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A STUDY OF THE REQUIREMENTS FOR A HEADS-UP DISPLAY FOR USE IN MOTOR TRANSPORTATION IN THE UNITED STATES MARINE CORPS

by

Harold Marcel Mosley
and
Rodney L. Lewis

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Thesis Advisor:	James Bret Michael
Second Reader:	Rudolph Darken

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In this thesis we investigate the high-level requirements for a concept system we refer to as Automated Vehicle Avoidance Identification and Location System (AVAILS). The primary goal that this system addresses is the safe operation of large ground vehicles, operated by the U.S. Marine Corps and Army, on both military reservations and public roadways. AVAILS is comprised of an integrated collision warning and collision avoidance system. These two subsystems are used to support both low-speed docking and convoy operations. The objective is to provide the driver with real-time information that will help him or her act to avoid or mitigate the effects of a crash with another vehicle during convoy operations, and with another vehicle or the docking facilities during docking operations.

The high-level requirements for the human-computer interface, AVAILS-HCI, are discussed in the context of the following: the characteristics of the drivers, the nature of their tasks, the environment in which ground-based military vehicles operate, and the doctrine, policy, law, regulations, and procedures which govern the operation of such vehicles on military reservations and public roadways. A high-level treatment is given of the mapping of the high-level requirements for the human-computer interface to in-vehicle display technology, in particular, head-up displays. We developed a limited-function prototype of the system in order to explain and reason about the requirements for the AVAILS-HCI. We conclude the thesis with recommendations for future research.

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A STUDY OF THE REQUIREMENTS FOR A HEADS-UP DISPLAY FOR USE IN MOTOR TRANSPORTATION IN THE UNITED STATES MARINE CORPS

Harold M. Mosley
Captain, United States Marine Corps
B.S., Florida Agricultural and Mechanical University, 1992

Rodney L. Lewis
Captain, United States Marine Corps
B.S., University of Alabama, Birmingham, 1992

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**NAVAL POSTGRADUATE SCHOOL
September 2001**

Authors: Harold M. Mosley

Rodney L. Lewis

Approved by: James Bret Michael, Thesis Advisor

Rudolph Darken, Second Reader

LCDR Chris Eagle, Chairman, Department of Computer Science

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ABSTRACT

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I. INTRODUCTION

The Automated Vehicle Identification and Location System (AVAILS) is an automated system that will provide collision avoidance and collision warning capability for ground-based military trucks and other heavy vehicles. AVAILS consists of an interactive graphical user interface (GUI). AVAILS is primarily intended for employment in military operations, although military operations are often indistinguishable from commercial operations because many military operations may involve a large degree of contracted commercial services. The key distinction in terms of requirements is that AVAILS must be capable of operating wherever the United States military may deploy.

AVAILS consists of an interactive display console with several sensor components. The driver has the capability to instantly configure certain aspects of the system by merely touching various menu options presented on the display console. The menu options allow the driver to cause AVAILS to switch to a different mode of operation, such as for low-speed backing into a loading dock, or for use in long-haul operations. If the distance falls below the threshold for the current mode of operation, then either the collision warning or collision avoidance system intervenes to assist the vehicle operator in re-establishing an acceptable distance from the vehicle and other objects. The post-processed sensor data is presented to the driver via the AVAILS-Human Computer Interface (HCI), located in the cab of the vehicle. When the driver of one vehicle overtakes another vehicle, the driver will visually know, by the console display, when it is safe to complete the passing maneuver and change lanes in front of the overtaken vehicle. AVAILS is intended to assist DoD personnel to safely operate motor transport vehicles to perform a variety of tasks under possibly adverse environmental conditions (e.g., low visibility).

A. BACKGROUND

Current DoD vehicle operating procedures closely mirror standardized commercial procedures, including those for parking, vehicle backing, and highway travel. The National Traffic Highway Safety Administration (NTHSA) influences many of today's vehicle operating procedures and safety regulations. The NTHSA adheres to the procedures and guidelines as set forth by the Department of Transportation (DOT). While there is no overall official document dictating the rules of the road, nearly all states follow the intent of the DOT and develop their highway driving laws and regulations through each state's department of motor vehicles (DMV). As a result, many military facilities involved with operating vehicles on public roadways, train their vehicle operators in accordance with local, city, and state highway laws and regulations. Operators of military vehicles receive training specific to the type of vehicle they will operate. That is to say that a potential crane or forklift operator is specifically trained to safely operate a crane or forklift, on or off military installations.

Of particular importance is the need to avoid costly vehicular mishaps and collisions. Today, most drivers rely on common driver courtesy and personal experience. While acquired driver experience may help an individual to operate a vehicle in a defensive manner, there are occasions in which drivers are placed in unique and precarious driving situations. Many external factors, such as driver fatigue, road rage, traffic congestion, and unfamiliarity with the driving environment, can influence how a driver performs while operating a vehicle.

Moreover, many military motor transport operations can involve convoy requirements where hazardous materials are being transported and vehicle mishaps could result in substantial harm to people or property, not to mention losses associated with efficacy, such as loss of productivity or not delivering cargo to its intended destination on time to support a mission. Transport operations can require the loading of military vehicles on aircraft or ships. Preparations for such intermodal loading operations can require vehicle consolidation and pre-staging in very confined areas. Situations such as these are envisioned to be environments for the employment of AVAILS.

AVAILS is a hybrid autonomous system (i.e., there is no communication between vehicles for the purpose of coordinating vehicle control) consisting of both a collision warning system (CWS) and a collision avoidance system (CAS). AVAILS will primarily serve as a CWS. If a driver attempts to park a vehicle in close proximity to other objects, AVAILS in its CWS mode, would indicate to the driver which area of the vehicle triggered the warning. Likewise, if a driver were required to operate a vehicle on the highway, AVAILS would warn the driver if other vehicles traveling in the same direction were operating within pre-set boundaries of the system. As a CAS, the only function of AVAILS would be to slow the vehicle if the rate of closure to the vehicle in front exceeds a safety threshold; that is, the CAS would function as an adaptive cruise control system.

AVAILS can best be visualized as an interactive display console. The driver can instantly configure certain aspects of the system by merely touching various menu options. The menu options are used by the driver to adjust some of the AVAILS parameters so that the system assists the driver in conforming to a specific set of vehicle operating procedures. A depiction of the vehicle, and the relation of other vehicles that are being passed or that are passing, will be the primary image on the console display, Figure 1.

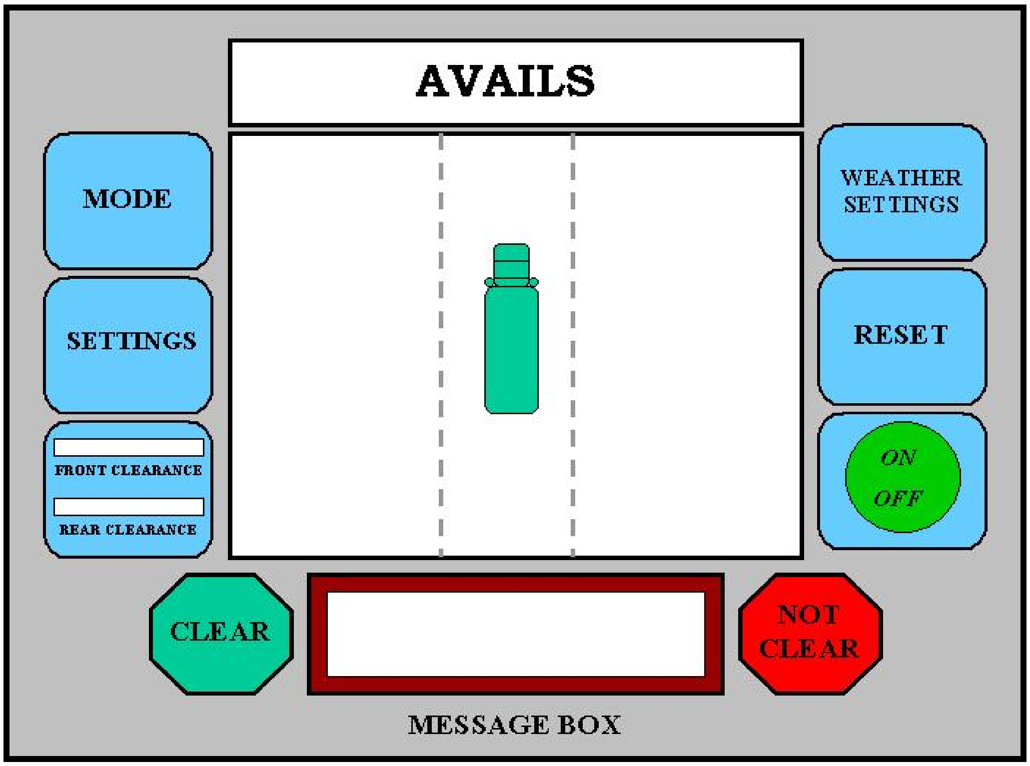

Figure 1. AVAILS Display Console.

AVAILS will only provide collision warning and avoidance for traffic moving in the same direction of travel. More specifically, AVAILS is intended to provide protection on both sides of the vehicle to a distance of one lane, as shown in Figure 1. Protection to the rear of the vehicle will be dependent upon the information entered by the driver. For example, if the driver is operating the vehicle under normal driving conditions, the commonly suggested distance should be one car length for every ten miles per hour. Therefore, if a driver were traveling at a speed of sixty miles per hour, there should be a minimum rear distance between vehicles of six car lengths. AVAILS will also provide forward-looking proximity warnings using the same guidelines.

Current DoD and commercial standard vehicle-operating procedures will be examined along with existing collision warning and collision avoidance systems in an attempt to develop system requirements for a prototype of the AVAILS-Human Computer Interface (AVAILS-HCI).

B. PURPOSE

The overall purpose of this research is to develop a generic prototype of AVAILS-HCI. The intended purpose of AVAILS is to provide collision warning and collision avoidance during vehicular operations conducted by the United States Department of Defense. As such, we specified requirements for AVAILS based upon the following: current DoD standard operating procedures; along with current highway traffic laws, regulations, and protocols; and the functionality of existing collision warning and collision avoidance systems.

C. SCOPE

The scope of this thesis is to explore the development of the user interface of AVAILS. As a user interface, AVAILS must be usable and attractive enough to gain some degree of trust from the user. As a result, emphasis was placed on both human factors issues and the physical structure of AVAILS. We leave to future research, the investigation of sensor technology, communication protocols, and algorithmic decision-making: these are needed to assess the technical feasibility of realizing AVAILS.

D. ORGANIZATION OF THE REPORT

Chapter II describes the operating environment of AVAILS. An initial set of requirements for AVAILS are presented in Chapter III. In chapter IV, we examine existing collision avoidance and collision warning systems. Chapter V, we introduce the architectural framework of the AVAILS-HCI. We close with the conclusions and recommendations for future research.

II. AVAILS OPERATING ENVIRONMENT

AVAILS is a system specifically designed for use in military vehicles. As such, the operating environment of AVAILS will be wherever the military may deploy. Only the United States Army (U.S. Army) and the United States Marine Corps (USMC) routinely operate convoys on the nation's highway systems. The policies and procedures governing motor vehicle operation are nearly identical for each service. The Marine Corps is usually the branch of DoD that initially deploys in response to crisis situations globally. As a result, military operations conducted abroad are usually governed in the early stages of deployment by, USMC doctrinal policy, and operating procedures. Therefore, further discussions of military and commercial operations will be explored with a preference toward Marine Corps doctrine, policy, and procedures.

A. TRANSPORTATION DEFINED

The Marine Corps considers transportation as one of the primary categories of combat service support (CSS) [18]. Combat service support, as a concept, provides doctrinal guidance for logistic support to every element of the Marine Corps. The six functional areas of operational logistics and combat service support are as follows: supply, maintenance, transportation, general engineering, health services, and general services [17]. The functional area of transportation can be further broken down into embarkation, landing support, port and terminal operations, air delivery, freight and passenger transportation, material handling equipment, and lastly motor transport. The Marine Corps defines motor transportation as surface transportation using wheeled vehicles. The Marine Corps considers motor transportation to be the most versatile and reliable of the six functional areas. Transportation is the cornerstone to any logistical effort, whether military or commercial. Motor transportation can be employed wherever there is navigatable terrain. Motor transportation provides the crucial link to all elements in the operational battlefield. That is to say, motor transportation can effectively provide links to aerial ports, seaports, supply facilities, and forward deployed combat units [18]. In short, motor transportation provides the very foundation for logistics.

Control of motor transportation, in the Marine Corps, is either centralized or decentralized [18]. Centralized control of motor transportation assets supports the interdependency of all the components of the transportation category. There is one designated central support center that controls all vehicle dispatching, convoy, and logistics requirements. In decentralized control, the independent tactical commander is given control over their motor transportation assets.

B. MARINE CORPS VEHICLES

The Marine Corps maintains and operates a wide range of motor transportation equipment. The vehicles are considered either general-purpose tactical vehicles or special-purpose tactical vehicles [18]. General-purpose vehicles provide standardized transportation requirements, while specialized vehicles are dedicated to specific mission requirements. General-purpose vehicles are further classified as light, medium, or heavy vehicles. As expected, light vehicles offer high mobility and are therefore ideally suited for combat missions. The most highly utilized light vehicle, in both the Army and Marine Corps, is the High Mobility Multi-purpose Wheeled Vehicle (HMMWV).

The HMMWV is a multi-configurable vehicle that is typically used as the head and tail vehicle for most convoys. Only four of the many configurations of the vehicle are depicted in Figure 2. . As a lead vehicle in a convoy, the HMMWV would be a prime candidate for the AVAILS.

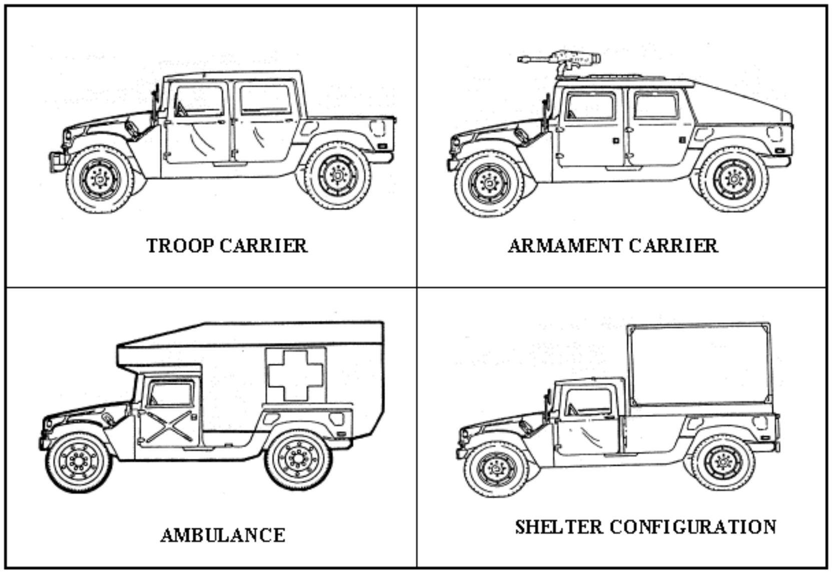

Figure 2. HMMVW (From: [21])

Medium-duty vehicles offer a high level of tactical mobility for combat operations and combat service support operation. Medium-duty vehicles can support a range of missions from troop transport, vehicle recovery, fuel and water carrier, mobile maintenance shops, and shelters.

