author.

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Introduction

The intent of this document is to define the interface requirements for generic crew station components within an AFV, and to identify existing standards that could be used to meet these requirements. The focus is not on the crew station or its components in themselves, but rather the electrical and data communication standards that they might use to communicate with the other vehicle systems. In instances where an existing standard may not be fully appropriate for the requirement, it may still be identified as a candidate for extension, or as a model for a standard that meets all of the requirements.

The traditional goal of a crew station designer is to develop a crew station that best meets the crews functional requirements -- for a particular vehicle configuration operating in a given operational context under a set of assumptions about the crew aptitude and training. A vetronics based crew station provides the flexibility to extend a common crew station design to multiple types of vehicles, mission specific equipment within a particular vehicle, or to have multiple modes of an interface for differing roles or types of operations. A vetronics based vehicle moves the crew station design from traditional human machine interface ergonomics to much more of a human computer interface.

The process of identifying commercial standards that are appropriate for applications in an AFV crew station must first begin with a level of understanding of the operator interaction requirements of the crew within the AFV. While the crew requirements may often be characterized as being similar to those of an automobile driver or of someone operating a video game, the stress and time pressures of combat coupled with the requirement for acceptable levels of safety introduce significant complications. Before commercial standards can be adopted they must be validated to ensure that they can meet the time and safety constraints of the environment and that the systems can be effectively operated by a crew that may be under extreme stress.

Design Goals and Constraints

A vehicle crew station needs to be designed to provide the user with a consistent mental model of the interface, so that he is never "surprised" by a system response. System inter-face responses should be predictable, so that the user knows what will happen when he takes a certain action. The more consistent the interface to the user, the easier it is for him to understand what the system is doing at all times, and the more effectively he will be able to fight his vehicle in battle.

Moving the vehicle crew into the hull, which is being suggested in number of NATO member countries, presents momentous challenges to the development, sustainment, and enhancement of situation awareness required to survive on the battlefield. No longer will the naked eye be used to monitor the surrounding terrain for targets, or to associate the observed terrain with one's estimated position on a paper map. The crew station design must make the preservation and enhancement of situational awareness a design priority. At all times the soldier must know where he is, where his threats are with respect to his own vehicle, and what the "big picture" of the unfolding battlefield scenario is. Situation awareness also implies that the soldier knows the state of the vehicle's systems, and his capability to fight using those systems, without becoming overloaded with information that isn't helpful.

Mission critical functions should be separated from non mission critical ones so that the number of choices available during combat phases of the mission are restricted to those necessary for combat. It must be possible to access all combat critical functions quickly, and in a completely consistent manner.

It may be desirable to provide multiple methods of accomplishing selected mission tasks so that task completion time can be reduced. Controls and functions that are available as menu selections may also need to be accessible through grip-mounted or dedicated switches, to allow the operator rapid access to these functions in differing modes of operation. Depending on the moment to moment conditions (e.g. if the vehicle was moving or stationary) the soldier can choose the most effective means of making inputs to the system.

The future crew station must also provide integration of functionality that transcends traditional system boundaries. The crew station functions, and importantly, the functions available to the operator at any specific time, must reflect the operational task requirements of the operator rather than the hardware design of the vehicle.

Task automation will likely be an important part of future vehicle designs to offload the mundane and repetitive tasks from the operator. However, the choice of tasks to be auto-mated and the way the automation is controlled will need very conscientious design. The crew must remain in control of the vehicle functions for both safety reasons and to achieve psychological acceptance. The crew must also remain "involved" in the routine operation of vehicle systems. This acts to preserve the situational awareness and overall alertness of the operator. The division of tasks between the operator and automation must recognize and reflect human strengths and weaknesses, taking advantage of the crews capability to analyze and interpret information in uncertain conditions.

The operator workstation is additionally constrained by the environment within an AFV. It is a challenging one for electronics; especially for the switches, controls and displays that the operator will use. They are fully exposed to the environment within the AFV and can not be sealed in a conditioned box. Further, the crew station components will often be exposed to the external environment through the crew hatch. This means that the equipment must survive temperature extremes and be effectively sealed against moisture and dust. The equipment must also survive the tremendous wear and abuse associated with armoured vehicles. Not merely the shock and vibration but also the potential for accidental damage as the crew climbs in and out of the vehicle. Ultimately, this environment, in conjunction with the very tight and irregular space constraints of AFVs may preclude the adoption of many human computer interface concepts that are well accepted in other applications.

