ITS Technologies in Military Wheeled Tactical Vehicles: Status Quo and the Future

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ABSTRACT

The U.S. Army operates and maintains the largest trucking fleet in the United States. Its fleet consists of over 246,000 trucks, and it is responsible for buying and developing trucks for all branches of the armed forces. The Army's tactical wheeled vehicle fleet is the logistical backbone of the Army, and annually, the fleet logs about 823 million miles. The fleet consists of a number of types of vehicles. They include eight different families of trucks from the High Mobility Multi-Purpose Wheeled Vehicles to M900 series line haul tractors and special bodies. The average age of all the trucks within the Army fleet is 15 years, and very few have more than traditional driving instrumentation on-board.

Over the past decade, the Department of Transportation's (DOT's) Intelligent Transportation Systems (ITS) Program has conducted research and deployment activities in a number of areas including in-vehicle systems, communication and telematics technologies. Many current model passenger vehicles have demonstrated the assimilation of these technologies to enhance safety and trip quality. Commercial vehicles are also demonstrating many new electronic devices that are assisting in making them safer and more efficient. Moreover, a plethora of new technologies are about to be introduced to drivers that promise greater safety, enhanced efficiency, congestion avoidance, fuel usage reduction, and enhanced trip quality.

The U.S. Army has special needs with regard to fleet management, logistics, sustainability, reliability, survivability, and fuel consumption that goes beyond similar requirements within the private industry. In order to effectively apply emerging ITS technologies to the special needs of the U.S. Army, planning for the conduct of the Army's Vehicle Intelligence Program (AVIP) has now commenced. The AVIP will be focused on the conduct of research that: 1) will apply ITS technologies to the special needs of the Army, and 2) will conduct research for special needs with regard to vehicle control, driver assistance, integration of vehicle intelligence and robotic technologies, managing effectively the information flow to drivers, enhanced logistics capabilities and sustainability of the Army's fleet during battlefield conditions.

This paper will highlight the special needs of the Army, briefly describe two programs, which are embracing ITS technologies to a limited extent, will outline the AVIP, and will provide some insight into future Army vehicle intelligence efforts.

INTRODUCTION/STATUS QUO

The Army's tactical wheeled vehicle fleet consists of several different families of trucks. They include:

- Commercial Utility Cargo Vehicles (CUCVs)
- High Mobility Multi-Purpose Wheeled Vehicles (HMMWVs)
- Family of Medium Tactical Vehicles (FMTVs)
- M900 series line haul tractors and special bodies
- Heavy Expanded Mobility Tactical Truck (HEMTTs)
- Palletized Loading Systems
- Heavy Equipment Transporter Systems (HETSs)
- M809/M939 and older series 5-Ton Trucks
  Representative pictures of three of these family types are presented below.

Class IIB – HMMWV M998 Utility Vehicle

Class VI – FMTV Tactical Truck

Class VIII – M915 Line Haul Rig

Most of these trucks have traditional driving instrumentation. Most utilize standard radio dispatch technologies, and very few employ what is being referred to as vehicle intelligence (VI), ITS, or telematics. The Army has special needs with regard to the following areas:

- Logistics: Being able to have the right resources at the right time with optimum resource utilization. Special needs exist with regard to managing resources in battlefield or combat situations. Dynamic route planning, navigation, global positioning systems, enhanced vision capabilities, and centralized fleet management technologies are applicable.

- Sustainability and Reliability: Related to logistics, but focused on assuring that sufficient resources are available in locations that can assure mission success. Also involves very high reliability (ultra-reliability) to assure vehicle availability and mission readiness. During wartime, this involves the ability to deploy a fleet for a sustained period of time with minimal requirements for maintenance or other vehicle-based requirements.

- Fuel Consumption: Fuel constitutes 70% of the bulk tonnage needed to sustain a military force on the battlefield. Better fuel consumption characteristics by the Army's wheeled tactical vehicles will significantly reduce the fuel requirements needed, and minimize the Army's significant dependence on fuel for efficiently carrying out Army missions.

- Survivability: During peacetime, military vehicle convoying represents the highest rate of fatalities in the Army. During wartime, survivability requires a significantly different and greater emphasis than the safety issues present in commercial or private vehicles.