Like medium-duty vehicles, heavy vehicles are highly supportive of a wide variety of missions. Heavy vehicles are usually the vehicles used for massive convoy operations since they typically carry the bulk of oversized cargo. AVAILS must be capable of supporting such vehicles because their unusual size and possibly dangerous cargo may require safe handling during transport.

Special purpose vehicles, as their title implies, are generally designed with a specific purpose in mind. Special purpose vehicles are themselves classified as light individual vehicles, all-terrain vehicles, special operations vehicles, and fire-fighting vehicles. AVAILS will be capable of supporting these vehicles too.

If AVAILS will be used to support DoD motor transportation assets, then it must be multi-configurable, flexible, durable, and portable. As previously mentioned, nearly every classification of vehicle used by the Marine Corps is multi-configurable. Figure 3 depicts some of the medium-duty and heavy vehicles utilized by both the Army and Marine Corps.

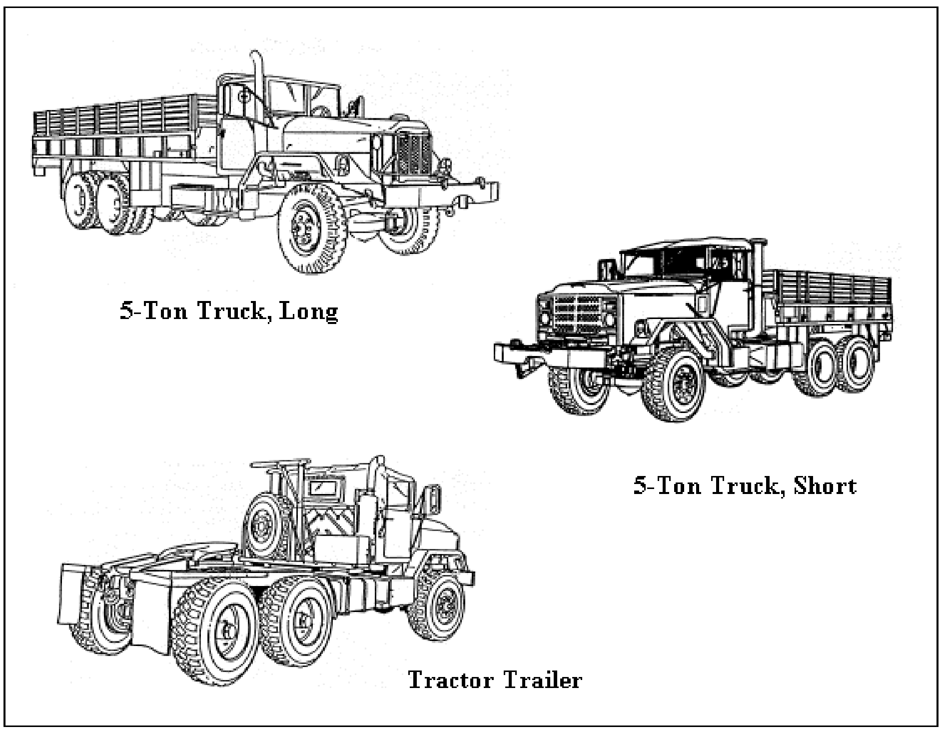

Figure 3. Medium-duty and Heavy Vehicles (From: [21])

The trailer portion of the vehicles can be attached or detached. The driver's vehicle cabin can either be collapsed or expanded. AVAILS must be versatile enough to support the majority of the configurations that these vehicles may assume. Figure 4 depicts just a few of the trailers that are used by the Marine Corps.

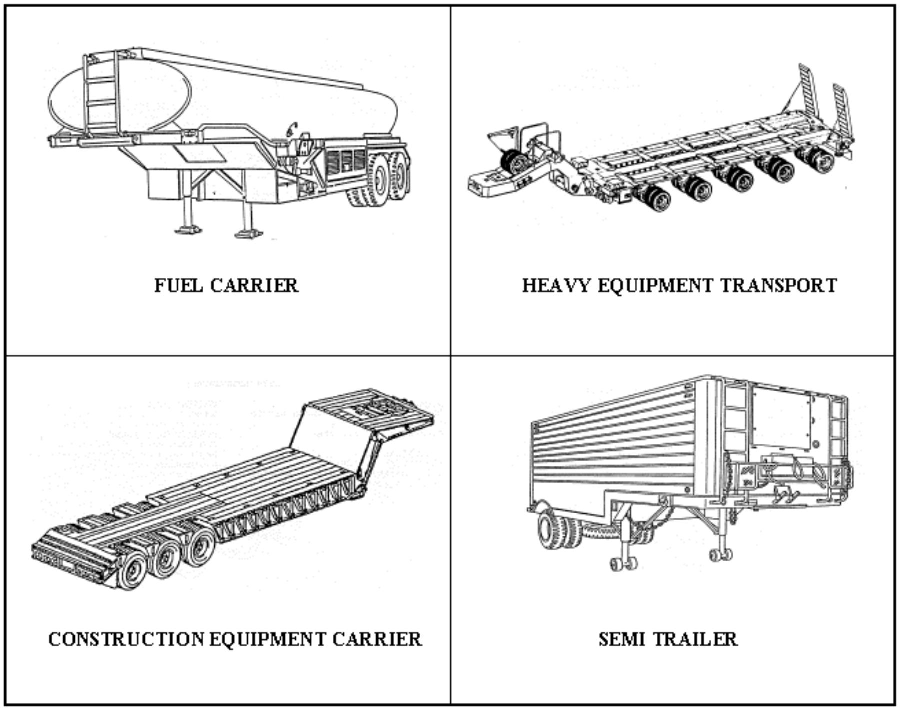

Figure 4. Trailers (From: [21])

Chapter IV contains a description of several commercial intelligent transportation systems (ITS) that support vehicles similar to those used by the Marine Corps.

C. MILITARY AND COMMERCIAL OPERATIONS

Military operations involving motor transportation are dynamic by nature. The Marine Corps can be deployed by land, sea, or air. Each method of deployment has some unique requirements. However, initial preparation for each method involves pre-staging of motor transportation assets. Pre-staging is basically the mobilization and load preparation of trucks and equipment. Mobilization often involves parking vehicles within inches of each other. The same parking requirements exist whether these transportation assets are loaded onto ships or aircraft. Nearly all vehicles arrive at pre-staging by means of a convoy. In fact, convoys are key to any military deployment.

Commercial operations are generally approached and handled in the same manner as military operations. One major difference is that commercial operations are more likely to be conducted within the United States, whereas military operations are conducted nationally and internationally.

D. MARINE CORPS AND ARMY CONVOYS

A convoy is defined as a group of vehicles organized for the purpose of control and orderly movement of personnel, supplies, and equipment. Convoys are organized by task to meet the requirements of the specific missions. Convoys are always utilized to transport troops and equipment from one location to another. Convoys are highly utilized by the U.S. Army and the Marine Corps. Military convoys interact with civilian traffic on the nation's public highways. Accidents involving civilian and military vehicles are highly undesirable but at times do occur. AVAILS is intended to minimize the risk of crashes between military vehicles and between military and non-military vehicles. The Marine Corps utilizes three types of convoys: a march column, a serial column, and the march unit [18]. Each type of convoy is a derivative of a basic column, that is, a linear line of vehicles. Differences among each type of convoy are determined by various policies and procedures that are used to govern the conduct convoy movement. Regardless of the convoy type, the common goal of each convoy is the safe and timely transport of personnel, supplies, and equipment.

The convoy is further broken down into three subsections: the head, the main body, and the tail. As its name dictates, the convoy head controls the convoy's pace and direction. The main body typically transports the crucial supplies and equipment. The trail element ensures convoy security and integrity throughout the convoy's lifetime. Determining the vehicles in the convoy on which to place AVAILS is also vitally important. The size, type, and convoy configuration are all factors that must be considered. However, it should be quite plausible to consider placing AVAILS on the lead vehicle and the last vehicle, in the convoy. The lead vehicle will undoubtedly utilize CAS, if its rate of closure to other vehicles were too great. Importantly, the last vehicle will need to be completely aware of any other vehicles in the immediate proximity before it signals the column to change lanes.

Current methods used for convoy communications are simplistic and effective. Convoys use a system of flags or lights and movement control numbers for identification. In peacetime operations, all convoys are required to travel with low-beam headlights. The convoy commander, and local policies and regulations of the highways being used, nearly always dictate convoy movement. In an attempt to control convoy movement, convoys have assumed three formations: close column, open column, and infiltration. The close column allows each vehicle to follow the vehicle to the front at a distance that minimizes the chance of a collision. In the open column, vehicle distance is increased to enhance dispersion. In an infiltration, small batches of vehicles are dispersed randomly in an effort to control traffic congestion. In each of these instances, there may be several lead and trail vehicles that can all benefit from AVAILS.

E. SAFETY ISSUES

In recent decades, safety has moved to the forefront of DoD's doctrinal procedures. Every service component of DoD has an official safety program. One major aspect of each program is devoted to motor vehicle safety. Army Regulation 190 – 5, Operational Naval Instruction (OPNAV) 11200.5C, Air Force Regulation 125 – 14, Marine Corps Order 5110.1C, and Defense Logistics Agency 5720.1, represents a joint doctrinal publication which outlines all aspects of motor vehicle regulation [15]. The document is titled "*Motor Vehicle Traffic Supervision*". As previously stated, nearly all aspects of motor vehicle safety and regulation are addressed in this document. The document will undoubtedly prove beneficial in formulating a few of the system requirements for AVAILS. The Insurance Institute for Highway Safety maintains statistical data concerning highway incidents and vehicle safety [27].

Large trucks comprise a huge portion of DoD's motor transportation assets. A large truck, whether military or commercial, poses a significant risk on the highway. Due to their frequency of travel, large trucks have accounted for more than their share of highway fatalities. Tractor-trailers have a higher fatal crash rates per mile than passenger vehicles [6]. In 1999, 5,282 people died in crashes involving large trucks. Sixty percent of 1999 deaths in large truck crashes occurred on major roads while twenty-nine percent occurred on freeways and ten percent occurred on minor roads. Ninety-eight percent of fatalities involving two-vehicles between large trucks and passenger vehicles were the occupants of the passenger vehicle. These facts were obtained from the United States Department of Transportation's Fatality Analysis and Reporting System (FARS), [6]. While it is not immediately obvious how many of the large trucks were military vehicles, these facts clearly support the concept of AVAILS. Figure 5 list statistics spanning a twenty-five year history of large truck crash fatalities.

DEATHS IN LARGE TRUCK CRASHES							
	Tractor-Trailer Occupants	Single-Unit Truck Occupants	Truck Type Unknown	Passenger Vehicle Occupants	Other or Unknown Vehicle	Nonoccupant Deaths	Total
1975	660	162	94	2,757	104	528	4,305
1976	809	291	0	3,071	100	622	4,893
1977	915	231	83	3,631	101	653	5,614
1978	968	251	96	3,954	115	776	6,160
1979	1,008	282	82	4,226	111	830	6,539
1980	867	234	82	3,623	90	844	5,740
1981	832	186	64	3,752	74	772	5,680
1982	720	141	56	3,448	81	679	5,125
1983	733	132	95	3,615	97	732	5,404
1984	853	125	62	3,713	85	712	5,550
1985	747	123	71	3,825	123	724	5,613
1986	689	139	64	3,752	106	718	5,468
1987	654	112	55	3,833	105	712	5,471
1988	706	119	61	3,938	95	647	5,566
1989	643	116	63	3,847	104	587	5,360
1990	503	126	55	3,790	85	615	5,174
1991	448	130	72	3,447	69	562	4,728
1992	412	136	32	3,300	61	481	4,422
1993	423	142	25	3,611	115	462	4,778
1994	453	165	40	3,764	92	555	5,069
1995	443	168	23	3,626	79	495	4,834
1996	426	149	27	3,866	115	465	5,048
1997	481	196	40	3,992	89	497	5,295
1998	501	212	26	3,981	101	495	5,316
1999	536	189	21	3,907	119	510	5,282

Figure 5. Death Rate for Large Truck Crashes (From: [6])

One column of particular interest is the "Passenger Vehicle Occupants" column. This column represents the number of people killed in an accident involving a large truck. The exact cause of each crash varies greatly, but undoubtedly many of the accidents occurred because the truck driver simply did not see the passenger vehicle.

Figure 6 offers a look into the number of deaths and the truck configuration. By truck configuration it is meant that the truck either was attached or unattached to a trailer unit. The greatest number of fatalities occurred when the truck has a trailer attached.

DEATHS IN LARGE TRUCK CRASHES BY TRUCK CONFIGURATION, 1999	
Tractor-trailer	3,888
Single-unit truck	1,373
Unknown truck configuration	140
Total	**5,282**
NOTE: Total is less than sum of deaths because deaths in crashes with more than one truck type are counted once.	

Figure 6. Truck Configuration (From: [6])

Figure 7 lists the fatalities based on the type of highway used by large trucks. As expected, major roads account for the greater number of crash fatalities. These roads are traveled by a large number of passenger vehicles and large trucks traveling together.

DEATHS IN LARGE TRUCK CRASHES BY HIGHWAY TYPE, 1999					
	Freeways	Major Roads	Minor Roads	Unknown	Total
Single-vehicle crashes	186	209	64	4	463
Multiple-vehicle crashes	1,167	2,647	334	42	4,190
Crashes with pedestrians, bicyclists, motorcyclists	146	249	108	7	510
Other/unknown	33	63	22	1	119

Figure 7. Truck Crashes by Highway Type (From: [6])

Naturally DoD desires to limit the number of crash fatalities involving its large trucks. Military vehicles and convoys pose a significant risk to each other and non-military vehicles in terms of crash severity. The Marine Corps attributes motor vehicle accidents to the following four factors: speed, pre-occupation, fatigue, and drugs and alcohol. The Marine Corps and DoD for that matter, seeks to deter motor vehicle incidents through aggressive motor vehicle safety programs, vehicle operator training, and vehicle maintenance and inspections.

Every component of DoD has an active safety program to include Internet sites and an officially designated safety headquarters location. Motor vehicle and traffic safety are a major issue in each of these safety programs. The Army maintains an Internet site called Safety and Health Resources (http://safety.army.mil/pages/links/index.html) [36], where it lists dozens of links to a majority of DoD's safety related Internet sites.

The Marine Corps attacks safety very aggressively. Marine Corps units are mandated to adhere to regulations set forth by the Occupational Safety and Health Administration (OSHA) [20]. Additionally, every Marine Corps unit is required to have a "safe driving council"[19]. The purpose of the safety program is to assist the commanding officer in establishing and maintaining a vehicle mishap prevention program. In short, traffic safety begins before the driver enters their vehicle. Vehicles operators are not allowed to enter a vehicle unless they are in good mental and physical condition. Special attention is given to the frequency of use of a particular driver. Operators are briefed on their routes, checkpoints, and points of contacts prior to operating a vehicle. Operators are provided detailed maps indicating specific routes. More importantly, operators are made aware of road and weather conditions, including probable forecasted changes [18].

AVAILS, in concept, will provide an extra perimeter of safety for motor vehicle operators. In addition to being made aware of vehicles in their proximity, vehicle operators will be allowed to adjust their vehicle's perimeter of safety based upon weather conditions. The weather module in AVAILS takes into account, daytime and nighttime conditions, as well as rain, fog, sleet and snow.