Functional Requirements

Prior to identification of the interface requirements for a crew station one should first explore the current and potential future requirements of the crew for interaction with the vehicle systems. There are numerous configurations of AFVs and the vehicles and crews will have differing roles and requirements in each type of vehicle. The detailed requirements will also be a function of the conflict scenario and the current tasking of the vehicle and its supporting formation. Despite the difference in the detailed requirements for particular vehicles there is still scope for compiling common crew requirements that are typical of most vehicles.

Functional requirements include:

- receiving and transmitting orders (by voice, text, map overlays and photo overlays)
- receiving and transmitting geo-referenced data (point locations, area boundaries, etc...)
- receiving real time imagery from other manned or unmanned vehicles, or transmitting imagery from on-board systems;
- receiving and transmitting vehicle / crew state data (logistic state, failure synopsis, crew condition)
- maintaining situational awareness (self-location in a context of terrain features, cultural features, obstacles, and known / reported locations of friendly and enemy forces)
- tactical planning (movement planning, threat assessment, inter-visibility assessment, mobility analysis, time / motion analysis)
- vehicle state awareness (speed, RPM, fuel, ammunition, battery state, general automotive info (coolant temp, air pressure,) system health reporting)
- target location (geo-location of observed enemy forces or landmarks of interest), automatically through the targeting system or manually relative to vehicle position, manual relative to map....
- communications / crypto system control (communication plan setup / entry / validation of transferred plan, call sign setup, line of command reversion, crypto key control)
- Vehicle / systems state control (automotive function control, starting, HVAC control, battery / energy management)

- targeting system control (FOV, FOR setup, band selection, ATR setup / control, pointing control, target designation)
- weapon control (arming, ammunition selection, ammunition "programming", aim point control, weapon release)
- defensive aid systems control (threat characterization / system tuning, countermeasure selection, mode selection, arming)
- driving / automotive control (steering, braking, transmission and differential control, mobility aid control)
- bulk data entry (data base entry / loading mechanisms for map / GIS / back-ground intelligence data)
- data download to co-located unit (to infantry... GIS data with / without orders...)

Few, if any, vehicles will have the complete set of functional requirements, however, the trend to digitization of the battlefield will make more and more data available within the vehicle. In a fully "digitized" battlefield the level of functional capability required in individual vehicles envisioned is very high. Digital messaging coupled with digital map displays representing the battlefield and available intelligence information will become pervasive. Crew stations will have to provide information visualization tools as well as sys-tem control. The design of crew workstations to provide those capabilities will require careful attention to the ability of individual crewmembers to absorb and use the information provided and to provide control inputs.

Interface Interaction Requirements

While there are very diverse functional requirements within an AFV, the crew interaction requirements can be reduced to a few, very generic capabilities. These generic capabilities remain the same over a broad range of human computer interaction, although the displayed information or the function being controlled may change. It is important to note, however, that while the interaction requirement may not change across a range of functional requirements, the timing constraints may well change.

Some specific crew interaction requirements include:

- Crew identification (passwords, hardware "key", biometrics...)
- Image display for both still images and motion video from on-board or remote sources
- Geo-coded graphics display – electronic maps with intelligence / tactical overlays
- State display (gauges, counters, indicator lights or graphical equivalents)
- Text display
- Audio (external, internal communications and state annunciation)
- Continuous control inputs (control handles, joysticks, etc for weapon and target system control)
- Discrete control inputs (conventional switches or functional equivalents)
- Text input
- Voice input
- Graphical point / motion input (computer display interaction to designate targets, locations and to draw tactical overlays)

Interaction Mechanisms

Many current AFVs include displays, switches and pointing devices that meet some of the interaction requirements identified above. However, in most instances these devices are associated with the control / monitoring of a single function or device. As the complexity of the control requirements grows within the AFV, it becomes impossible to physically integrate independent displays, controls and switches for all of the functions desired. Hence, the crew workstation needs to adopt generic interaction mechanisms so that controls and displays can be shared among many functions. This type of interaction is common place in many computer systems, particularly those used in geographic information systems, computer aided design systems and those used as game consoles. Some of the interface mechanisms used in these systems are appropriate for implementation in AFVs, although great care must be taken to ensure that the cognitive workload imposed on the operator is reasonable.

Fundamental requirements include multi-functional displays with an ability to display computer generated graphics and text. These displays may also be required to support still images and full motion video imagery for many (if not all) crew positions. An ability to mix video with computer generated information, either with graphic overlays on the video or video windows inserted into graphical screens may be required. These displays will need to support or incorporate a pointing device through either a cursor overlay or a touch sensitive panel. Displays may be conventional flat panel displays or in certain situations head mounted displays may be appropriate.