In addition to these special need areas, there are a number of other ITS technologies and application areas that could be of benefit to the U.S. Army. Table 1 provides an alphabetical list of ITS/VI technologies and opportunities in which VI is being applied, or is being contemplated for application in the commercial domain. Many of these technologies are being developed from

Table 1: Selected ITS/VI Technologies and Application Areas

Adaptive Cruise Control	Electronic Braking	On-Vehicle System Monitoring
Advanced Air Bags	Electronic Credentialing	Platooning (E-Tow Bar)
Advanced Lighting Systems	Electronic Mirrors	Pre-Crash Hazard Sensing/Tracking
Advanced Vehicle Control Systems	Electronic Refueling	Rear-End Collision Avoidance
Aggressive Drivers	Electronic Tolling	Road/Bridge Condition Monitoring
Automated Clearance	End-of Queue Warning Systems	Roadway Departure Collision Avoidance
Automated Collision Notification	Frontal Crash Testing	Rollover Warning Systems
Automated Driving Functions	Fuel Quality-Based Fuel Burn Optimization	Roll Stability Advisor
Black Ice Warning Systems	Highway Geometry-based Fuel Burn Optimization	Roll Stability Control
Advanced Cell Phones	Hours of Service	Runaway Trucks
Congestion Avoidance	Human Presence Detection	Seat Belt Usage
Driver Assistance Systems	Intersection Collision Avoidance	Side Impact
Driver Associate Systems	In-Vehicle Information Integration	Vehicle Compatibility
Driver Attention	In-Vehicle Office Functions	Vehicle Rollover
Driver Distraction	In-Vehicle Signing	Vehicle Self-Diagnostics
Driver Monitoring Systems	Lane Change/Merge Collision Avoidance	Vehicle-to-Vehicle Communication
Driver Workload	Lane Guidance System	Vision Enhancement
Drowsy Driver Warning	Lateral Control System	Voice Recognition
Drunk Driving	Navigation Systems	Weigh-in-Motion
Dynamic Route Guidance	Night Vision	X-by-Wire
Ejection Mitigation	No-Zone	
Electronic Brake Stroke Indicator		

a safety perspective. For example, the collision avoidance technologies, driver warning systems, etc., clearly have safety as their primary motivation. Additionally, however, such technologies have secondary effects in the form of fuel efficiencies, and mission or job efficiencies. Such crash/accident avoidance will minimize the disruption to traffic flow, minimize congestion, enhance vehicle throughput, minimize travel time, minimize fuel consumption, and enhance trip efficiencies. Some of these technologies are clearly geared to enhancing vehicle/trip efficiencies. For example, fuel burn optimization, congestion avoidance, electronic credentialing, navigation systems, platooning, route guidance, and weigh-in-motion are clearly geared toward greater fuel efficiencies, and improved mission/job efficiencies. Additionally, however, such systems also have safety benefits associated with their usage. For example, weigh-in-motion and electronic credentialing minimizes the number of stops, reduce fuel consumption, and enhance mission/job efficiencies. Avoidance of the congestion at stops also reduces the potential for accidents, and therefore also has a safety function. Other technologies such as advanced control systems, advanced lighting systems, night vision, vehicle-to-vehicle communication, in vehicle signing, etc., similarly have safety and efficiency enhancement benefits. As this list suggests, these technologies have the potential for significantly changing the traditional driving role of commercial and military drivers. Some of these technologies are making their way into current generation driving platforms, and many of these technologies will be introduced into the driving environment over the next five years. These technologies imply that drivers will not only have to engage in effective driving, but that they will also be occupied by new tasks that are the result of having to interact with new on-board systems. Tasks involving cognitive activities such as visual searches/scanning, prioritization, data fusion, data selection, data refresh rates, and decision making will be vying for the drivers attention and cognitive resources in addition to the tasks associated with driving (e.g., lane keeping, routing, headway control, safety, fuel management, turn maneuvers, etc.). As the demand for the driver's attention increases, it is foreseeable that the driver will have to be elevated to the role of driver/supervisory controller. That is, the driver's primary function will still be to assure safe, economical and timely driving, but he/she will also provide oversight to the multiple functions that assist him/her in the driving activities.