III. AVAILS-HCI REQUIREMENTS

A. HUMAN COMPUTER INTERACTION (HCI)

Human-computer interaction (HCI) is an integral issue to be addressed in the design of information systems. If the user of the information systems judges the HCI to be too difficult or cumbersome to use, then he or she may turn off the HCI or the entire system, resulting in the effectiveness of the information system being zero. There are a host of issues that must be considered when designing a human computer interface. The psychological effect must be such that the user has a high degree confidence in the interface and in their ability to use it to complete tasks. The human user must have some confidence that the system will perform as expected, if not better than expected. At the same time, the user should not totally rely on software. The primary question we address is what are the requirements for the AVAILS-HCI? In addition to these issues, there are concerns about the operational benefits, safety related factors, and the pro and cons of Heads-Up-Displays (HUD). Due to the fact that we treat the AVAIL-HCI at an abstract level, we will answer the preceding question in general terms based on the functional requirements for collision warning and avoidance. We leave the detailed analysis of the HCI design to future work, which would entail, among other things, a task analysis to be conducted.

1. What is Human Computer Interaction (HCI)?

Human-computer interaction is the way in which a user interacts with a computer-based system. Human factors is the engineering discipline that addresses the design of systems to accommodate the needs of users. Let us begin our discussion of HCI, in the context of information systems, with some examples. A simple example is a pointing device in a windows environment, which may be elementary to learn to use by some users of software applications, but difficult for others. For instance, if someone working in a graphical design shop has to grab and pull items to construct an object, their visualization of a hand that grips and carries the object to where the user wants it to be placed in the virtual workspace may be more intuitive to that particular type of user. If the user happens to be a graphical artist and uses a pointing device to draw, there are several scenarios for that pointing device that the user may be more comfortable with such as a paintbrush, marker, or pencil image vice just having a tip on an arrow as a pointer.

Pointing devices are just the tip of the iceberg when it comes to HCI. The graphical layout of a computer screen or the program itself can influence how a user will interact with the system. If the colors are too bright then those colors may disorient the user, or if they are too plain it may disinterest the user. These are simple examples but are potentially be major factors in the development of a system and the effective use of the system. Nielsen [11] introduced the following heuristics regarding usability as it pertains to HCI:

- Simple and Natural Dialogue – Using an automobile collision-detection alarm-system application as an example, it would not be practical to flash a green light when the vehicle is about to hit something. Any user with driving experience in the United States would rather have a red light for stop, a yellow light for exercising caution and a green light for go. Our society has developed certain perceptions that may not be universal but certainly easily recognizable by a grand majority.

- Speak the User's Language – Using the same example as above, verbalizing, "The driver is 1.2 meters from the encroachment on space of an unanimated object", is not the way the majority of drivers (especially truck drivers) would talk. Direct statements such as "Please stop the vehicle, you are about to crash into something on your rear left side" would be much more user friendly and understandable.
- Minimize User Memory Load – The user should not have to memorize several screens in order to accomplish a task. Everything that the user needs to make an informed decision should be on the page or in the view of the user at one time. Putting trust in someone's memory to make a major decision could have disastrous results and therefore should be avoided. A user interface should be designed to enhance the users ability to make a decision rather than hinder it.
- Be Consistent - Being consistent covers several areas including the color scheme as well as how the system interacts with the user. If verbal messages are being utilized then they should be the same or if you use different tones to show the sensitivity of an action then it should be known upfront and should be strictly adhered.
- Provide Feedback – The user must know whether something is going on or not. For instance in most Microsoft Windows applications, when the processor is busy it will show an hourglass to tell that the system is busy but working. This same concept would be used in a vehicle collision system, as in the example given

earlier, where the screen would have some blinking device or some other noticeable but not annoying signal to let the user know the system is armed and working.

- Provide Shortcuts - The user should have the ability to retrieve embedded information or screens without going through a large amount of screens to get to the needed information or function.

In regard to audible warnings, consideration must be given to the type of voice that is used in a warning. Some synthesized voices can be annoying or not recognizable. If the intonation is incorrect, then the speech will be unintelligible to the user. Some would describe digital language as machinelike, choppy, harsh, grainy, and lacking co-articulation (i.e., blending of words) and natural intonation [12]. Some guidelines for synthesized speech developed from experience with designing real-world systems are as follows [12]:

- Voice warnings should be presented in a voice that is qualitatively different from other voices that will be heard in the situation.
- If synthesized speech is used exclusively for warnings, there should be no alerting tones before the voice warning.
- If synthesized speech is used for other types of information in addition to warnings, some means of directing attention to the voice warning might be required.
- Maximize intelligibility of the messages.

- For general-purpose use, maximize user acceptance by making the voice as natural as possible.

- Give the user the ability to interrupt the message; this is especially important for experienced users who do not need to listen to the entire message each time the system is used.

- Provide an introductory or training message to familiarize the user with the system's voice.

- Do not get caught up in "high-tech fever." Use synthesized speech sparingly and only where it is appropriate and acceptable to the users.

This, like many other aspects of the development of systems, depends on the user's likes and dislikes.

2. How does HCI affect AVAILS?

The effectiveness of AVAILS at assisting the driver in avoiding crashes is dependent to some degree on the design of its HCI. This is why the potential users of AVAILS need to be involved in the initial development of any system to ensure that it meets the user's requirements. Although some degree user input was utilized on the initial conceptual design of the AVAILS-HCI, we relied on our knowledge of ground transport by the Marine Corps.

In development of AVAILS consideration has been made on the delivery and look and feel of the system, which will affect the interaction between the user and the system. Although there may be several ways to deliver the system to the users, Head-Down Display (HDD) and Head-Up Display will be the primary focus of this study.

3. Head-Down Display (HDD)

HDDs are traditionally used in automobiles. These are the devices that are currently located on the dashboard or somewhere that is not in the driver's immediate field-of-view (FOV) [5]. If a device is placed where the user has to look down or away from the focus of primary interest, the device is known as a HDDs. For example, the speedometer and tachometer are often part of a HDD in passenger vehicles, buses, and trucks. There are also high-head-down-displays (HHDD). HHDDs are typically mounted above the driver or operator of the vehicle [10]. These devices are similar to HDDs because it makes the driver look above the FOV. Both of these techniques are considered older technology but are explored as a possible implementation for AVAILS.

4. Head-Up Display (HUD)

The Heads-Up Display (HUD) is the term used for in-dash or windshield displays that may be used by pilots or drivers of automobiles to assist them in navigating or operating their vehicle without having to take their focus off the FOV [22]. AVAILS could also be developed as a HUD because of its possible position in the FOV of the users operating the vehicle and because of the way the users will utilize it. One major difference between a HUD and a HDD lies in the location of the device in the driver's environment.

a. Operational Considerations

The test results from the study of a HUD speedometer indicated that 70 percent of the drivers felt that the HUD was easier to use and more comfortable than HDD speedometers [14]. The study also showed that subjects were more aware of their speeds and were able to maintain the posted speed limits. Unfortunately, when a comparison is made between the manufacturing costs for traditional speedometers and HUD technology, the HDD speedometers are far less expensive.

At present, vehicles are not equipped with collision warning or avoidance technology. The use of a HUD gives the driver immediate information without the operator having to take his eyes off the road or the view they currently are fixed on. With information readily available in the driver's view, the time taken in redirecting gaze and refocusing when using an HDD, in theory, should theoretically be reduced with the use of a HUD [22]. Ninety percent of all input to the driver is obtained via direct vision. The reliance on vision can make it difficult, for instance, for the driver to monitor a HDD [13]. When traffic is heavy, the roadway is unfamiliar to the driver.

b. Safety Considerations

The AVAILS HUD is intended to assist the driver to make decisions by providing information to the driver about his or her vehicle's proximity to other vehicles. The distance to other vehicles is reported to the AVAILS HUD by a set of sensors, which in combination have a 360-degree FOV. The sensors must be able to sense other vehicles at a distance equal to or greater than the minimum safe separation distance to the sensed vehicle and the additional distance needed to permit AVAILS to do the following: acquire the target vehicle, track its closing rate, process the input data, display the proximity information to the driver via a HUD, and provide the driver with enough time to react to the information.

A HUD is supposed to be setup in the drivers primary FOV so that it does not take the drivers attention away from the roadway [7]. Some of the safety concerns are as follows: preventing the loss of all displayed information due to a change of the driver's head position, designing graphics for maximum comprehensibility and minimum confusion with elements in the real world, ensuring clear visibility of display and outside scene, establishing the right moment for presenting or updating information and assessing the acceptance of the system with the intended users [7].

The AVAILS HUD is intended to enhance the driver's ability to drive safely. If the system interrupts the user or is in some way difficult to use, then it detracts from the safety of the operation of the vehicle. The measure of effectiveness of the HUD in terms of safety will be zero if the driver turns the system off. This measure will be low if the information is not timely (i.e., updated) enough to prevent a crash or the display distracts the driver in such a way to contribute to a crash. The measure of effectiveness will likely be high otherwise.

c. Advantages, Disadvantages and Concerns of HUD

There are advantages as well as disadvantages to the use of a HUD. Possible advantages include:

1. Augmented eyes-on-the-road measure - In contrast to an HDD, the HUD permits the driver to view vital information while his or her attention is still on the roadway. For example, if the user looked down to check the vehicle's current speed and anther vehicle enters the intersection fifty meters ahead. With the HUD the user's eyes are not off the road, therefore providing the driver with time to react in such a scenario [37].

2. Readjusting to FOV - HDDs display information approximately thirty inches from the driver while HUDs are displayed somewhere between 1.5 to 6 meters away from the driver. Studies of aircraft HUDs demonstrated improvements in re-accommodation time, which means the operators can respond ably to blurry images [3]. These studies are controversial because of the mean age of the subjects, which was 21.9 years of age. Young drivers may be able to respond to visual stimuli before fully accommodating to it. The users of the AVAILS-HCI are expected to range in age between nineteen and twenty-six years old. Officers and senior enlisted personnel rarely operate large military vehicles. The target age of AVAILS-HCI operators, to some degree, makes the "age controversy" a moot issue.

Some disadvantages of a HUD include [1]:

- Luminance may be a limiting factor in the automobile due to the presence of glare.
- Stringent cost constraints to install the HUD with the optimal configuration could be a challenge because the minimum standards represent a tradeoff with safety.
- A HUD that is too dim would be worse than an in-dash display.
- The fact that a driver is looking forward does not mean that the driver is able to effectively process the information in all driving scenarios.

Most of the challenges of concern deal with the operator's ability. Most pilots go through extensive training and have an ability to comprehend many different things at the same time, at a high level. One cannot assume that the average driver of military transport vehicles have the same qualities and level of training as a pilot. Although HUD technology is well accepted for use by pilots, one must take into consideration the variations in the population of military personnel trained to operate military transport vehicles. The average automobile driver's attention is a major issue when talking about in-vehicle instrumentation and their ability to manage their concentration. The driver must be able to keep focus and not let the amount of information available from a HUD distract him or her or keep the driver from the primary tasks associated with driving [2]. What this means is that extensive training will have to be offered in order for a new system to work and be useful. Military personnel will have to be trained to use HUD and encouraged to embrace this and other types of intelligent transportation systems. Systems must be ergonomically correct and adjustable to ensure the system fits the user and not the user trying to fit the system [28].

5. Head-Up Display Examples

a. HUD Use in the Civilian Sector

There are several examples in the civilian sector of the use of HUDs. Some of the HUDs for use in civilian passenger vehicles are designed to project information currently available in HDD form, such as speed and engine information to the operator. General Motors (GM) has an exclusive patent on a HUD that allows the operator to view the speedometer, tachometer, water temperature, oil pressure, fuel level, and turn signal [24]. This technology was first tested in the Chevrolet Corvette, which, at one time, gave it the label of "The most intelligent car you've ever driven." GM based its design on the HUDs used in aircraft. Sixty-two percent of the buyers of corvette opted to purchase the HUD option. In GM's system, the operator can choose what is to be displayed via the Driver Information Center (DIC), which is located below the gauge cluster. The DIC is also capable of displaying information in several different languages, including English, German, French and Spanish, and the operator is able to display in English or metric units as well [24]. GM calls their display system EyeCue. EyeCue is also available on the Pontiac Bonneville SSE, Grand Prix and the Park Avenue.

Before GM came out with these comfort upgrades computer programmers were coming up with ideas for the network vehicle of the future. The Network Vehicle, first displayed at COMDEX ’97 in Las Vegas, November 16-21 1997, included devices with features such as the following:

- Separate, advanced driver and passenger displays with flat panel, touch screen technology and both keyboard and voice command entry
- A driver side, re-configurable, voice-command HUD in the windshield
- A simulated navigation system with traffic updates for real-time route guidance
- Hughes Electronics’ DirecTV and DirectPC satellite links
- Text-to-speech audio delivery of practically all onboard and broadcast information
- Docked IBM WorkPad PDA

This vehicle was designed in a collaborative fashion by IBM, Netscape, Sun Micro-systems and Delco Electronics, provided the system’s processors, audio and video equipment, high-speed fiber-optic Mobile Media link, touch-screen re-configurable LCD displays, HUD, and software specifications. Java was used to integrate the different technologies [23].

Initially the predominant use of HUD was being used to display current information in the HUD, but today there are several vehicle manufacturers that are thinking innovatively and looking to enhance the different types of information they can provide to the user. For instance, GM is set to offer a night vision system for the Cadillac Deville that will allow the driver to see up to five times further down a dark road by using infrared sensors [28]. This information would be displayed via a HUD and enable the driver to react quickly to looming surprises down the road or to enhance their vision of the road on very dark streets or in poor weather conditions [28]. This vision enhancement system (VES) will also have additional sensors for information such as digital maps and special installations to direct headlights to certain areas of the road.

Daimler Chrysler researchers in Ulm, Germany have also developed an infrared laser night vision system that significantly enhances the driver's night visibility. The system enables the driver to see darkly clothed individuals or even cyclists at great distances. It also has an option to illuminate the road 500 feet in front of the vehicle, vice the average of conventional high-beam lights of 130 feet, without blinding the drivers of oncoming vehicles. Their system uses a video camera to record the reflected image and then send it to a black and white screen located in the driver's FOV. Initial tests of the system were performed on buses, but plans to test this system in trucks transporting hazardous materials, emergency service vehicles, and taxis. Daimler Chrysler has targeted the development of this system on vehicles that require high levels of safety [37].

In the European Darwin Project, for automotive Visual Enhancement Systems (VES), there has been a study of the use of HUDs to assist the driver in poor visibility conditions. This system uses an infrared sensor, operating in the spectral wavelength range of eight to fourteen microns, which is capable of detecting thermal radiation emitted by all objects within a certain scenario. Developed by the Boeing Corporation, the system consists of a 320x240 pixel matrix of microbolometers integrated into an automotive camera design, with the thermal image of the scene to be broadcasted to the HUD [37].

b. HUD Use in the Government

The U.S. Intelligent Vehicle Highway System (IVHS) Program, was chartered under the Inter-modal Surface Transportation Efficiency Act of 1991 to improve highway safety, reduce congestion, enhance mobility, minimize environmental impact, save energy, and promote economic productivity in the national transportation system [16]. The IVHS strategic plan was developed in part based on the modeling and simulation of the following: urban traffic networks, vehicles, highway infrastructure, driver population, traffic models with dynamic traffic assignment, driving scenarios simulation, and advanced vehicle control systems (AVCS) architecture, to study the effects of HUDs and safety. The objectives were to assure in-vehicle information systems are safe and usable, and to test different formats and how they affect the workload of operators of commercial vehicles. The studies, conducted under the auspices of the U.S. Department of Transportation (DOT), produced results that have been applied by the developers of in-vehicle information systems such as HUDs used in commercial vehicles [16].

