

NATIONAL AUTOMOTIVE CENTER 21ST CENTURY TRUCK (21T) DUAL USE SAFETY FOCUS

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ABSTRACT

This paper provides background and suggestions for safety research for the Army's 21st Century Truck program (21T). The goal of that program is to reduce large truck related fatalities by 50 percent by the year 2010. As background for the proposed research program, this paper contrasts military and civilian trucks and their drivers. Based on that information and considerations of new technology, human factors research needs are identified in the areas of:

1. driver workload measures and assessment
2. collision avoidance and warning systems
3. night vision
4. interface integration
5. baseline studies of driving
6. in-vehicle interfaces
7. alertness monitoring

INTRODUCTION – THE NEED

Although the U.S. Army has had an outstanding combat record in recent actions, a review of those actions has revealed significant concerns of getting units to the scene fast enough, and keeping them supplied once they are there. Much of that activity relies upon trucks. By weight, 70 percent of the bulk tonnage to support a military unit in the field is fuel (<http://www.tacom.army.mil/tardec/nac/newsletter21century.htm>). Hence, improving the fuel economy of trucks will allow the Army to deploy its forces more rapidly and reduce the logistical costs of support, providing a significant combat advantage. There are many military campaigns in the textbooks that were delayed or failed because of a lack of fuel. For that reason, the U.S. Army, in partnership with the Departments of Energy,

Transportation, the Environmental Protection Agency, and major manufacturers of heavy trucks, buses, and engines, has established the 21st Century Truck (21T) Initiative [1]. The goals of that program are to reduce the deployed force fuel requirements by 75 percent by 2010 by a variety of means including doubling the fuel economy of tractor trailers.

This program has encouraged all of those involved to rethink how trucks are designed and has led to a broader review of propulsion technology, fuels, materials, vehicle intelligence, aerodynamics, auxiliary components, and safety, all of which bear upon fuel economy and vehicle use, and vehicle effectiveness. Figure 1 provides a graphical overview of the 21T program technology elements.

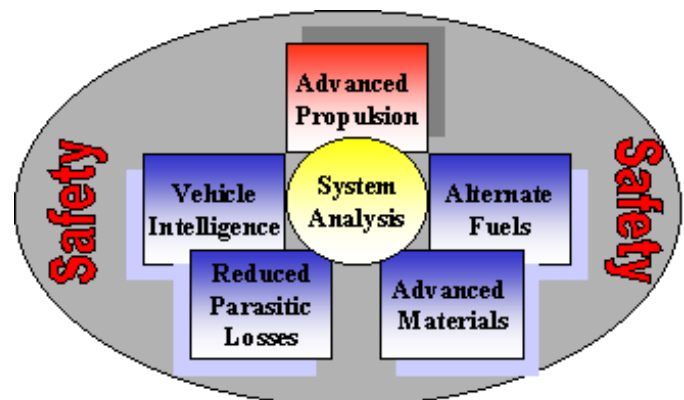


Figure 1. Elements of the 21T Program

This systems approach has led the Army to include safety as an element of the 21T initiative. From 1992 through 1998, the last year for complete data, the fatality

rate per 100 million vehicle miles traveled has ranged from 2.5 to 2.7 for trucks and 2.0 to 2.2 for passenger cars in the United States [2]. In 1998, 4,935 large trucks were involved in fatal crashes; an estimated 89,000 were involved in injury crashes; and, 318,000 were involved in property damage only crashes [3]. (See references 4 and 5 for additional truck crash statistics.)

In comparison, the Army had 2,224 ground vehicle accidents and 458 fatalities in 1998. Of these, 209 accidents and 62 fatalities were in Army vehicles, while the others were in privately owned vehicles (POV) driven by soldiers [6]. Figure 2 provides an overview of military fatalities from the U.S. Army Safety Center Web site <http://safety.army.mil/home.html>. (For further information, under “accident overview,” click on “Army Statistics.”) Notice that the overwhelming majority of the deaths are not related to combat training or military specific activities, but ordinary driving, most often in their own vehicles. The leading cause of Army POV accidents are excessive speed, fatigue and driver skill. The same general picture emerges for the U.S. armed services overall [7] and for each of the individual services. For example, for data on the U.S. Marines see <http://www.hqmc.usmc.mil/safety.nsf>. For links to the other services see <http://knox-www.army.mil/center/safety/links.htm>. Similar data for the armies of other nations has not yet been found on the web. Thus, to protect the lives of U.S. Army personnel (and in fact all military personnel), it is important for the Army to reduce crashes in both military and civilian vehicles. This dual benefit is central to several Army dual use programs (<http://www.dtic.mil/dust/army/indextop.htm>).