The Army's interest in ITS/VI technologies involve the following objectives:

- Create a dual use paradigm to develop, operate and maintain a military vehicle fleet that is capable of utilizing emerging commercial in-vehicle technologies in ways that are supportive Army transformation initiatives.
- Utilize VI technologies to enhance the functionality of military vehicles both during peacetime and wartime operations.
- Integrate VI technologies into the military fleet in ways that not increase the cognitive and physical workloads of the drivers.
- Select VI technologies that have the strongest impact on mission efficiencies, fuel economy, safety, and emissions.
- Merge VI and robotics technologies to move toward higher levels of vehicle operation automation.
- Driver/Crewman associates should be utilized to balance the need for effective driver workload and the need for appropriate feedback for decision-making purposes.
- Utilize VI to cut development costs and operations/sustainment costs for military vehicle platforms.

These objectives will be applied within the Army's Vehicle Intelligence Program (AVIP)

THE FUTURE: THE ARMY'S VEHICLE INTELLIGENCE PROGRAM (AVIP)

The U.S. Army's Tank automotive and Armaments Research and Development Center (TARDEC) is home to the National Automotive Center (NAC). The NAC was founded in 1992 and is the Department of Defense (DOD)/Army focal point for collaborative ground vehicle research and development (R&D). The NAC leverages government, commercial industry and academia investment in advanced automotive technology R&D, and initiates shared automotive technology programs. Its primary focus is to benefit current and future military ground vehicle systems through: performance improvements, service life extensions, and reduction in ground vehicle design, manufacturing, production and operating and support costs.

The vision for the work/research to be conducted through AVIP is supportive of the dual use philosophy that is at the heart of all programs conducted through the NAC, but extends this philosophy to include other federal agencies with similar interests. Such jointly sponsored research will leverage the limited resources of the partner organizations, will support the conduct of research that individually would be too expensive to undertake, and provide an opportunity to share in the benefits of cutting edge research.

AVIP research will involve a complete spectrum of research domains including computer-based simulation, workstation experiments, simulator studies, closed-loop test track experiments, controlled field-operational test (FOTs), and open FOTs. The specific road mapping activities associated with these efforts will be more specifically defined in FY-2001 and will be accomplished through close collaboration with subject-matter experts from within the DOD, other federal agencies, academia, national laboratories, and private industry. While the objectives of the AVIP will be on the enhancement of the U.S. Army's ground fleet for Army transformation initiatives, the research will be tailored to assure that non-DOD partners can easily share in and benefit from the research results.

Some of the major activities that will be addressed within the AVIP road mapping effort will include:

- ITS/VI technology evaluation,
- definition of viable vehicle architectures including databus configurations,
- technology integration (both physical and functional),
- definition of the driver-vehicle interface,
- design of laboratory-to-FOT studies,
- definition of performance measures,
- design of the ITS/VI data acquisition systems,
- conduct of the FOT including the collection of baseline data,
- analysis of collected FOT data, and
- conduct of benefit analyses.

Once an initial roadmap is developed, the AVIP will issue requests for proposals (RFPs) to identify the most capable team(s) for refinement of the roadmap, execution of associated activities, and clearly defining the benefits that result from the utilization of ITS/VI technologies.

CANDIDATE ITS/VI TECHNOLOGIES FOR THE AVIP

Over the past year, the NAC has completed a technology assessment that included a literature review of ITS/VI technologies, visits/discussions with Original Equipment Manufacturers and first tier suppliers, and visits/discussions with representatives from DOT's Federal Motor Carrier Safety Administration (FMCSA), National Highway Traffic Safety Administration (NHTSA), Federal Highway Administration (FHWA), and Research and Special Projects Administration (RSPA). From information obtained from these various sources, a list of VI technologies was formulated as initial candidates for consideration by the AVIP. These technologies are listed in Table 2, and represent those technologies that are currently believed to provide a strong impact