Most of the military's development of technology for HUDs has been for aircraft. The United States Air Force (USAF) Office of Scientific Research sponsored the University of Idaho to conduct a study on the use of HUDs and presenting information to support the peripheral vision of pilots [25]. The three-year simulation-based study, which concludes in 2001, will provide some consensus to questions about operator's perceptual systems, helping to delineate how to build better HUDs for use in the cockpit of an aircraft.

USAF MSgt Fletcher Burns' work on HUDs is a great example of what the military is doing in the advancement technology. Burns, chief of maintenance for the 412th Flight Test Squadron, received an exclusive Air Force license to develop and market a HUD mount he designed while working on a flight test project [35]. The HUD mount is currently being used on Speckled Trout aircraft.

HUDs are used in some of the aircraft operated by the Test Pilot School of the U.S. Air Force. The Air Force is convinced that the use of HUDs can significantly enhance flight safety and has tested HUDs extensively, using students at the Test Pilot School (TPS) as subjects. The Flight Safety Foundation determined that HUD technology could have helped or positively influenced the outcome of one-third of some 1,000 civilian jet aircraft crashes, from 1959 to 1989 [32]. TPS' objective is to enhance the pilot's situational awareness in difficult flying conditions. The aircraft that TPS uses is the Speckled Trout, which is the same aircraft CMSgt Burns developed the HUD mount for. The study they are conducting is named Project Have Vision, with goals of collecting sufficient data on the performance of basic HUD technology and to seek Air Force Flight Standards Agency certification of HUD as a primary flight display.

6. Standards

In the advent that HUD use becomes widespread, government agencies have begun to implement standards and guidelines for HUD development. The U.S. DOT released standards for visual displays within vehicles. The standards offer guidance in the use of color, display characteristics, location, and brightness. The stated reason for setting standards for HUDs is safety. The U.S. DOT wants to ensure that developers of such systems follow guidelines that are based on basic and applied research, such as that conducted by Chrysler, Boeing, and other government agencies.

Guidelines for the paramount in-vehicle display have been determined by a formula derived by Kimura, Sugira, Shinkia and Nagai in 1988 [25]. These guidelines were for setting a HUD's parameters to be optimal. The HUD should have a large FOV and be positioned in the correct angle of the user. The FOV should be 2.0 degrees vertical by 4.0 degrees horizontal, with an image distance of 4000mm, lookdown angle of 6.0 degrees and an image brightness variation of 2:1. These specifications are optimal but small variances would likely be amenable for the first iteration of the use of AVAILS. All examples are based on an average size male driver of 5'9" to 5'10" and variances would certainly play a factor for the size of the operator of the vehicle [2].

The ideal environment for vehicle cabs for persons between the 5th and 95th percentile of operators has been described in the literature [12] The environment consists of twenty-eight inches maximum to prime displays, with the prime display being within the range of fifteen to thirty degrees above the direct horizontal line of sight, and a 90-degree angle from standard line of sight to in-dash display [12]. These standards are all considerations for the implementation of AVAILS.

7. Discussion

The needs and limitations of users must be examined as part of the development of the HUD to be used in AVAILS. Some areas of importance are:

- Needs analysis
- Situation of concern
- What is currently in use?
- Goals of product
- What is the desired end state?

It is also important to ensure that features are going to be usable and user friendly. In order to address usability and user-friendliness, one needs to consider the following:

- What will the user be able to do with system?
- User analysis
- User characteristics
- What skill is required (computer knowledge)?

In considering the user needs and features we can then deliberate design support and prototyping, which includes such things as the following:

- Conceptual design
- Physical design
- Objects used
- Where will it be located?

- Visual design
- How big, color scheme?
- How will functionality be accessed (e.g., buttons, menu, voice)?

Once there is a prototype available, it must be shown to potential users. It also needs to be tested on a user that may be new to the task being done by the actual user base; the reason for this is to demonstrate the ease of use and understanding of the system. If a person unfamiliar with the task of driving in a convoy or using electronic devices to assist in driving can use this tool without much difficulty, then there is evidence that may be able to quickly learn to use the new system in an effective manner. Extensive user analysis with AVAILS will be left to future research. The focus of this thesis is on the specification of requirements for AVAILS and its HUD, rather than on a detailed design. We use a software-based prototype of the HUD to illustrate the requirements that we have developed. The following is suggested as future research:

- Run experiments to determine what percentage of the drivers of military transport vehicles can learn to effectively use AVAILS
- Perform design evaluation
- Perform usability specification
- Refine AVAILS based on feedback from operation's data
- Develop, collect, and analyze measures of the system's effectiveness

Other questions include, but are not limited to the following:

- Can users use the system optimally?

- Are all options easy to use?
- How long does it take to go through options?
- What can be done to help drivers use the system?
- Was the system easy to use and understand?
- How much training is required to use the system?
- Will efficiency increase and error rate decrease with training?
- Do the users make errors?
- When they make an error, are they able to recover?
- What errors were made?

Some of the questions that should be addressed during the detailed design of AVAILS include the following:

- Did we meet the user specification?
- What changes were suggested?
- Would users actually like to see this system fielded?

Consideration must be taken in the implementation of AVAILS so it will be beneficial to its users and in the following guidelines set forth, AVAILS will have a great chance of meeting its goals.

B. ENVIRONMENTAL CONSIDERATIONS

Seasonal weather conditions (e.g., fog, snow, sleet, rain) and other environmental conditions will shape the requirements for AVAILS. AVAILS will assist vehicle operators in operating their vehicle around other objects over a wide spectrum of environmental conditions. The highest rate of motor vehicle accidents occur under some of the more extreme weather conditions. AVAILS will only be concerned with providing collision warning or collision avoidance for the host vehicle as it operates near other objects under the most common environmental conditions in which military vehicles are operated, some of which could be severe, but would likely not include extreme environmental conditions such as hurricanes, flash floods, tsunamis, and typhoons.

C. DRIVING PROTOCOLS

Currently, there is no standard overall document dictating specific rules and guidelines for driving on the nation's highways. The NHTSA, under the cognizance of DOT, may provide information for developing guidelines for traffic laws, but NTHSA's primary charter is to reduce the frequency and severity of motor vehicle crashes [29]. The majority of highway regulations are derived from individual state governmental agencies. This practice explains why speed limits and other basic traffic regulations vary from state to state [46]. State agencies also play a role in regulating the deployment of intelligent transportation systems, (ITS), such as smart cards, electronic toll collection and semi-automated metropolitan transit systems. There does exist a certain commonality of law in regards to governing basic vehicle operation. These rules range from obeying common traffic signs (e.g., stop signs, highway entry signs), highway information signs (e.g., construction area, driver assistance points), and right-of-way privileges. Accordingly, AVAILS requirements need to be congruent with DoD traffic regulations with adherence to the "commonality" of inter-state highway rules and regulations. The driving protocols will form the basis of the core system requirements of AVAILS. The following system requirements demonstrate a few of the "commonality" law interpretations:

- Maintain sufficient distance from lead vehicles when operating vehicles in weather conditions that are known to make vehicle operation hazardous.
- Complete passing maneuver only when the vehicle being passed has been sighted in rear or side mirrors.

These are just a few of the driver protocols that may actually become desired system requirement in AVAILS. As with most ITS, driving distance requirements will have the most impact on system requirements.

D. CONCEPTUALIZED AVAILS-HCI

AVAILS has been generically derived from examining environmental conditions and common driver protocols, and interpreting these items into system requirements. Figure 8, depicts the process used to conceptualize AVAILS. AVAILS can be derived by combining DoD motor vehicle operating protocols, common state and local highway regulations, and specific environmental conditions under which the system must continue to operate. The requirements for AVAILS-HCI, as conceptualized in this thesis is shown in Figure 1.

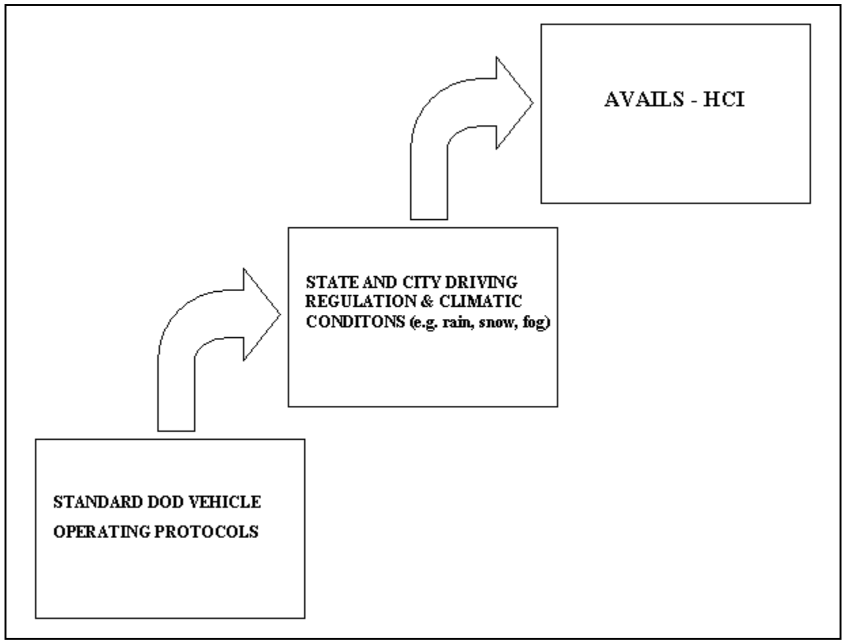

Figure 8. The conceptualization of the AVAILS-HCI.

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IV. RELATED WORK

The desire to develop intelligent transportation systems (ITS) to assist the efficiency and safety of the nation's highways is not a new concept. The California Partners for Advanced Transit Highways (PATH) Program, for instance, has been conducting ITS research since its inception in the 1980s [33]. The California PATH also maintains a large database of literature on ITS programs and research conducted by other institutions [34]. There are many technological devices that assist highway and vehicle management. There are electronic toll collections devices, smart cards, and automated (i.e., driverless) metropolitan transit systems. Many devices are now being added to the vehicle itself such as rear object detection devices, intelligent navigation and adaptive cruise control systems. Improvements on these devices are always desirable and research in these areas has gained a new momentum as the nation's highway infrastructure becomes better suited for supporting in-vehicle applications of ITS.

> *Safety benefits of collision avoidance systems has been a subject of considerable experimental and analytical research which has established conceptual descriptions of various kinds of CAS, CAS designs and sub-system performance guidelines, crash types targeted by different CAS, crash mitigation benefits estimates for different CAS concepts], and design and specification guidelines for CAS human-machine interfaces. The research has aimed to characterize the performance of prototype systems the operating environment of CAS sensor subsystems, driver behavior under normal driving conditions, and driver interaction with partially automated vehicles. Although a great deal progress has been made in these areas, much work is still required to better understand the relationships between benefits, user acceptance, CAS subsystem requirements, driver behavior and the driving environment…*[4]

Due to recent advances in technology, it is possible to detect, using software-controlled sensors, many types of stationary and moving objects in the path of a vehicle.

These obstacle-detection systems can warn the driver of an impending collision and initiate preventive actions, on the vehicle itself, to avoid the collision. A few systems to note are the Eaton Vehicle Onboard RADar (VORAD), Maneuvering Aids for Low Speed Operation (MALSO), and Automotive Collision Avoidance System (ACAS). VORAD is one of the systems that closely resemble AVAILS. MALSO employs similar object detection methodologies into its' design. ACAS is a development concept sponsored by NHTSA [30] in an attempt to explore and develop collision avoidance systems that will assist drivers in safely executing lane changes, merging, and backing maneuvers. These are just a few of the systems under development that either serve as CWS, CAS, or a combination of both. Due to the varying degrees of expertise, variety of new ideas, application experimentation and results analysis, there has never been a predefined guideline or set of protocols for developing automated vehicle software systems or ITS [4]. The Hierarchical Assessment and Requirement Tools for Crash Avoidance System (HARTCAS) is a development tool that proposes a five–layered hierarchical modeling framework for CAS benefit assessment and requirements development [4]. The HARTCAS framework is intended to reduce the complexity of the analysis of a proposed system, which would allow the study of system parameters over a range of values, driving scenarios, environmental conditions, and system capabilities. In this thesis we focus on the specification of the requirements for the driver interface of AVAILS. The requirement specification is a prerequisite for using the HARTCAS modeling hierarchy shown in Figure 9.

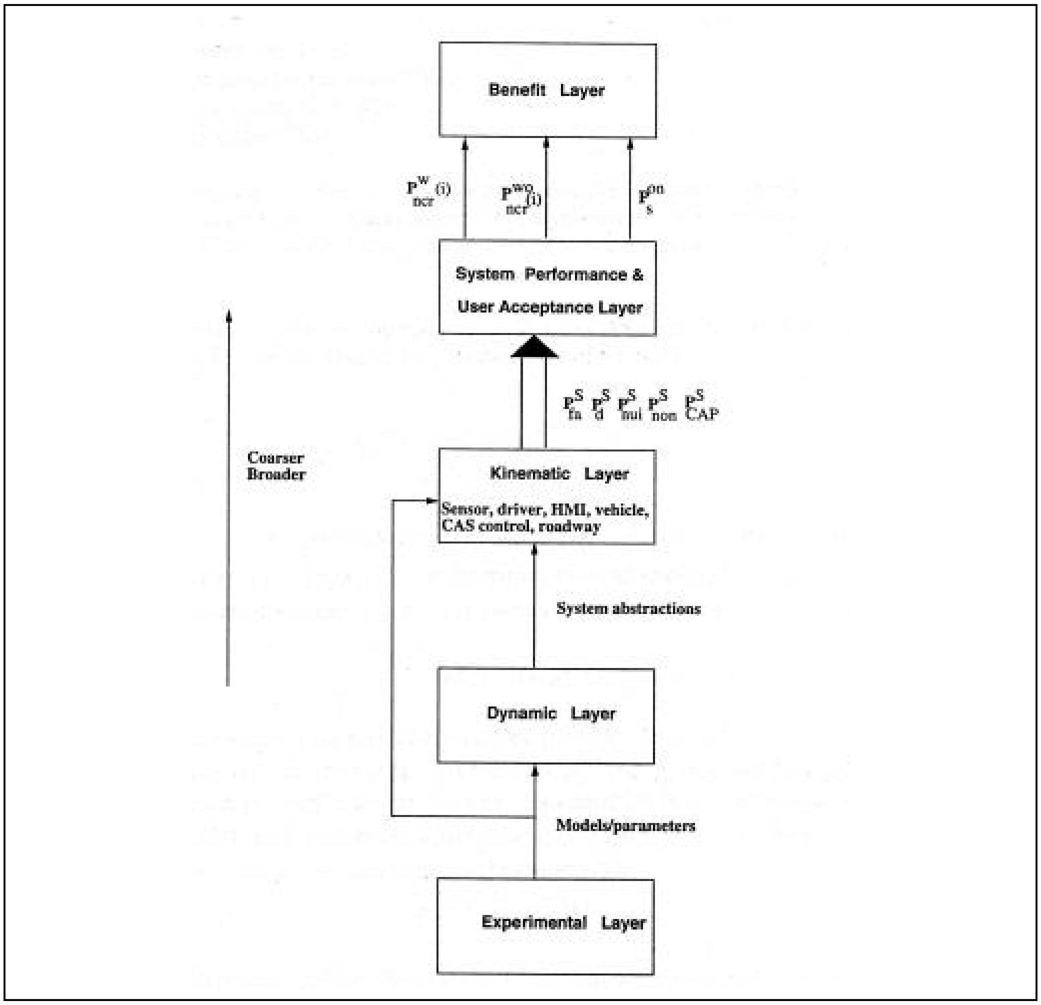

Figure 9. HARTCAS Modeling Hierarchy (From: [4])

All of the previously mentioned systems serve a CWS with only ACAS venturing into the realm of CAS. Each system will be examined briefly in subsequent sections. The point of emphasis should be directed at the fact each of the systems are inherently designed as a CWS or CAS. The two terms are, although conceptually similar, are distinctly different in their roles they share in autonomous systems. CWS and CAS will be examined separately.