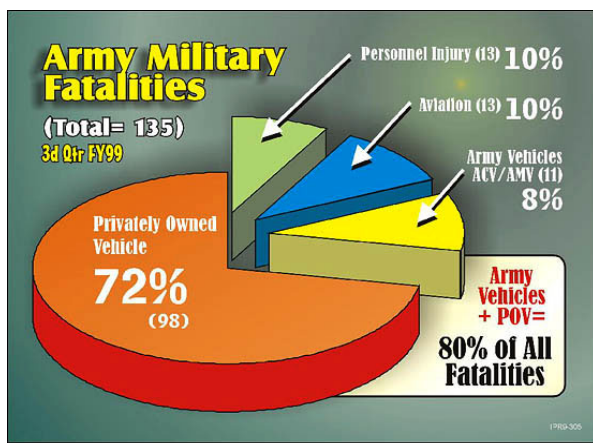


Figure 2. U.S. Army Fatalities in 3rd Quarter of 1999

To enhance the welfare of its members, the Army has established a goal within the 21st Century Truck Program of reducing truck fatalities 50 percent by 2010. This is not an easy task because the civilian crash data show that

in truck-car crashes, the car driver is much more likely to be responsible [8].

Review of the number of fatalities over the last few decades indicate that while the total number of fatalities per year and the rate per mile driven have been declining in the U.S., the changes are becoming increasingly smaller. The declines are the result of efforts to improve the passive safety of vehicles—vehicle crumple zones, common use of air bags and seat belts, and other occupant protection measures. Although these innovations have proven to be very useful, further reductions in crash rates will occur from active safety measures, particularly devices that help drivers avoid crashes. The Army holds a similar view and, therefore, believes that to achieve a significant reduction in fatalities, a better understanding of human factors and topics related to crash warning/avoidance is needed. Much of this work will occur under the vehicle intelligence aspect of the 21T program.

At outset, program planners must realize that the desired safety goal will not be achieved by wholesale replacement of the truck fleet. The Army has more than 200,000 trucks designed to last 20 to 25 years. The Army’s budget to modernize the fleet is \$942 million for fiscal year 2001. However, at the current rate of spending the tactical vehicle fleet will be replaced in 48 years [9]. Therefore, field modifications and aftermarket products may be an important aspect of safety enhancements to Army vehicles.

Both the U.S. Department of Transportation (DOT) and the 21T program have a goal of reducing accidents 50 percent. DOT uses a measure of fatalities/crashes per 100,000 miles driven. The number of miles driven per year by military trucks is very low in comparison with civilian commercial trucks. For the Army, a simple reduction in the total number of peacetime fatalities is appropriate. If any combat, or police keeping accidents are excluded, a 50 percent reduction would require a reduction in fatalities from 10 to 5 and accidents from 226 to 113. These figures are based on a 3-year average for on-duty accidents [6]. The off-duty fatality average of 27 and accident average of 441 is also of significant concern to the Army and is receiving considerable attention by the Army Safety Center.

Consideration of future safety problems must not only include the review of how vehicles are used and crash records, but also a look to how driving might change in the future. There are a host of new systems – navigation, cellular phone, collision avoidance, email, etc. – that have been recently introduced or are soon to be introduced to civilian motor vehicles [10]. These systems, referred to by the names of Intelligent Transportation Systems (ITS), telematics, and others, are operated by drivers in moving vehicles and have the potential of distracting drivers from the primary task of controlling the vehicle. Other systems, such as adaptive

cruise control, automatic lane control, and the like, may alter the driving task as well.