Table 2: Candidate ITS/VI Technologies for the AVIP	
Navigation Systems: on-board map databases associated with GPS technologies to allow self location and provide the basis for optimizing route planning	**Adaptive Cruise Control**: technologies that maintain a pre-set headway condition. Some systems involve safe headway for current vehicle velocity. Usually is tied to the engine throttle control.
Route Guidance: algorithms that provide an optimal route based on various forcing functions such as timing, minimization of exposure to the enemy, minimization of fuel consumption, etc. Dynamic route guidance provides real-time route planning and can be sensitive to traffic conditions, and environmental factors (e.g., road conditions). Typically works in conjunction with map databases.	**Driver Condition Monitoring**: systems that observe/monitor the condition of the driver. Such systems include drowsy driver detection systems, hours of operation monitoring, physiological data collection systems, and video surveillance. Advanced systems could involve eye tracking.
Fleet Management/Logistics: provides the capabilities for optimizing the simultaneous movement of multiple vehicles to achieve various goals/missions. Can be used effectively with dynamic route guidance and navigation systems.	**Lane Tracking**: typically utilizes video-based technologies to identify roadway markings or edges of the road to assist in lane keeping and run-off-the-road warning systems. In automated driving, can be utilized in vehicle trajectory planning and maintenance.
In-Vehicle Information Integration: provides for optimal data and information flow to the driver. Typically it is the clearinghouse for data to be displayed to the driver. High stress, high workload situations will allow only highest priority information to be displayed (safety and mission critical). Filters, prioritizes, synchronizes, selects the appropriate modality, and adjusts for ambient conditions.	**Collision Avoidance Warning and Prevention Technologies**: technologies for warning the driver about various types of collisions, e.g., intersection, forward, lateral, backing, run-off-the-road and lane change. Collision prevention systems will require automated brake control technologies. Limited differential braking is associated with electronic braking and stability control systems.
Truck Rollover Warning: utilizes vehicle dynamics, and highway geometry information to provide warning of potentially unsafe condition in sufficient time for the driver to make appropriate corrections.	**Fuel Burn Optimization**: utilizes information about highway geometry and/or fuel quality to optimize fuel consumption.
Driver's Associate: a centralized system monitors all driving systems, and the driver, and provides advice for meeting mission goals. Typically functions within a subordinate role, but can perform certain driving/mission functions as conditions necessitate, and as the driver needs. Can function closely with the in-vehicle information integration system.	**Platooning**: also called the electronic tow-bar, this technology allows the platooned vehicles to travel in close proximity of one another in an organized fashion. Information about braking and steering maneuvers are shared among all vehicles to optimize synchronized responses. Such synchronized driving contributes to optimal traffic flow.
Night Vision/Vision Enhancement: Typically involves infrared systems that detect IR radiation from hot bodies. Vision enhancement	**Truck Stability**: vehicle dynamics are utilized in a similar fashion as in truck rollover systems to engage differential braking. Appropriately applied differential braking will aid in vehicle stability.

on enhanced mission efficiencies (including fuel efficiencies) enhanced safety, and reduced environmental emissions. Some of these technologies such as night vision, navigation systems, and adaptive cruise control are already being addressed in some military platforms. Other systems such as collision avoidance technologies and truck rollover technologies are being addressed to a limited extent. Technologies such as fuel burn optimization have not been studied to a great extent within military systems but are of interest because of their strong potential to minimize fuel consumption.

The AVIP will focus on further integrating these systems within military platforms. It should be emphasized that integration within the AVIP involves complete systems engineering perspective. That is, requirements for VI functionality will be developed with a particular vehicle platform in mind. These requirements will be validated, in an interactive manner to provide a baseline for developing system and component level specifications. These specifications will be used to design a VI architecture that can be inserted into the selected vehicle platform. The design specification can be used to impact other similar platforms as well. This creates a true open system approach. A core focus of the AVIP is in-vehicle information integration (IVII). It is felt to be a critical element of any integrated control system that continues to have a soldier-in-the-loop. Since almost all in-vehicle systems were developed independently from others, the simultaneous use of such systems requires the driver to function as a filter for determining which information is pertinent at a particular time for the given situation. An IVII system that filters, prioritizes, displays the information in the most appropriate modality, accounts for ambient conditions, and appropriately times the information display will allow each of the selected VI systems to have their most optimal impact on driver performance.