A. COLLISION WARNING SYSTEMS (CWS)

Collision warning systems warn the driver to impending collisions either through physical, audible, or visual means. The CWS warnings can be given in a variety of ways. Physical warnings can be through haptic feedback, such as vibrating the steering wheel or the driver's seat. Audible warnings can be provided by a variety of messages, beeps, or sounds. Visual warnings can be given by flashing lights or indicators. As a CWS, no direct action is taken to take active control of the vehicle and initiate preventive measures for avoiding collisions. The CWS only alerts the driver of an impending collision. Once alerted, the driver can employ evasive actions to avoid a collision. AVAILS is primarily a CWS. The system interface is designed to provide the driver audible warnings when a collision with another vehicle or a docking platform is impending. The system is not intended to warn the driver of the presence of pedestrians.

B. COLLISION AVOIDANCE SYSTEMS (CAS)

CAS, unlike CWS, seeks to initiate some action on the vehicle. The most common form of CAS can be seen in adaptive cruise control (ACC). Current adaptive cruise control technologies employ both radar and LIDAR (light detecting and ranging) [9]. Using object detection, the system adjusts the speed of the vehicle in an attempt to maintain a safe following distance from the lead vehicle. The driver must turn on the ACC and retake control of the vehicle once the ACC is turned off or deactivates itself because the minimum safe-following distance was violated. Other forms of CAS are limited braking, throttle integration/resistance, or forward-looking sensors. The role of CAS in AVAILS is very limited. The only CAS functionality considered for inclusion in

AVAILS is adaptive cruise control. This functionality can be borrowed, to some extent, from existing commercial products.

C. EXISTING SYSTEMS

As previously mentioned, VORAD, MALSO, and ACAS are all systems that serve the role of a CWS. Only ACAS, as a developmental concept inspired by NHTSA, explores CAS in automotive systems. AVAILS echoes the same intent as each of these systems.

1. VORAD

VORAD is a CWS designed, specifically for large trucks, by the Eaton Corporation as part of its intelligent truck components for fuel economy and safety business. Eaton claims that the usage of CWS can reduce total accident costs by thirty-three percent [26]. An Iowa State University study concluded that the majority of forward and side collisions account for approximately ninety-four percent of all accident costs involving large trucks. VORAD uses radar as its principle means of object detection. The radar is federally approved, does not pose any danger to other motorists, nor does it affect law enforcement radar usage or any other radar devices in other vehicles. VORAD consists of three major components: the antenna transceiver assembly, the central processing unit, and the driver display unit. The AVAILS-HCI more closely resembles VORAD than any of the other systems. The placements of the three major devices in VORAD are depicted in Figure 10.

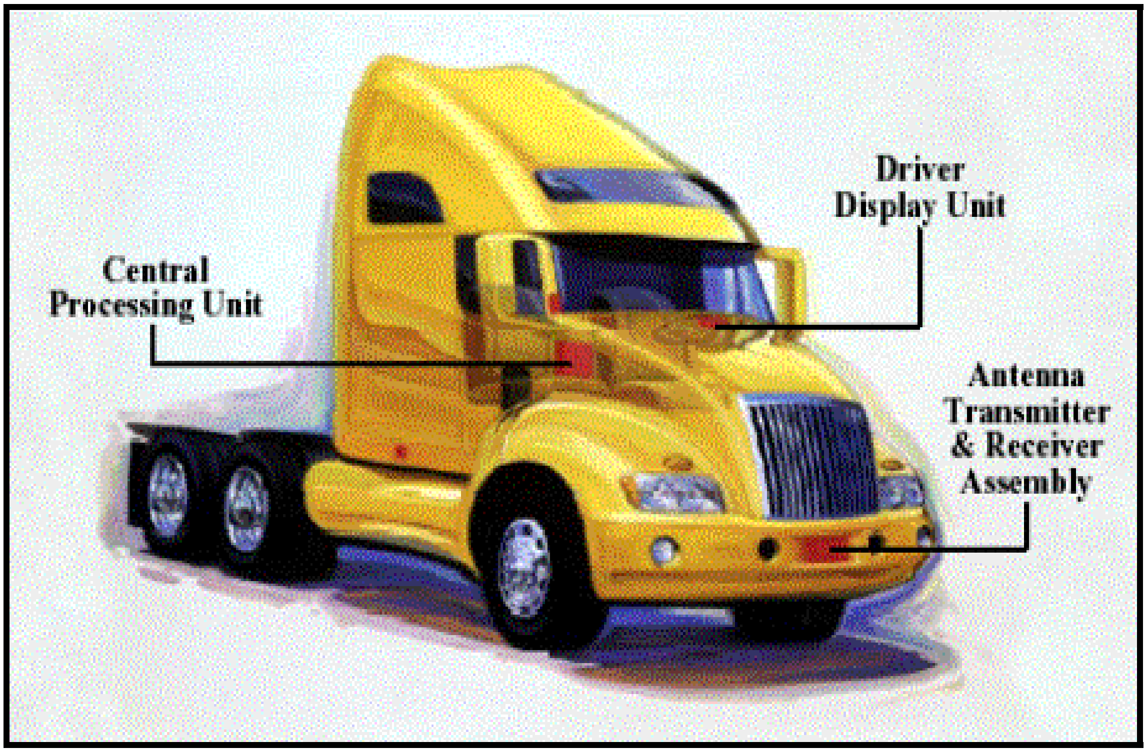

Figure 10. Eaton VORAD (From: [26])

In addition to the three major components, there are sensors mounted on either side of the cab. These sensors can detect objects anywhere from two to ten feet near the truck. Vorad equips the truck with one sensor that is mounted on the passenger side of the truck. The driver has a full range of view on the driver's side. However, a second sensor mounted on the driver's side is optional. The antenna beam coverage for VORAD will spans a height of five degrees and a width of twelve degrees, allowing Vorad to detect most objects in its immediate path, as shown in Figure 11. If the driver were maneuver around a curve, the gyroscope housed in the central processing unit shapes the radar detection zone to the curvature of the roadway. This would effectively keep the radar coverage on the road rather than perpendicular to the road.

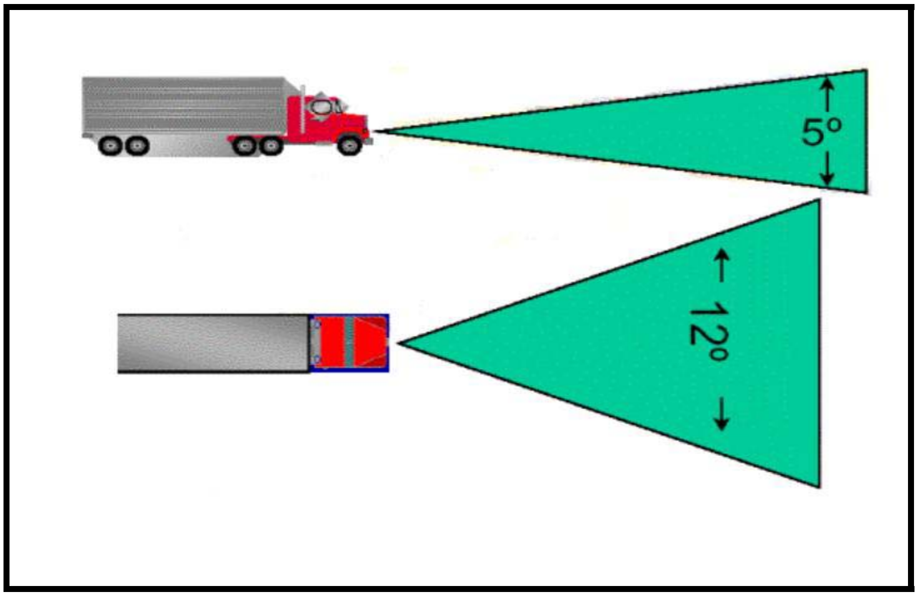

Figure 11. Antenna Beam Coverage (From: [26])

Figure 12. Driver Display Unit (From: [26])

The driver display unit has a rather simple design, as shown by Figure 12. The driver display unit provides audible warning alerts to the driver. There is a slot for the driver's identification card. Depressing the range knob in or out, allows the driver to manipulate various functions of the system. The various warning-level lights (ovals in the center of

Figure 12, from left to right), increase in criticality. The warning lights change in color, from yellow to a reddish tint. VORAD offers adaptive cruise control and a host of other options as optional functionality.

2. Maneuvering Aids for Low Speed Operation (MALSO)

MALSO are detection devices with non-contact sensors that are intended for use on light-duty vehicles to assist the driver during low-speed maneuvering. MALSO systems indicate to the driver the presence of front, rear, or corner objects when maneuvering into small parking spaces or negotiating narrow passages. They are regarded as an aid to drivers for use at speeds of up to one meter-per-second, but they do not relieve the driver of the driving task. MALSO systems use object-detection devices for ranging in order to provide the driver with information based on distance to obstacles. It specifies minimum functionality requirements that the driver can generally expect of the device, that is, detection and identification of obstacles within a defined detection range. It defines minimum requirements for failure indication as well as performance test procedures, and it includes rules for the general information strategy, but does not place restrictions on the kind of information or display system that can be used.

The sensing technology is not addressed. However, technology affects the performance test procedures set up in this standard. The current test objects were defined based on systems using ultrasonic sensors, which is the most commonly used technology at the time of editing this standard. For future sensing technologies, these test objects shall be checked and changed if required. MALSO is depicted in Figure 13.

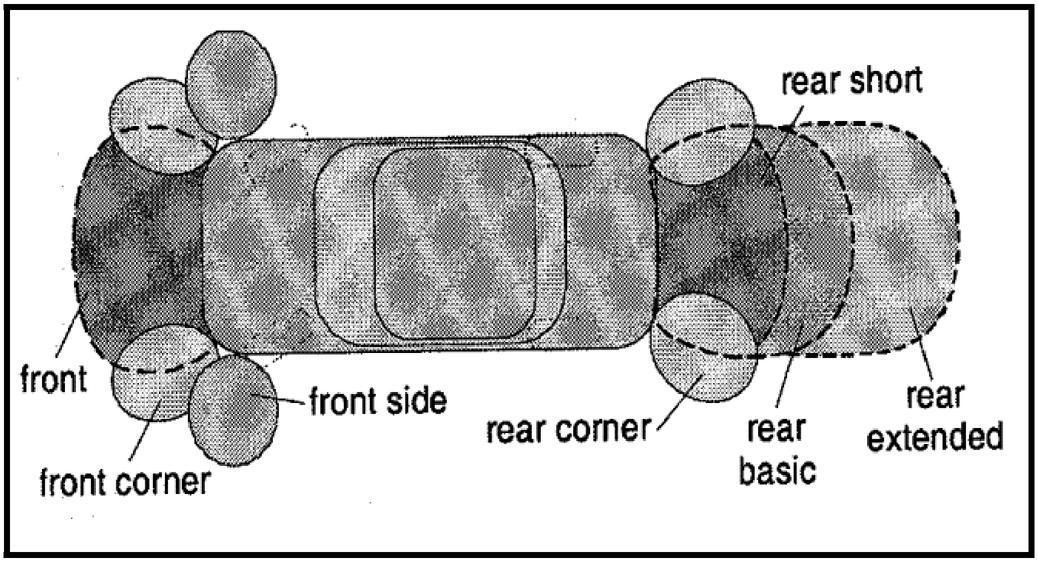

Figure 13. Possible Cover Ranges for MALSO (From: [8])

MALSO are categorized according to their capability of covering different monitoring areas of the vehicle. Each monitoring area corresponds to a particular part of the host vehicle and is expected to prevent the vehicle from colliding with an object. Table 1, lists the abbreviations for each monitoring area. Table 1 directly corresponds to Figure 13.

Monitoring Range	Abbreviation
Rear short	Rs
Rear basic	Rb
Rear extended	Re
Rear corner driver side	Rcd
Rear corner passenger side	Rcp
Front	F
Front corner driver side	Fcd
Front corner passenger side	Fcp
Front side driver side	Fsd
Front side passenger side	Fsp

Table 1. MALSO Monitoring Ranges (From: [8])

MALSO can be activated or deactivated by a switch or push button. When activated, the system indicates readiness either acoustically or visually. The driver's interface contains an audible information channel. Visual information and warning information are considered to be additional means of relaying information to the driver. The most valuable information to the driver is the distance information of objects near the vehicle. MALSO contains only a bit more functionality than the information required for AVAILS. However, the concept of CWS and CAS are present.

3. Automotive Collision Avoidance Systems (ACAS) Development

ACAS is entirely supported by NHTSA, which is under the direction of the U.S. DOT.

> *As a developmental concept, the main objective the main objective of the program was to provide a focused approach to accelerate the commercial availability of a portfolio of promising key fundamental collision warning countermeasure technologies and or systems. As a result, the void between research and development and the actual deployment of the new technology, in the real world, was substantially bridged. ACAS was accomplished through a cooperative arrangement between the U.S. Government and a ACAS consortium, whose membership is comprised of both industry and academic participants. Financial support for the ACAS program was provided by, both the United States government and consortium members. The government financially sponsored ACAS through the Defense Advanced Research Project Agency (DARPA), in accordance with the guidelines of the Technology Reinvestment Program (TRP). The Additionally, the government actively participated in the ACAS Program activities, through NHTSA, which administered the ACAS Program on behalf of government [39].*

Furthermore:

> *The ACAS Program has laid a solid foundation towards the implementation of a comprehensive collision warning system, which is capable of detecting and warning the driver of potential hazard conditions in the forward, side, and rear regions of the vehicle. Performance requirements of the major components of the CW system, such as long*

> *range forward-looking detection sensors (radar or optical, short range side and rear detection sensors, and a lane detection vision-based were investigated. Finally, the effectiveness of a variety of warning cues was also studied. The results of this program have generated new insights for how the CW system should be configured and deployed [31].*

ACAS produced substantial gains in knowledge of CWS/CAS. However, there is a vast amount of research yet to be conducted. The real-world traffic environment is extremely diverse and presents an almost insurmountable obstacle for making such systems relatively free of false alarms and missed detections. New systems could take advantage of new sensor technologies in order to increase potential CWS/CAS robustness. We believe that ACAS can assist the development and maturation of systems such as AVAILS.