It is therefore essential that any program with connections to driving safety examine the implications of these systems in depth. Programs should also provide methods to assess their safety and usability, offer design guidance to enhance such, and finally, provide a more robust understanding of the driving process.

COMPARISON OF MILITARY AND CIVILIAN SITUATIONS – THE PROBLEM CONTEXT

DRIVING CONDITIONS

An understanding of how trucks are used is only just beginning to emerge. Blower [11] provides data on items such as the time of day driven by age group, trip length, and other characteristics. Detailed data are also available identifying the frequency of violations for various driver age groups. Detailed published data on vehicle use are not available for military vehicles, though data could be obtained on violation histories of military drivers. Further review of the driving conditions could be helpful in developing collision avoidance countermeasures for military vehicles and identifying appropriate test conditions for assessments of driver workload.

VEHICLES DRIVEN

Some Army vehicles such as “line-hall” trucks are essentially semi-trailer trucks and are operated in a very similar manner to their commercial counterparts. However, most of the Army vehicles operate in a distinctly different manner. The most common vehicle in the U.S. Army fleet is the High Mobility Multipurpose Wheeled Vehicle (HMMWV) representing 120,000 of the over 200,000 Army vehicles. The HMMWV, pronounced “HumVee,” was the Army’s replacement for the jeep. The HMMWV is designed to operate one-third of the time cross-country, one-third on secondary roads, and one-third of the time on improved roads. By comparison, auto company engineers estimate that their sport-utility vehicles (SUVs) are operated off-road no more than five percent of the time. There is interest in the Army for using modified civilian light trucks for selected HMMWV tasks that do not require the vehicle’s full capabilities. Those vehicles are expected to be much less expensive than HMMWVs.

Data on commercial trucks is contained in the U.S. Census Bureau Vehicle Inventory and Use Survey (<http://www.census.gov/econ/www/viusmain.html>). Data is collected every 5 years for years ending in 2 and 7. Data collected includes date of purchase, weight, number of axles, overall length, type of engine, and body type. Operational data include type of use, lease characteristics, operator classification, base of operation, gas mileage, annual and lifetime miles driven, weeks

operated, commodities hauled by type, and hazardous materials carried. Less detailed data are collected for pickups, vans, minivans, and sport utility vehicles because they are relatively homogenous in design and use.

Detailed comparisons of military and civilian vehicles have not been carried out, though it is believed that heavy trucks are a larger fraction of the civilian fleet. Statistics on trucks types could be helpful to identify vehicle types to target in future work.

DRIVER DEMOGRAPHICS

Table 1 provides demographic data for Army enlisted personnel who form the majority of Army drivers [12]. Army drivers tend to fall at the lower end of the age and educational level groups.

Total Number		488,000
Sex	Male	85.2%
	Female	14.8%
Age Median Age 26 years	17-20	16.9%
	21-24	26.2%
	25-29	24%
	30-39	27.2%
	>40	6%
Education	<HS or GED	4.2%
	HS & above	95.8%
	Some College	23.6%
	BA Deg +	3.7%

Table 1. U.S. Army Demographics

The 50th percentile male weighs 171 pounds and is 69 inches tall. The 50th percentile female weighs 135 pounds and is 64 inches tall.

The demographics and anthropometry of civilian truck drivers is quite different from that of the military. In a recent sample of heavy truck drivers, the mean age of the men was 44 and of the women was 33 years old [13]. It is believed about four percent of all heavy truck drivers are female. Men had an average of 20 years of driving experience versus about five for the women. Civilian truck drivers are often overweight, with mean weights of 199.6 and 149.5 pounds [13]. The 50th percentile height for civilian males is 69.4 inches tall and for females is 64.6 inches, values that are essentially identical to those for the military drivers [14,15].

Thus, there are physical differences between civilian and military drivers. This is discussed in further detail later, but the primary difference is that military drivers are much

younger and have significantly less driving experience than civilian drivers.