Another common requirement is a pointing device to control a cursor and provide designation actions. Trackballs and joysticks are in common use. Other options include head / eye motion trackers, touch screen interfaces, and hand gesture trackers (data glove).

Conventional switches may be used for state control functions, however, the switches may need to be re-assigned to control different functions for different operator roles. State control may also be achieved through menu selection or other common computer interaction means. Programmable display pushbuttons, which incorporate a computer controlled label as a cue to the function currently assigned to the button action may be useful to provide flexibility.

Conventional keyboards may be required for some AFV roles requiring extensive text entry. These may be augmented / supplemented in some instances with other text entry methods including speech recognition and handwriting recognition.

Voice command systems may also provide a natural interface for some classes of action, most likely for state / discrete control actions such as changing to a different communications net, or switching display modes. Speech recognition systems may also be of benefit to replace, or augment keyboards for text entry roles.

As noted above, the interaction mechanisms chosen for implementation in a particular combat vehicle will have to be chosen in the context of the ability of the operator to physically use the mechanisms and to manage the complexity of the resulting interface. Conventional ergonomic considerations will need to be observed to ensure that the devices are usable in the range of environmental conditions and motion dynamics that the vehicle en-counters. Some conventional ergonomic considerations, relating to button placement, labelling, may have to be adapted to accommodate the generic nature of a computer based, multi-function, interface.

Potential Interface Standards

Many of the interaction requirements identified above are similar to those of the general computer industry, hence much of the supporting infrastructure of devices, interface and protocol standards exist. However, in many instances the equipment and even the underlying standards aren't directly usable in a vehicle environment. Most of the commercially available devices are not designed for a broad range of environmental conditions and some of the standards explicitly specify cabling and connectors that are not appropriate for harsh environments. Further, few of the standards consider fault tolerance, or provide mechanisms for continued systems operation (possibly degraded) in the event of a component (or sub-system) failure.

As a result, many commercial interface standards will need to be adapted to the military vehicle environment. In some instances this may be as simple as choosing alternatives connectors and cabling; in others, it may be required to vary details of the protocol, or to duplicate the interface to provide a level of fault tolerance. In the absence of appropriate military standards, system integrators are adapting commercial standards on a system by system basis as new vehicles and sub-systems are fielded.

Some potentially applicable commercial standards are discussed below. Additional details for many of these standards are available through the Internet at the web addresses included.

Controller Area Network (CAN):

CAN is a low speed but (not higher than 1 megabit per second) that is widely used in the automotive market. It is well qualified for electromagnetic interference and almost all CAN components are available for extended temperature ranges. Much of the automotive functions of future vehicles will be hosted on a CAN bus and the crew workstation will have to be able to extract data from this type of bus, and to provide control information onto the bus.

The bus itself may also be appropriate for much of the HMI interface requirements of the crew workstation. It could be used to support all of the discrete/continuous control requirements and simple status displays (switches, control handles, indicator lights, gauges, etc).

The electrical characteristics of a CAN bus are well specified as well are some common aspects of the protocol. Certain aspects of bit timing and all aspects of address and packet content interpretation are determined by an overlying protocol. Numerous protocols have been specified for operation over a CAN bus. Work is in progress under the auspices of the International High Speed Data Bus Users Group –

CAN Bus Working Group to select an appropriate commercial protocol for adoption as a common protocol for military vehicles. Current activity within the group is directed to definition and evaluation of two protocols, as follows:

MilCAN A – A variation of the SAE J1939 protocol developed for the truck and bus vehicle community. The protocol is modified to increase the speed and add additional messages and to provide a level of deterministic behaviours. A conventional J1939 bus device could not de directly connected (due to the speed change), but a simple bridge would be possible. Additional information on the J1939 protocol is available for order through the SAE web site at http://www.sae.org.

MilCAN B – A variation / implementation of the CANopen protocol. The extent to which proposal will be interoperable with existing CANopen devices is not known at the moment. Additional CANopen protocol information is available at http://www.canopen.org.

FlexRay:

FlexRay is a higher speed bus being developed for automotive applications. It is being developed by a consortia including BMW, Daimler-Chrysler, Bosch, Phillips and Motorola. The nominal bus speed will be 10 Mbits per second. In addition the bus will sup-port fully deterministic behaviour at a hardware / firmware level. In the longer term, this bus, or some comparable alternative, may supersede the CAN bus for general automotive applications. It would appear to be well suited for all of the applications that a CAN bus could be used in, and would provide much greater capacity for growth. If this bus standard gains commercial acceptance, a effort to generate a military standard should be considered. Additional information is available at http://www.flexray-group.com.