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V. AVAILS-HCI SOFTWARE DESIGN SPECIFICATION

A. SYSTEM INTRODUCTION

As previously mentioned, the purpose of this document is to provide an introduction into the AVAILS-HCI. AVAILS, as an entire system, will not be described in this document. Only the requirements for the AVAILS-Human Computer Interface (HCI) will be described in detail. The HCI display on the main console is of particular importance and will be discussed in detail since it is the main focus of this research. The main console is depicted in Figure 14. The HCI consists of the display of the main menu and sub-menu options. The sub-menus are the mode menu options, the settings menu option, and weather settings menu.

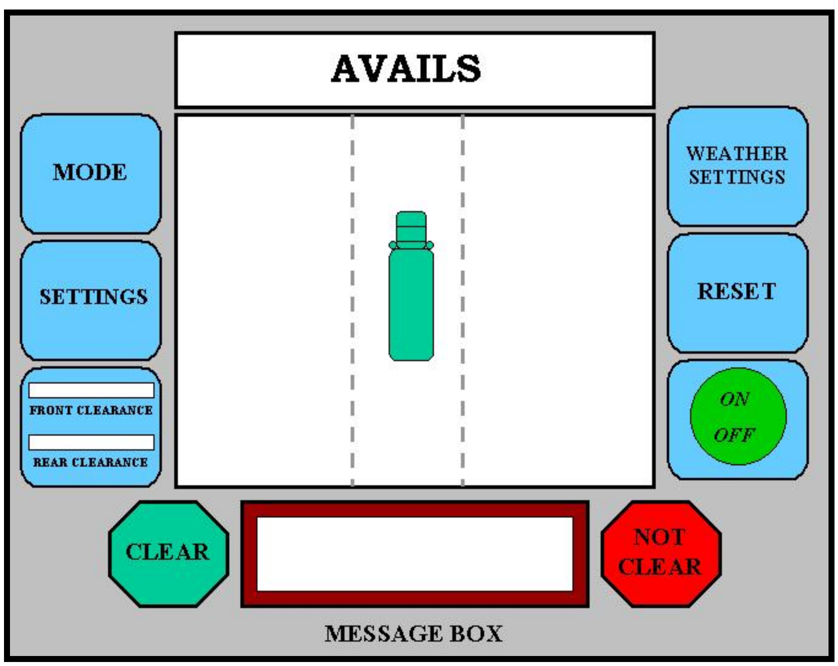

Figure 14. THE AVAILS-HCI

B. SYSTEM OVERVIEW

The main console is designed with the intent of providing the user with a readily accessible and user-friendly display where each button on the display provides an intuitive meaning. The labeling of each menu option was done in a manner as to imply its direct meaning.

Figure 15, depicts the basic process associated with operating the AVAILS-HCI.

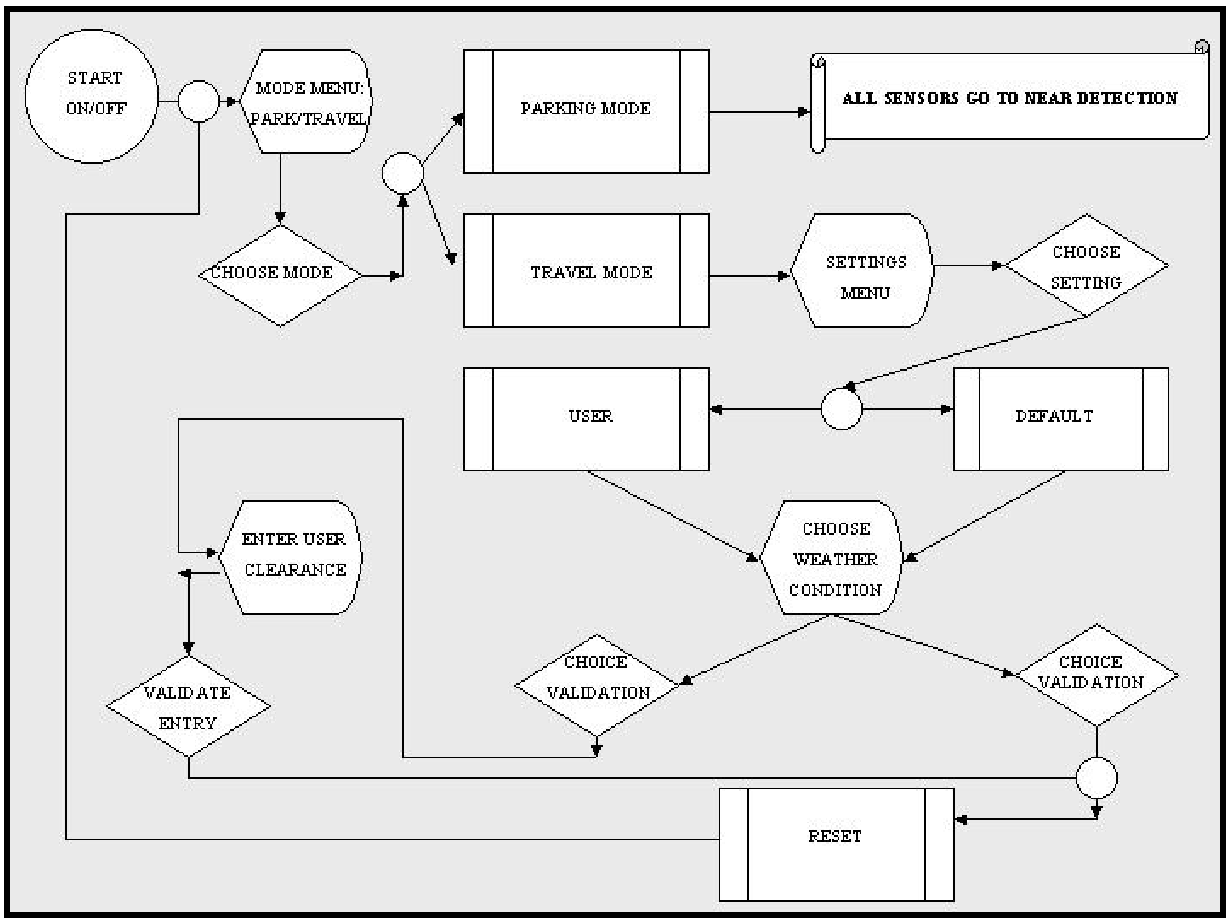

Figure 15. AVAILS-HCI Flowchart

AVAILS is activated by pressing the ON/OFF button. Upon being activated, the user is presented with the first sub-menu. The user must select either the "Park" mode or the

“Travel” mode. If the park mode is selected, all sensors located alongside the truck will automatically be set for near-object detection; that is, all the sensors will be preset to detect nearby stationary objects. Park mode allows the driver to maneuver and park their trailers within inches of other objects. This mode is designed with pre-embarkation operations where equipment is staged in lots for loading on shipping or aircraft.

The travel mode is expected to be the most utilized of the system. As its name implies, travel mode is used when a vehicle is being driven. By selecting the travel mode, the user is then presented with the “Settings” menu option. The two options available here are the “User” and “Default”. The default settings initialize preset vehicle distances for all pre-programmed environmental conditions. The “User” option allows the user to input his or her trailing or passing distance.

The user is then presented with the “Weather Settings” menu. The menu allows the user to select their current driving condition (e.g., rain, fog, snow). The user must select a weather condition before preceding any further. Under the “User” mode, the user is presented with the window to enter the desired trailing or passing distance. Lateral separation is only a factor in low-speed docking maneuvers. The “Reset” process is used when the user needs to start the process all over again, or clear previous entries.

The user can either set the system while the vehicle is at rest or in motion. If the vehicle is in motion, it is probably best to present the user with a HUD. The user must input a selection for every menu that is presented. If a selection is not made, the user will continually be presented with that particular menu until either the system is turned off or the reset button is used. The minimum distance for any menu option, involving distance, in the travel mode is computed based on the acceleration and other performance characteristics of the vehicle. For example, the braking distance at maximum deceleration for a five-ton long truck (see Figure 3) is different from that of a tractor-trailer that is hauling a fully loaded fuel carrier (see Figure 4). The computations are based on a range of speeds up to the maximum allowable speed limit within the U.S., which is seventy-five miles-per-hour [46]. Speed limits in other countries are of little concern simply because military convoys operating in other countries would never approach such unsafe speeds, especially if bulk cargo is being carried.

1. User Option and First-Level Menus

Figure 16, depicts the relationships between the options and menus shown on the AVAILS-HCI main console (see Figure 14).

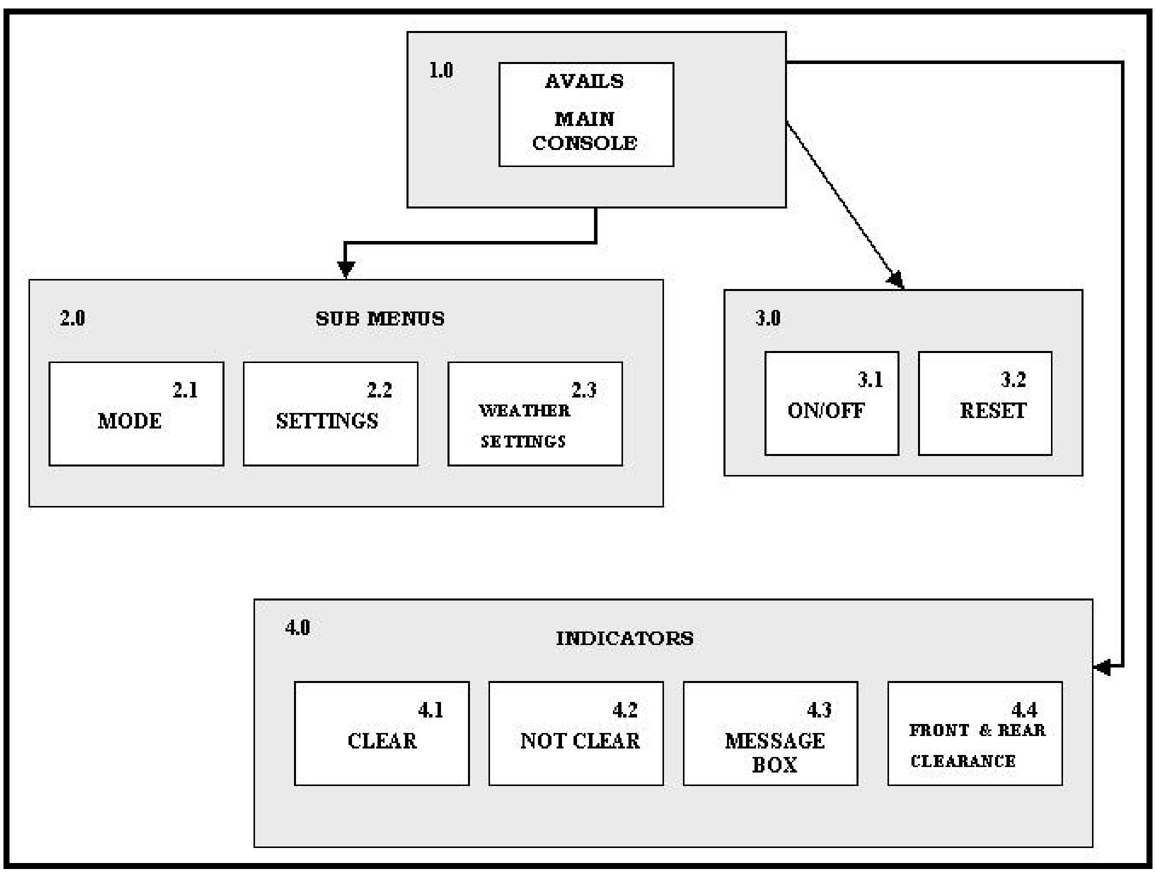

Figure 16. First-Level Menus and Options

Item	Name	Function
1.0	**MAIN CONSOLE**	The entire user interface pictured in Figures 1, & 14.
2.0	**SUB-MENUS**	The first-level menu options.
2.1	**MODE**	The first menu presented to the user allowing them to choose between "Park" and "Travel" modes.
2.2	**SETTINGS**	The second menu presented to the user allowing them to choose between "User" and "Default" mode.
2.3	**WEATHER SETTINGS**	The third menu option presented to the user allowing them to choose between various weather conditions.
3.0	**OPTIONS**	Represents all basic function items.
3.1	**ON / OFF**	Activates and de-activates the AVAILS console.
3.2	**RESET**	Clears all previous system settings.
4.0	**INDICATORS**	Represents all warning devices.
4.1	**CLEAR**	Flashes green and is accompanied with a beep when it is clear to pass.
4.2	**NOT CLEAR**	Flashes red and is accompanied with a beep when it is not clear to pass.
4.3	**MESSAGES**	A text box that shows various messages.
4.4	**CLEARANCES**	A text box that shows the current distance to vehicles being passed.

Table 2. AVAILS Function Chart.

Table 2, provides a brief description of each numbered options shown in Figure 16.

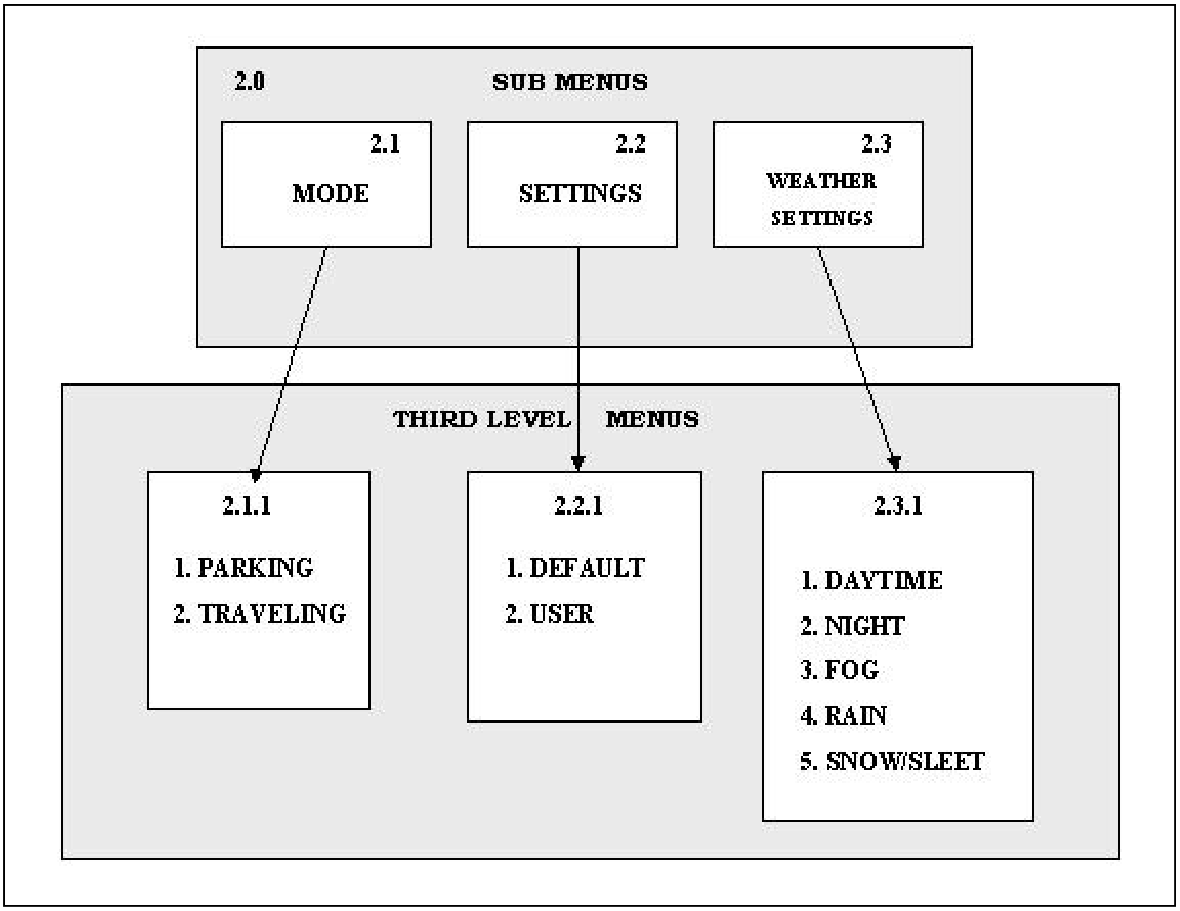

Figure 17. 2nd and 3rd Level Menus.