TRUCK DRIVER LICENSING AND TRAINING

Army drivers operating off-post are required to have a valid civilian drivers license [16]. However, they are not required to have a Commercial Driver's License due to a Department of Defense waiver. They must have a valid Army equivalent, an Optional Form (OF) 346, which documents the individual's training and qualifications to drive specific Army vehicles. The Army does not, however, provide the National Drivers Register with data on OF 346 suspension or revocation actions.

Army drivers must be licensed, know the driving laws, exhibit good driving skills, and satisfy other requirements. The Army safety program is extensive and provides a wide range of instructional material including training circulars, videotapes, and computer-based instruction distributed on compact disks [6].

In general, the Army drivers are in excellent physical condition, much better than their civilian counterparts [17, 18]. All Army uniformed personnel must pass an Army Physical Fitness Test (APFT) test twice a year, along with meeting certain height and weight criteria. This is designed to ensure that each soldier is physically capable of performing his/her duties when the circumstances require it. A failed test means that the soldier is given six months to either meet the criteria or be discharged.

Civilian licensing requirements vary from state to state. Commercial Drivers License (CDL) requirements for Michigan are typical. Applicants must be 21 years old (or 18 in some cases), not hold a suspended or cancelled license from another state, pass the Michigan CDL exam, and satisfy other requirements. Individual companies may have additional requirements such as a higher minimum age requirement to reduce insurance costs.

To prepare for the CDL license examinations, applicants may elect to take a class as preparation. Some of them guarantee passage. To the best of the authors' knowledge, there is no state-required curriculum for Michigan or state certification of training programs, though there have been weak efforts at industry certification. Data on the effectiveness of training programs is lacking and truck driver training has not been fully examined as a countermeasure. Some critics have questioned the value of these schools.

Most commercial drivers learn to drive through on-the-job training or somewhat formal training provided by their employer [8]. For many older drivers, their initial exposure to operating heavy machinery was a part of growing up on a farm, and driving a large truck was part of that experience.

Training should not be viewed as a substitute for good design. However, there are many examples, such as in the U.S. Navy nuclear submarine fleet, where safety training (coupled with high manning levels) has been an important factor in achieving a high degree of safety .

Thus, military truck drivers may have slightly more formal training than civilians, but the value of training in this context is unknown. Training to deal with high technology systems is system specific, and for civilians, often not formal.

In view of the Army's exceedingly slow vehicle replacement rate, training may be the only practical option for achieving a 50 percent reduction in fatalities. The effectiveness of training is always in question. However, there is some evidence that it can be effective. The methodology used in one extensive study covering over 850 organizations was a self-management strategy in which the worker had significant involvement and/or control of the monitoring and feedback system [19]. The process involves identifying behaviors common to the organization and then developing methods to gather data, provide feedback, and encourage improvement. Figure 3 shows how effective this method can be in reducing lost time accidents.

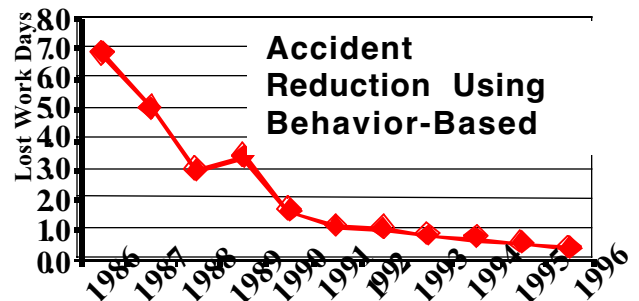


Figure 3

HUMAN FACTORS RESEARCH NEEDS

Given the safety context described and the need to support the introduction of new technology into military and civilian vehicles, a human-centered, forward-looking research program is proposed. Human factors research planned for the NAC 21T safety effort falls into seven broad categories:

1. driver workload measures and assessment
2. collision avoidance and warning systems
3. night vision and displays
4. interface integration
5. baseline studies of driving
6. in-vehicle interfaces
7. alertness monitoring

TOPIC 1. DRIVER WORKLOAD AND ASSESSMENT

Many methods – primary task performance (e.g., lane departures, lane variance), secondary task performance [20], subjective ratings (e.g., NASA TLX), physiological measures, and visual occlusion [21] – have been proposed to assess the workload of driving. Data relating these measures to crash statistics, crash outcomes in scenarios, and related indicators would be most useful. Although there has been significant progress on measures of workload, little is known about the relationships between workload measures and situations in which some measures are predictive and others are not. Pulling this literature together and additional research comparing measures will be extremely useful.