Universal Serial Bus (USB):

USB is broadly used in the commercial computer market to connect low to medium speed peripherals to computers. It provides an interconnect mechanism for keyboards, all classes of control / pointing devices (mice, control handles, switches, etc), audio devices (both microphones and speakers / headsets) and medium speed bulk storage (CD-ROMs and some other disc drives). The nominal data rate for the USB (version 1) is 12 Mbits / second. The maximum cable length is 5 metres. The USB specification includes a specific connector which is inappropriate for harsh environments.

USB could be used (with a substitute connector) to integrate many of the components of a crew workstation to a common workstation computer. The bus length limit would likely preclude more general application. The bus was not specifically developed for operation in high noise, or low latency applications; its performance capabilities under those conditions are uncertain.

A revised version of the USB specification (Version 2.0) has greatly enhanced the speed characteristics of the bus (to a nominal speed of 480 Mbits / second). Additional information on the bus can be found at http://www.usb.org.

IEEE 1394a:

A standards committee of the Institute of Electrical and Electronic Engineers (IEEE) has defined a high speed serial bus standard – IEEE 1394a. This bus, often referred to by the tradenames Firewire and iLink, is a high speed (400 Mbits / second) bus that is widely used in the personal computer area for both video data transfer and data storage. IEEE 1394 has been used in industrial environments.

A new version of this standard (1394b) is currently being finalized. This will provide a number of options for both copper and optical fibre based connections, extend the maxi-mum distance for a 1394b bus connection (to 300 m over fibre) and increase the nominal bus speeds to include versions at 800 and 1600 Mbits / second.

IEEE 1394 may provide a workable video integration bus to allow video, digitized at source, to be routed around an AFV. The 1394b specification includes changes to increase the noise immunity of the signalling and provides options to transmit the bus data over optical fibre as well as copper. Further information on this bus can be found at http://www.1394ta.org.

Numerous other commercial standards are applicable to the crew workstation design including a variety of video standards, such as RS 170 and older serial data interface standards such as RS 485. More modern flat panel displays may connect to the supporting graphics interface through direct digital interconnects based on the DVI or DFP standards.

Conclusion

Few examples of commercial equipment will meet all of the requirements of an AFV, especially when the environmental requirements are considered. For several computer industry standards (such as USB) the actual standard extends to the connectors and the cabling, technically prohibiting the substitution of more robust alternatives. However, it may still be possible to extract the electrical and protocol elements of the commercial standard while adopting some specific variations (possibly through a NATO standardization process). This would allow the use of many commercial electronic components (possibly after selection for temperature compliance) and much of the supporting commercial software.

Much work would need to be done to select appropriate standards, and to explore / model the performance of these standards in the military vehicle applications. Issues such as EMI tolerance, error recovery and latency need to be more thoroughly understood than is typical of "desktop PC" applications. In addition the ability of the interface to inherently support fault detection, fault isolation and fault tolerant behaviour needs to be well understood to allow the system designer to introduce redundant systems where necessary to meet system performance goals.

In the absence of more definitive evaluations of protocols supporting crew workstation integration, system developers will have to select and adapt commercial standards on an ad hoc basis. Wherever possible, choices should be biased toward solutions that provide re-configurable interface solutions using general purpose, multi-function displays and digitized control inputs (including voice, is some instances) that can be re-assigned in software to support additional, or modified functionality. Solutions that adopt commercial standards with minimal modification should be explicitly preferred over proprietary developments.

Finally, as in most system developments, the crew workstations need to be tested, both from an environmental viewpoint for EMI, shock, vibration and temperature, and also for usability. The flexibility of the computer interface can easily be stretched to exceed the flexibility, or cognitive capacity of the user, especially if the user is in a highly stressful environment. The physical performance of the operator can also be limited by cold, protective equipment or merely by the motion of the vehicle in ways that preclude interface concepts that are commonplace for office environments.

List of symbols/abbreviations/acronyms/initialisms

AFV	Armoured Fighting Vehicle
ATR	Automated Target Recognition
CAN	Controller Area Network
CD-ROM	Compact Disk – Read Only Memory
DFP	Digital Flat Panel
DVI	Digital Video Interface
EMI	Electromagnetic Interference
FOR	Field of Regard
FOV	Field of View
GIS	Geographic Information Systems
HVAC	Heating Ventilation and Air Conditioning
IEEE	Institute of Electrical and Electronics Engineers
NATO	North Atlantic Treaty Organization
RS	Recommended Standard
RPM	Revolutions per Minute
SAE	Society of Automotive Engineers
TACOM	U.S. Army Tank-automotive & Armaments Command
USB	Universal Serial Bus

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