Figure 17 presents the remaining menu options; their meaning is implicit and do not require further explanation. Menu item (2.3.1.) shows all of the available weather conditions. Menu item (2.1.1) represents the two modes of AVAILS. As previously mentioned, parking mode automatically sets the sensor nodes to detect nearby stationary objects whereas traveling mode opens the sensors to further ranges. Menu item (2.2.1) shows the default setting, which automatically sets a distance for each weather condition. The user option allows the driver to enter their own distance for their driving condition.

2. System Messages

The message box located at the bottom of the AVAILS-HCI will only display a limited amount of messages. The only audible warnings provided to the driver are a series of beeps. There will not be any voice messages within the system. The general messages are shown in Table 3.

Number	Message
1	**WARNING!**
2	**USER PASSING DISTANCE SET AT => *n***
3	**DEFAULT PASSING DISTANCE SET AT => *n***
4	**PRESS RESET FOR NEW ENTRIES OR TO START OVER**
5	**DO NOT PASS!**
6	**COMPLETE PASS!**
7	**MAKE A SELECTION OR HIT RESET TO START OVER**

Table 3. AVAILS-HCI Messages.

The "*n*" shown in message numbers two and three represents either the default distance or the user-entered distance. The distance is an integer value selected by the user. If the user chooses to use the default system settings, the distance is chosen for them based upon the weather condition chosen by the user.

3. The Main Display

Figure 18, shows the main display, which is located in the center of the AVAILS-HCI console.

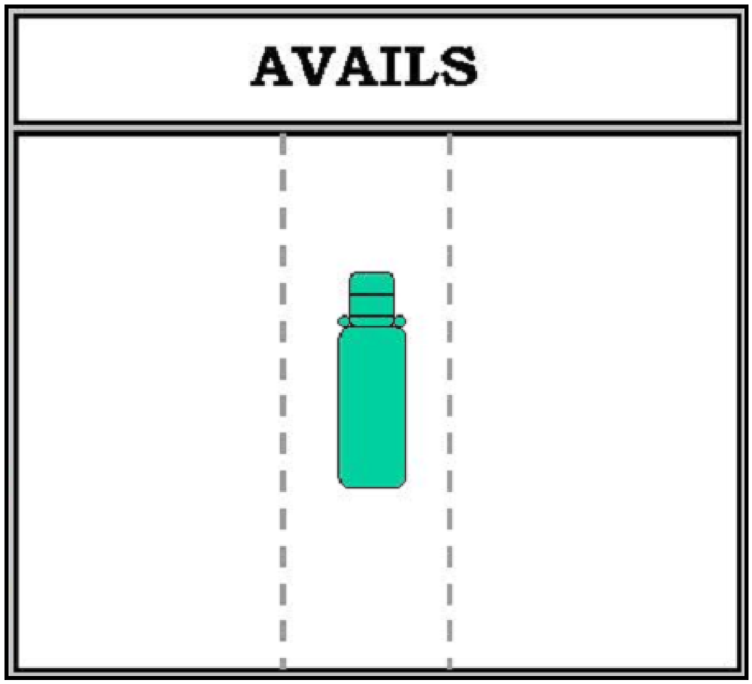

Figure 18. AVAILS Main Display.

The main display depicts the vehicle in the center of the map. A distance of one lane is represented on each side of the vehicle. Each side-mounted sensor node will cover a range equal to the distance of one lane. As the driver passes an object (a vehicle), that object will be shown on the display. When the object reaches the preset distance, the system will let the driver know if it is ok to complete the pass or not. The map is not to scale so the driver must look at the distances. The driver can view the distances of lead and rear objects by viewing the clearance text boxes on the main console, as shown in Figure 19. Side distances are not provided since the driver must execute a pass in a separate lane.

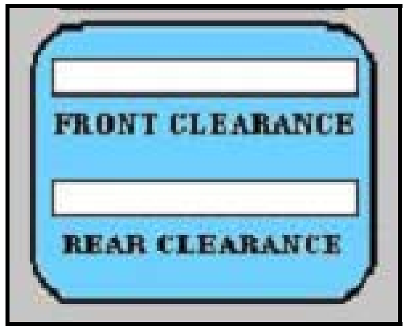

Figure 19. Front and Rear Clearances.

The distances detected from the sensors will be displayed in the text boxes. If the situation arises where more than one vehicle is being passed (a vehicle on the right and left), then each detected object would have to be uniquely identified. Multiple object detection and processing are ideal topics for future research.

C. DESIGN CONSIDERATIONS

AVAILS represents a software application that consists of three hardware components, the main console and the sensor nodes and their interconnecting transmission media. Memory requirements, as well as a capable operating system, must be sufficient in order to perform data sensor fusion.

1. Assumptions and Dependencies

There are a few assumptions made concerning the driver, the presumed user of AVAILS. We assume that the driver has, at the very least, a high school education and has limited exposure to in-vehicle computer applications. We also assume that the host vehicle will power AVAILS. We also assume that existing military motor pool personnel and contractors can instrument the vehicles with the AVAILS system.

2. General Constraints

We designed the prototype of the AVAILS-HCI in the Java programming language. The main console can only function inside the operator compartment with an ample power supply. AVAILS was not designed to run absent a host vehicle. AVAILS is not currently interoperable with any other software applications.

3. Goals and Guidelines

The main goal of this thesis was to produce a generic HCI and demonstrate the functionality of the main display and sub-menus options. The desired outcome is to have a functioning user interface that is simple, efficient, and one that promotes usability.

4. Development Methods

A typical software design approach was utilized to develop the AVAILS-HCI. That is to say that AVAILS was first conceptualized and modularized. Then system requirements were generated and subsequently coded. JAVA was chosen as the core programming language due to its simplicity, portability, and enhanced GUI capability.

VI. CONCLUSION

A. SUMMARY

The high-level requirements for AVAILS are as follows:

- Assist the driver to avoid crashes with other vehicles under nominal and adverse environmental conditions
- Provide for multiple operation modes, each of which corresponds to the current combination of the following: configuration of the vehicle, environmental conditions, and type of maneuver (e.g., lane change) or driving activity (i.e., low-speed docking versus convoy operation)

The high-level requirements for the AVAILS-HCI are as follows:

- Be designed to the needs of military personnel who operate military vehicles, all of which have the following characteristics: typical age of between nineteen and twenty-six, hold at a minimum a high-school diploma or equivalent, and receive training for operating military vehicles
- Permit the user of the HCI to input information about the configuration of the vehicle, environmental conditions, and type of maneuver or driving activity
- Provide for displaying collision-warning information and limited control actions (e.g., engine-braking with haptic feedback to the pedal that controls the throttle) without distracting the drivers attention from critical driving tasks

In this thesis we explored some of the ways in which a heads-up display (HUD) could be used to address the foregoing high-level requirements. We also compared the high-level requirements for AVAILS with the functionality provided by commercially available collision warning and collision avoidance systems. Lastly, we used the prototype of the AVAILS-HCI, implemented in the Java programming language, to explore some of the high-level design requirements for the AVAILS-HCI.

B. FUTURE WORK

There are many possible avenues for future research. In order to refine the high-level requirements for the HCI into detailed design specifications, the next step in the research should consist of an assessment of the human-performance requirements, followed by a task description and analysis.

The prototype of the AVAILS-HCI can be refined to correspond to the design specifications, and then integrated into a driving simulator for use in assessing design alternatives through experimentation. Such experiments, although they are conducted in a virtual environment with human subjects, could be used to obtain rough approximations of the effectiveness of the AVAILS-HCI in terms of safety, usability, and other measures of the effectiveness of the system. Much work remains to be done to determine what types of warnings should be provided to the driver and how these warnings should be presented (e.g., audible versus visual-based). Issues associated with missed false alarms and nuisance alarms need to be addressed in the context of the effectiveness of the system at preventing crashes.

The focus in this thesis is on the human-computer interface. However, now that some of the high-level requirements for AVAILS and its HCI are known, research needs to be conducted to determine the technical feasibility of supporting such requirements. For example, can present-day sensor (e.g., radar) technology or data-sensor-fusion algorithms support the requirements for AVAILS? The general rule in the US Department of Defense is that new systems should be implemented using commercial-off-the-shelf (COTS) components, or reusable components from legacy systems, whenever possible. Do the requirements for AVAILS require the development of new technology, or is it possible to reuse existing technology to meet the requirements?

As other types of intelligent transportation systems are introduced into military ground transportation vehicles, how will their introduction affect the requirements or redesign of AVAILS and its human-computer interface? For instance, will an onboard interactive navigation system distract the driver from paying attention to the information displayed by the AVAILS-HCI?

The requirements for AVAILS, as articulated in this thesis, are based on transportation laws, traffic regulations, and military doctrine, policy, and procedures. How might it be necessary to make changes to existing laws, regulations, doctrine, policy, and procedures in order to take full advantage of the functionality of AVAILS in mitigating the risk associated with crashes? In addition, what types of standards or guidelines would need to be put in place to ensure that the components comprising AVAILS, likely to be manufactured by more than one source, would be interoperable and meet minimum requirements for reliability and safety?

From the perspective of safety, there are many issues to be addressed. For example, should the driver be permitted to directly enter values for the various system parameters (e.g., current environmental conditions), should the system determine those settings itself, or should the system parameters be set via some combination of the preceding alternatives? If the user is kept in the loop for inputting data into the system, how might a safety-interlock be used to prevent users from initiating a mode in the system is not capable of functioning in a particular point in time? For example, when some of the sensors are not available due to the configuration of the vehicle or the malfunction of a sensor.

Although AVAILS, as it is described in this thesis, is in essence autonomous, it could be used as part of a cooperative system in which the data collected by AVAILS on one vehicle could be made available to upstream vehicles. For example, downstream vehicles could provide preview information to upstream vehicles about traffic conditions (e.g., the following distance and speed of vehicles, as a surrogate measure of traffic congestion) or other safety-related information (e.g., condition of the pavement, such as dry or wet).

APPENDIX A: AVAILS-HCI MODULES (CODE)

The following code represents the generic implementation of the AVAILS-HCI. Essentially, only the menus and sub-menus were activated. The sensor modules, involving the processing and translation of radar and sensor data were not implemented as they were beyond the scope of this thesis, which was to conceptualize the AVAILS-HCI. This implementation was used to construct the sub menu options and test the usability (e.g., look, feel, color) of the console for the user. Further code refinement and implementation are left for future work.