To facilitate comparisons of studies, investigators are encouraged to use multiple measures of driving workload. Also needed are basic tools to model workload, an area in which the U.S. Department of Transportation has made significant strides. Efforts to disseminate, validate, and use workload software are needed, along with efforts to explore simulation tools and models commonly used for military applications such as IPME, SOAR, ACT, EPIC, and others.

TOPIC 2. COLLISION AVOIDANCE AND WARNING SYSTEMS

Warning systems currently available are primarily stand-alone, aftermarket devices. These may warn of objects ahead, indicate vehicles in blind spots, or other hazards. Lane-keeping systems have been introduced in Japan and should appear in the U.S. shortly. The effectiveness of these devices is unknown and their usefulness in both civilian and army operational contexts, especially for unpaved roads, is unknown. Laboratory, test track, and field data on warning usefulness is desired.

TOPIC 3. NIGHT VISION

Night vision goggles are an integral part of Army helicopter operations and regularly used by ground troops when driving under “blackout” conditions. Commercial adaptation of this technology is evident in the Cadillac Night Vision system, which provides the driver with an IR scene image on a head-up display just below the driver’s normal line of sight. Reports in the press and anecdotal stories indicate that the system works well. Other companies such as DaimlerChrysler and Jaguar Cars are reportedly working on similar systems.

The contention is that night vision can help improve driving safety by enhancing the driver’s ability to detect potentially dangerous situations beyond the range of the headlamps, or to see objects in areas not well illuminated by headlamps because of glare problems. Night vision systems could enhance driving safety considerably because of the disproportionate number of crashes that

occur at night. Furthermore, certain situations such as a person changing a tire on the side of the road, or an animal in the road, may not be visible with the naked eye until it is too late. The primary customers for night vision systems are older drivers who often avoid driving at night. One potential outcome of the fielding of night vision systems, is that drivers will be encouraged to drive in potentially dangerous situations, and instead of a crash reduction, crashes will increase.

Thus, investigation of night vision systems is desired, but not systems with head-up displays (HUD). HUDs are unsuitable for trucks and other vehicles under blackout conditions. Further, almost all military vehicles have flat dashboards which would necessitate an “over the shoulder” projection system.

The current night vision system for military truck drivers is a light amplification monocular. This device has drawbacks. Unlike thermal vision, light amplification “bloom,” such as from oncoming headlights, effectively blinds the driver. Further, the monocular provides no depth perception and the devices are very tiring to wear. Augmentation of this device for driving under blackout conditions would obviously be a safety improvement. However, this will only be possible if low cost commercial components are available.

A display of some type will be incorporated into new and most retrofitted military trucks. If a night vision display is provided, it will probably incorporate navigation and information capability for daytime as well as nighttime use. This added distraction might be less of a problem in the military. Integrated head-mounted displays are just beginning to be considered for ground applications and are worthy of further exploration in this program.

AREA 4. INTERFACE INTEGRATION

All drivers, commercial and military, will benefit from integration of the many instruments, warning systems, and communication/navigation devices. The Army has been investigating the use of an instrument display which provides only basic information until additional information is required. To be totally effective, something akin to an artificial intelligence routine is required to “watch” for trends. That is, a sensor reading can be in range but an increase or decrease can identify a potential failure.

The lack of standards for warnings and methods for coordinating the operation of these “add-on” devices can make their operation distracting and confusing to drivers, thus defeating the purpose of warnings. Research on warning differentiation and the practical implications of prioritization is desired.

AREA 5. BASELINE STUDIES OF DRIVING

Some have referred to this topic as “plain old driving.” To make assessments of the impact and effectiveness of various safety systems and new driver interfaces, information is needed on how people normally drive now. This includes data on speed and speed variability on various types of roads, gaps and closure rates for various driving situations, and norms and variability for various types of maneuvers (passing, lane change, intersection approach, etc.).