SELECTED MILITARY PLATFORMS WITH ITS/VI TECHNOLOGIES

The NAC has been involved with several platforms and applications that involve ITS/VI technologies. These include the Commercially Based Tactical Truck (COMBATT) and Smart Truck. The NAC has also been involved with other technologies such as advanced driver-vehicle interfaces, collision avoidance systems, enhanced crash protection, next generation electrical architecture, occupant protection, and thermal imaging. Only COMBATT and Smart Truck will be addressed in this paper.

Combatt

The Commercially Based Tactical Truck - COMBATT (see figure 1), is one of the Army's possible near-term solutions for its light tactical vehicle needs. It is being developed under the Dual Use Science and Technology Program with Ford Motor Company, DaimlerChrysler, AM General, and Veridian-Erim International serves as system integrator for the project. Objectives of the program include demonstration of the utilization of commercial technology to satisfy military requirements; fast adaptation of civilian production to wartime needs, and simplified support for Army vehicles. The project is focused on balancing the military's 21st century HMMWV needs through the use of commercial platforms. Such a concept will significantly reduce the Army's acquisition, operations and spare parts costs. Features of COMBATT include adaptive cruise control, enhanced body and chassis protection, upsized tires and wheels, air

Figure 1; The Army's COMBATT Vehicle

springs, active dampers, extended suspension travel, advanced differentials, central tire inflation system, 4-wheel ABS, yaw stability management system, self diagnostic capability, wireless communication and navigation, and a black box recorder.

Smart Truck

Smart Truck (FMTV version) is an initiative that was conducted by the NAC to address the Army's need for inserting the latest information and communication technologies into its trucks. Reduction of the cost of acquiring those capabilities was also a prime consideration of he project. The objective of the project was to demonstrate "Smart Truck" technology on Army tactical wheeled vehicles through the electronic integration of commercially available intelligent subsystems using an SAE standard serial data link. This initiative involved the integration and evaluation of a SAE J1939 data bus, integration of an electronically controlled power train (Caterpillar engine/Allison Transmission) into a FMTV M1083 5-ton truck (see figure 2), development of tech data for the re-buy of the FMTV 5-ton truck, and the remanufacture of the M939 5-ton truck.

Figure 2; The Army's Smart Truck Vehicle

From a VI perspective, the Smart Truck initiative integrated a flat panel display, diagnostic computer, a satellite communications link, and a navigation computer with an associated map display. Other technologies on board include GPS communication, WABCO anti-lock brakes, and Eaton central tire inflation. Benefits to the army will include; the inclusion of the SAE J1939 data bus in FMTV 5 ton rebuys and the M939 5 ton remanufacture; successful demonstration of the electronic integration of data bus, power train, flat panel display, night vision camera, and diagnostics technologies; reduction in maintenance, operations and spare parts costs; improvement of reliability, availability, and maintainability; and reduction of cost and schedule of technology insertion through interface standardization. The prime contractor of this initiative is Veridian-ERIM International. Other members of the initiative team are NAC, PM MTV, Caterpillar, Allison, Eaton, and Rockwell/Wabco.

The next phase of the Smart Truck initiative will involve upfitting a Ford F-350 Super Duty truck with hybrid engine technologies and selected ITS/VI technologies. Advanced electronic architectures, the J1939 data bus, the ITS data bus standard, or another advanced data bus concept will be employed. Candidate VI technologies are a head-up display, on-board navigation system, GPS, lane tracking, night vision, head-up display, collision avoidance systems, adaptive cruise control, and advanced steering. Consideration is being given to the implementation of an on-board driver monitoring system.

CONCLUSIONS

The U.S. Army is stepping up its activities to include ITS/VI technologies into its ground vehicle fleet. The Army has a number of special needs that ITS/VI technologies can help to meet. These are in the areas of logistics, sustainability, fuel consumption, and survivability. The AVIP will build on the successes of DOT's ITS Program to meet these needs and to enhance mission efficiencies, fuel efficiency, safety and environmental emissions. The AVIP will be accomplished through close collaboration with subject-matter experts from within the DOD, other federal agencies, academia, national laboratories, and private industry. Following the concept development phase of the Program, which is expected to be completed in FY-2002, partnerships will be formed to engage in specific Program activities, expected in late FY-2002/early FY-2003.