1. The MainDisplay file represents the main display on the AVAILS-HCI:

```
/**
 *  File: MainDisplay.java
 *  Harold M Mosley
 *  AVAILS Code - AVAILS- HCI
 *  Thesis Appendix
 *  September 20, 2001
 *  This file represents the main console display.  The file is only intended to
 *  test the look, feel, and usability of the AVAILS-HCI.  There are no validity
 *  check routines or sensor modules to simulate the input of radar data.  This file
 *  only represents the conceptual phase for the AVAILS-HCI.
 */
import java.io.*;
import java.net.*;
import java.awt.*;
import java.awt.event.*;
import javax.swing.*;

public class MainDisplay extends JFrame {
  //All necessary panel and buttons are created here
```

```java
private JPanel centerPanel, northPanel, southPanel, eastPanel, westPanel;
private JButton modeButton, settingsButton, clearanceButton,
            weatherSetButton, resetButton, onOffButton,
            logoButton, clearButton, textButton, notClearButton,
            centerButton;

//variables are declared here
private Color pb, np, ep;
private JTextField messageDisplay;
private JLabel label2, textLabel;
private boolean wasModeSelectedFirst;
boolean modeMenuVisible;
boolean settingsSubMenuVisible;
boolean modeSubMenuVisible;
boolean weatherSettingsVisible;

//constructor
public MainDisplay()
{
  super( "AVAILS Main Display" );
  Container c = getContentPane();

  //create instances of panels
  southPanel = new JPanel();
  centerPanel = new JPanel();
  northPanel = new JPanel();
  eastPanel = new JPanel();
  westPanel = new JPanel();

  //buttons in the west panel
  modeButton = new JButton( "MODE" );
  settingsButton = new JButton( "SETTINGS" );
  clearanceButton = new JButton( "Front/Rear Clearance" );
```

```
//buttons on the east panel
weatherSetButton = new JButton( "WEATHER SETTINGS" );
resetButton = new JButton( "RESET" );
onOffButton = new JButton( "ON / OFF" );

//buttons on the south panel
Icon clear = new ImageIcon( "clear.gif" );
clearButton = new JButton( clear );
clearButton.setHorizontalAlignment( SwingConstants.CENTER );
Icon notClear = new ImageIcon( "notClear.gif" );
notClearButton = new JButton( notClear );
notClearButton.setHorizontalAlignment( SwingConstants.CENTER );

//west panel construction
westPanel.setLayout( new GridLayout( 3,1 ));
westPanel.add( modeButton);
westPanel.add( settingsButton );
westPanel.add( clearanceButton );
c.add( westPanel, BorderLayout.WEST );

//west panel button handlers
modeButtonHandler modeHandler = new modeButtonHandler();
modeButton.addActionListener( modeHandler );
settingsButtonHandler settingsHandler = new settingsButtonHandler();
settingsButton.addActionListener( settingsHandler );
clearanceButtonHandler clearanceHandler = new clearanceButtonHandler();
clearanceButton.addActionListener( clearanceHandler );

/* *
 * This part displays the "AVAILS" logo on the top of the console.
 */
Icon logo = new ImageIcon( "top_logo3.gif" );
```

```
label2 = new JLabel();
label2.setIcon( logo );
label2.setHorizontalTextPosition( SwingConstants.CENTER );
northPanel.add( label2 );
c.add( northPanel, BorderLayout.NORTH );

//east panel construction
eastPanel.setLayout( new GridLayout( 3, 1 ) );
eastPanel.add( weatherSetButton );
eastPanel.add( resetButton );
eastPanel.add( onOffButton );
c.add( eastPanel, BorderLayout.EAST );

//east panel button handlers
weatherButtonHandler weatherSetHandler = new weatherButtonHandler();
weatherSetButton.addActionListener( weatherSetHandler );
resetButtonHandler resetHandler = new resetButtonHandler();
resetButton.addActionListener( resetHandler );
onOffButtonHandler onOffHandler = new onOffButtonHandler();
onOffButton.addActionListener( onOffHandler );

//the message box
textButton = new JButton( );
messageDisplay = new JTextField();
//messageDisplay.setEditable( false );
textButton.add( messageDisplay );
textButton.setHorizontalAlignment( SwingConstants.CENTER );

//south panel construction
southPanel.setLayout( new GridLayout( 1, 3 ) );
southPanel.add( clearButton );
southPanel.add( textButton );
southPanel.add( notClearButton );
```

```
    c.add( southPanel, BorderLayout.SOUTH );



    /**
     * This is the center piece of the console.  Currently, there is only a ".gif"
     * file shown on the display.  Ideally, this would involve some degree of graphics
     * simulation and represent the data obtained from the sensors and processed
     * accordingly.  Sensor coding was not including in this file and extends beyond the
     * current scope of this thesis which was to conceptualize the AVAILS-HCI.
     * /
    Icon mainmap = new ImageIcon( "mainmap.gif" );
    centerButton = new JButton( mainmap );
    clearButton.setHorizontalAlignment( SwingConstants.CENTER );
    centerPanel.add( centerButton );
    c.add( centerPanel, BorderLayout.CENTER );

    //boolean toggle values
    modeSubMenuVisible = false;
    settingsSubMenuVisible = false;
    modeMenuVisible = false;
    weatherSettingsVisible = false;


    //set panel size
    setSize( 650, 600 );
    show();
  }

  /**
   * The main method
   */
  public static void main( String args[] )
```

```
{
  MainDisplay app = new MainDisplay();

  app.addWindowListener(
    new WindowAdapter() {
      public void windowClosing( WindowEvent e )
      {
        System.exit( 0 );
      }
    }
  );
} //end of main

 /**
  * This button opens the mode sub menu
  */
 private class modeButtonHandler implements ActionListener {
   public void actionPerformed( ActionEvent e )
   {
     //wasModeSelectedFirst = false;
     ModeSubMenu msm = new ModeSubMenu();
     //msm.show();
     modeSubMenuVisible = !modeSubMenuVisible;
     msm.setVisible( modeSubMenuVisible );
     if (!modeSubMenuVisible)
     {
       getContentPane().repaint();
     }
   }
 } //end of buttonhandler

 /**
  * This button opens the settingssubmenu
```

```
 */
private class settingsButtonHandler implements ActionListener {
  public void actionPerformed( ActionEvent e )
  {
    SettingsSubMenu ssm = new SettingsSubMenu();
    //msm.show();
    settingsSubMenuVisible = !settingsSubMenuVisible;
    ssm.setVisible( settingsSubMenuVisible );
    if (!settingsSubMenuVisible)
    {
      getContentPane().repaint();
    }
  }
} //end of buttonhandler

/**
 * This button would display the front and rear clearances
 */
private class clearanceButtonHandler implements ActionListener {
  public void actionPerformed( ActionEvent e )
  {
    JOptionPane.showMessageDialog( null,
      "Button Pressed." );
  }
} //end of buttonhandler

/**
 * This button opens the weathersettings menu
 */
private class weatherButtonHandler implements ActionListener {
  public void actionPerformed( ActionEvent e )
  {
    WeatherSelection ws = new WeatherSelection();
```

```
        //msm.show();
        weatherSettingsVisible = !weatherSettingsVisible;
        ws.setVisible( weatherSettingsVisible );
        if (!weatherSettingsVisible)
        {
          getContentPane().repaint();
        }
      }
    } //end of buttonhandler

    /**
     * This button handler ideally would clear all prior settings
     */
    private class resetButtonHandler implements ActionListener {
      public void actionPerformed( ActionEvent e )
      {
        JOptionPane.showMessageDialog( null,
          "Options Cleared." );
      }
    } //end of buttonhandler

    /**
     * This button handler turns the system off.
     */
    private class onOffButtonHandler implements ActionListener {
      public void actionPerformed( ActionEvent e )
      {
       System.exit( 0 );
      }
    } //end of buttonhandler
}  // end of MainDisplay java
```

2. The Mode-Sub-Menu file allows the user to choose between the “Park” and “Travel” modes.

```
/**
 *  File: ModedSubMenu.java
 *  Harold M Mosley
 *  AVAILS Code - AVAILS- HCI
 *  Thesis Appendix
 *  Semptember 20, 2001
 *  This file presents the user with the mode sub menu, which list the "park" and
 *  "travel" modes to the user.  This is a generic implementation.
 */
import java.io.*;
import java.net.*;
import java.awt.*;
import java.awt.event.*;
import javax.swing.*;

public class ModeSubMenu extends JFrame {
  private JPanel centerPanel;
  private JButton parkButton, travelButton;
  private Color pb;
  private boolean parkModeWasSelected = false;
  private boolean travelModeWasSelected = false;

  //constructor
  public ModeSubMenu()
  {
    super( "Mode Sub-Menu" );
    Container c = getContentPane();

    //create panels
```

```
  centerPanel = new JPanel();

  //create buttons for the panel
  parkButton = new JButton("Parking");
  parkButton.setBackground( pb.yellow );
  travelButton = new JButton( "Traveling" );
  travelButton.setBackground( pb.yellow );

  //center panel layout
  centerPanel.add( parkButton );
  centerPanel.add( travelButton );
  centerPanel.setLayout( new GridLayout( 2,1 ));
  c.add( centerPanel, BorderLayout.CENTER );

  //create buttonhandlers
  parkButtonHandler parkModeHandler = new parkButtonHandler();
  parkButton.addActionListener( parkModeHandler );
  travelButtonHandler travelModeHandler = new travelButtonHandler();
  travelButton.addActionListener( travelModeHandler );

  //set panel size
  setSize( 180, 250 );
  show();
}// end constructor

/**
 * The main method was only used to independently test the compilation of this file
 */
 public static void main( String args[] )
 {
   ModeSubMenu app = new ModeSubMenu();
   app.addWindowListener(
     new WindowAdapter() {
```

```
        public void windowClosing( WindowEvent e )
        {
          System.exit( 0 );
        }
      }
    );
  } //end of main

 /**
  * This button handler sets the sensors to detect near objects.  The idea here
  * is to relay to the driver that he is in park mode.
  */
  private class parkButtonHandler implements ActionListener {
    public void actionPerformed( ActionEvent e )
    {
      JOptionPane.showMessageDialog( null,
        "All Sensors are set for near detection; .5 to 3 Feet.\n" +
          "You may now park!" );
      parkModeWasSelected = true;
    }
  } //end of parkButtonHandler

 /**
  * This button handler takes the user to the settings menus.  Once the travel
  * mode has been selected, the user must decide if they want default distances
  * or if they would like to enter their own distances.
  */
  private class travelButtonHandler implements ActionListener {
    public void actionPerformed( ActionEvent e )
    {


      JOptionPane.showMessageDialog( null,
        "You must now select an option from the [Settings] Button." );
```

```
            SettingsSubMenu setsm = new SettingsSubMenu();
            setsm.show();
            travelModeWasSelected = true;
        }
    } //end of travelButtonHandler
}  // end of ModeSubMenu.java
```

3. The SettingsSubMenu file allows the user to select either the “Default” or “User” options:

```
/**
 *  File: SettingsSubMenu.java
 *  Harold M Mosley
 *  AVAILS Code - AVAILS- HCI
 *  Thesis Appendix
 *  Semptember 20, 2001
 *  This file presents the user with the "user" and "default" settings options. It
 *  is here that the user can either use default settings or input their own distances.
 */
import java.io.*;
import java.net.*;
import java.awt.*;
import java.awt.event.*;
import javax.swing.*;

public class SettingsSubMenu extends JFrame {
  private JPanel centerPanel;
  private JButton defaultButton, userButton;
  private Color pb;

  //constructor
  public SettingsSubMenu()
  {
    super( "Settings Sub-Menu" );
    Container c = getContentPane();

    //create panels
    centerPanel = new JPanel();
```

```
    //create panels
    defaultButton = new JButton( "Default" );
    defaultButton.setBackground( pb.green );
    userButton = new JButton( "USER" );
    userButton.setBackground( pb.green );

    //center panel layout
    centerPanel.add( defaultButton );
    centerPanel.add( userButton );
    centerPanel.setLayout( new GridLayout( 2,1 ));
    c.add( centerPanel, BorderLayout.CENTER );

    //create buttonhandlers
    defaultButtonHandler defaultModeHandler = new defaultButtonHandler();
    defaultButton.addActionListener( defaultModeHandler );
    userButtonHandler userModeHandler = new userButtonHandler();
    userButton.addActionListener( userModeHandler );

    //set panel size
    setSize( 180, 250 );
    show();
  }// end constructor

  /**
   * The main method was used to independently test the compilation of this file
   */
   public static void main( String args[] )
   {
     SettingsSubMenu app = new SettingsSubMenu();
     app.addWindowListener(
       new WindowAdapter() {
         public void windowClosing( WindowEvent e )
         {
```

```
              System.exit( 0 );
            }
          }
        );
    } //end of main

   /**
    * This button handler implements the default option
    */
    private class defaultButtonHandler implements ActionListener {
      public void actionPerformed( ActionEvent e )
      {
        JOptionPane.showMessageDialog( null,
          "All weather settings will be set at default values.  Thank you." );
      }
    } //end of buttonhandler

   /**
    * This button handler implements the user option
    */
    private class userButtonHandler implements ActionListener {
      public void actionPerformed( ActionEvent e )
      {
        JOptionPane.showMessageDialog( null,
          "Please select the weather condition that you will\n" +
          "be driving in, from the Weather Settings Button." );
        WeatherSelection ws = new WeatherSelection();
        ws.show();
      }
    } //end of buttonhandler
}  // end SettingsSubMenu class
```

4. The Speed-Menu file lists the vehicle separation distances for the user.

```
/**
 *  File: SpeedMenu.java
 *  Harold M Mosley
 *  AVAILS Code - AVAILS- HCI
 *  Thesis Appendix
 *  Semptember 20, 2001
 *  This file merely lists the available speed limits
 */
import java.awt.*;
import java.awt.event.*;
import javax.swing.*;
import javax.swing.event.*;
public class SpeedMenu extends JFrame {
  private JList speedList;
  private Container c;
  private Color col;
  /*
   * The following speed limits are presented on a list for the user to select
   * appropriately the selected object would be used throughout the life time of the
   * current settings
   */
  private String speedLimits[] =
    { "30", "35", "40", "45", "50", "55", "60", "65",
     "70", "75", "80",  "85" };
  //constrcutor
  public SpeedMenu()
  {
    super( "Speed Limits" );
    c = getContentPane();
    c.setLayout( new FlowLayout() );
```

```
    speedList = new JList( speedLimits );
    speedList.setVisibleRowCount( 8 );
    speedList.setSelectionMode( ListSelectionModel.SINGLE_SELECTION );
    c.setBackground( col.darkGray );
    c.add( new JScrollPane( speedList ) );

    speedList.addListSelectionListener(
      new ListSelectionListener() {
        public void valueChanged( ListSelectionEvent e )
        {
          JOptionPane.showMessageDialog( null,
            "Thank you, safe driving!" );
        }
      }
    );
    setSize( 210, 200 );
    show();
  }// end constructor

  //This main section was used to independently test the implementatio of this file
  public static void main( String args[] )
  {
    SpeedMenu app = new SpeedMenu();
    app.addWindowListener(
      new WindowAdapter() {
        public void windowClosing( WindowEvent e )
        {
          System.exit( 0 );
        }
      }
    );
  }// end of main
}// end of SpeedMenu class
```

5. The Weather–Selection file allows the user to select the current weather condition under which they will be operating their vehicle. The code only represents a generic implementation of the weather selection list.

```
/**
 *  File: WeatherSelection.java
 *  Harold M Mosley
 *  AVAILS Code - AVAILS- HCI
 *  Thesis Appendix
 *  Semptember 20, 2001
 *
 *  This file only list the weather conditions that the user can select from the menu.
*/
import java.awt.*;
import java.awt.event.*;
import javax.swing.*;
import javax.swing.event.*;

public class WeatherSelection extends JFrame {
  private JList climateList;
  private Container c;
  private Color col;
  SpeedMenu sm = new SpeedMenu();
  MainDisplay md = new MainDisplay();

  //These are the current weather selections
  private String weaConditions[] ={ "Daytime", "Darkness", "Rain", "Fog", "Snow" };

  public WeatherSelection()
  {
    super( "Weather Settings" );
    c = getContentPane();
```

```
    c.setLayout( new FlowLayout() );
    climateList = new JList( weaConditions );
    climateList.setVisibleRowCount( 3 );
    climateList.setSelectionMode(ListSelectionModel.SINGLE_SELECTION );
    c.setBackground( col.orange );
    c.add( new JScrollPane( climateList ) );

    /*
     * The idea here is show the user confirmation that their selection was
     * indeed entered.  This is just a generic confirmation.  Actual imple
     * mentation would take the value selected and show the value to the user
    */
    climateList.addListSelectionListener(
      new ListSelectionListener() {
        public void valueChanged( ListSelectionEvent e )
        {
         JOptionPane.showMessageDialog( null,
         "Weather condition entered.\n" +
         "Now select your desired passing/trailing distance." );
         sm.show();
         md.repaint();
        }
      }
    );
    setSize( 250, 100 );
    show();
  } // end WeatherSelection constructor

  //This main section was used to independently test the implementatio of this file
  public static void main( String args[] )
  {
    WeatherSelection app = new WeatherSelection();
    app.addWindowListener(
```

```
      new WindowAdapter() {
        public void windowClosing( WindowEvent e )
        {
          System.exit( 0 );
        }
      }
    );
  }// end main
}//end of WeatherSelection class
```

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   sanftlebenka@tecom.usmc.mil

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   doranfv@mctssa.usmc.mil
   palanaj@mctssa.usmc.mil

7. Defense Logistics Studies Information Exchange..........1
   U.S. Army Logistics Management College
   Fort Lee, Virginia 23801-6043

8. Lieutenant Commander Christopher S. Eagle 1
   Naval Postgraduate School
   Monterey, CA 93943
   cseagle@nps.navy.mil

9. Prof. James Bret Michael……………………………………………………….....1
Naval Postgraduate School
Monterey, California 93943
bmichael@cs.nps.navy.mil

10. Prof. Rudolf Darken …………………………………………………………1
Naval Postgraduate School
Monterey, California 93943
darken@nps.navy.mil

11. Capt. Harold M. Mosley………………………………………………..…2
4503 Clyde Drive
Jacksonville, Florida 32208
hmosley@hotmail.com

12. Capt. Rodney L. Lewis………….……………………………………..1
501 Debby Lane
Adamsville, Alabama 35005

13. Dr. Steven Shladorer ……………………………………………………...1
University of California, Berkeley
ses@its.berkeley.edu

14. Mr. Jim Misener. ……………………………………………………………1
University of California, Berkeley
misener@path.berkeley.edu

15. Institute of Transportation Studies …...…………………………………...1
University of California, Berkeley
412 McLaughlin Hall
Berkeley, California 94720-1720