As an example, a recent study of navigation systems examined the frequency of lane departures [22]. However, in an otherwise excellent study, the absence of normative lane departure data from the literature or baseline data in the study in question clouded the safe implications of the research, that is which systems were safe or unsafe.

Important elements of research in this area is data on driver eye fixations [23], data from instrumented vehicles and driving simulators, and data collected using the vehicle motion environment tools [24]. In addition to papers and reports summarizing this research, a set of web accessible data bases should be created containing the processed data from various studies. This data could be extremely useful in developing test cases for collision avoidance algorithms and systems.

AREA 6. IN-VEHICLE INTERFACES

There has been explosion of the nature and types of driver interfaces in motor vehicles. Consequently, there is a need for basic research on voice interfaces, both input and output, the effect of using those interfaces on driving, as well as of the use of HUDs for presenting navigation data and system status. Given the controversy associated with the use of phones while driving, the voice research should include examination of the effects of communication on driving safety. Fundamental research on HUD information format is needed.

AREA 7. ALERTNESS MONITORING

Driver alertness and fatigue has become a major issue in reducing the number and severity of large truck-involved crashes [25]. Fatigue is considered to be a more significant factor than the indicated 4 percent of the commercial drivers involved in a fatigue-related crash. A survey of 511 regional and long-haul tractor-semi-trailer drivers showed that 28 percent reported dozing or falling asleep at the wheel at least once during the past month. In addition to proposed hours of service rule changes, there are a tremendous number of studies and hardware development addressing the problem. The military can expect to benefit from almost all of the work being done in this area.

The U.S Department of Transportation has supported very significant research to assess driver alertness and warn drivers when their alertness is reduced. However, the response to such systems is unknown. Will drivers respond as desired to a message by taking a break? Will drivers now push themselves until they are warned to stop instead of stopping when they feel fatigued?

Continuous military operations often push soldiers to the limit of their abilities. Unlike civilian activities where the concern is for daily protracted activities, military situations may involve events that last a day or two, such as at the beginning of a campaign. Furthermore, because of the urgent nature of their tasks, the willingness to accept risks may differ from the civilian context. The alertness of drivers in these situations deserves attention.

RESEARCH APPROACH

The success of this program not only depends upon picking the right topics, identifying the best investigators, and providing them with adequate funding and time, but also providing a supportive context for their efforts. There are four key elements to this program.

1. Investigator initiative – To the fullest extent possible, the Army wishes to take advantage of the creativity and wisdom of the scientific community. Therefore, many of the research initiatives will be funded under Broad Agency Announcements with only general direction indicating the issues to be examined.
2. Application of human performance models – Where feasible, proposals should rely upon and utilize models of human performance to reduce the number of test conditions to be explored.
3. Connections to consensus standards development – The Army intends to make greater use of civilian products in the future that comply with commercial standards. It is therefore important that research be coordinated with the development of automotive standards, especially those of the Society of Automotive Engineers and the International Standards Organization. Participation in standards efforts related to the research is one way to achieve coordination.
4. Distribution of the results – Broad dissemination of the results is encouraged, through meetings with key Army personnel, automotive manufacturers and suppliers (especially core members of the 21T program), and members of standards bodies. The preparation of journal articles, proceedings papers, and technical reports is also encouraged.

CONCLUSIONS

The recent technological advancements in safety related technology can help truck drivers avoid accidents, improve truck safety, and protect drivers in the event of a crash. A significant portion of this commercial technology can be used by the Army in the 21st Century Truck Program.

Although much of the content of this proposed program is on supporting technology, given the legacy nature of the military fleet, opportunities for exploring the safety benefits of training should not be ignored. This topic has not received much attention in commercial truck context.

We believe that this research effort, as outlined in this paper, will provide the information necessary to provide significant enhancements in the safety of future automotive products, especially trucks, and support the development of new in-vehicle technology. This effort will be of benefit to both users of civilian and military vehicles, an objective of the dual use program. We cannot envision how the 21T goal of cutting fatalities in half will be achieved without an effort of this kind.

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