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AMAS JCTD OPERATIONAL DEMONSTRATION LESSONS LEARNED

Bernard Theisen
Edward Schoenherr
U.S. Army TARDEC
Warren, MI

David Simon
Tim Schulteis
Lockheed Martian
Littleton, CO

ABSTRACT

This paper will describe the operational demonstration that the Autonomous Mobility Appliqué System (AMAS) Joint Capability Technology Demonstration (JCTD) held to prove military utility of the system. First it provides a high level technical overview of the system to assist in understanding how the system and its subsystems work. The paper will then describe the demonstration and provide a summary of the results from the Military Utility Assessment (MUA).

INTRODUCTION

The Autonomous Mobility Appliqué System (AMAS) is a complete set of hardware and software designed from the ground up to provide a low-cost, low-risk, modular kit-based solution to retrofit autonomy capabilities onto any vehicle in the fleet. With the use of these autonomy capabilities, vehicular accidents will be reduced if not eliminated, saving lives and reducing injuries, loss of materiel, and missed opportunity costs. Additionally, as the Warfighter is relieved of the continuous driving task at higher levels of autonomy, their expertise can be applied to other tasks.

The AMAS Joint Capability Technology Demonstration (JCTD) program validated the vehicle-agnostic kit design by equipping tactical wheeled vehicle (TWV) platform types with the kits, and conducting two Technical Demonstrations (TDs) and an Operational Demonstration (OD) over the two-year duration of the JCTD program. The JCTD program serves as a risk-reduction activity for the Automated Convoy Operations (ACO) program of record (PoR). The United States (US) Army Tank Automotive Research, Development and Engineering Center (TARDEC) is the acquiring agency and technical manager for the JCTD. As a joint program, the end users will be Warfighters from the US Army and Marines Corps. Figure 1, illustrates the AMAS kit paradigm and the progression of the JCTD program.

As shown in Figure 1, the AMAS JCTD kit paradigm includes development of the By Wire Active Safety Kit (BWASK) and Autonomy Kit, equipping a number of tactical vehicles with the kits for modernization and equipping the fleet with autonomy capabilities. During the Operational Demonstration (OD), in which Warfighters from the US Army and Marine Corps operated the system, a Military User Assessment (MUA) was conducted. The AMAS will eventually encompass a number of add-on expansion payload kits that enable the system to implement a variety of mission profiles.

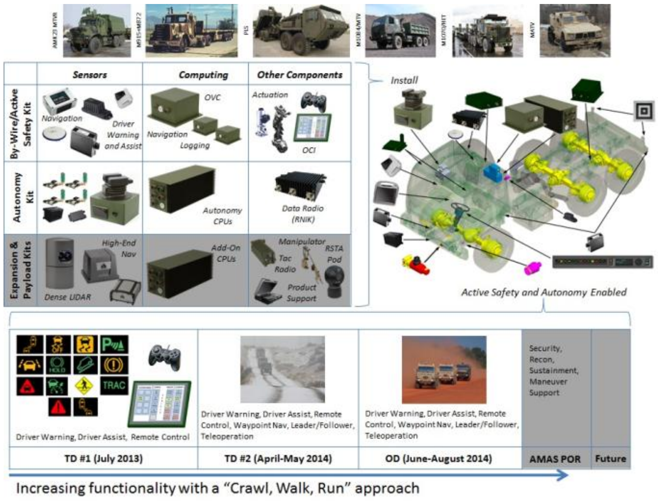

Figure 1: AMAS System Overview.

The BWASK is composed of automotive commercial off the self (COTS) driver warning and driver assist devices, navigation sensors, control actuators, a control computer, data logging, and dashboard operator control interface (DOCI) devices. When installed on a vehicle, the BWASK permits control of all primary vehicle controls (steering, throttle, brake, transmission), provides feedback and control of platform components (e.g., readout of engine temperature, turn headlights on, etc.), and provides active and passive safety mechanisms to the driver to aid the driving task and increase safety.

The Autonomy Kit is composed of low cost perception sensors, a suite of computers for processing sensor data for implementing high level autonomy behaviors, data logging, and a data radio for communicating with other assets. When installed on a vehicle with the BWASK installed, the Kit transforms the vehicle into a robotic asset that is able to perform various mission profiles autonomously or semi-autonomously.

BWASK MODES

The BWASK Modes include the following:

Manual Driver (MD) Mode – The primary function of MD Mode is to record vehicle data with the AMAS system in a non-emissive and non-actuating state. During this mode, all emissive sensors are powered down and no Driver Warning or Driver Assist functionality is available to the operator except for Electronic Stability Control (ESC) that is inherent in vehicle actuation upgrades and is independent of mode. Note: ESC was not demonstrated during the OD.

Driver Warning (DW) Mode – This mode provides audible and visual warnings to the driver. The following functions are part of the Driver Warning Mode: Backup Warning, Cross Traffic Warning, Forward Collision Warning, Blind Spot Warning, Lane Departure Warning, Pedestrian Detection Warning, Slick Surface Warning, and Automatic Wiper Assist. Note: the Automatic Wiper Assist is the only Driver Warning Mode functionality which allows actuation (it actuates the windshield wipers).

Driver Assist (DA) Mode – This mode provides audible and visual warnings to the driver along with automated actuation commands to the vehicle to assist with vehicle control. The following functions are part of the Driver Assist Mode: Backup Assist, Cross Traffic Assist, Collision Mitigation Braking Assist, Lane Change Assist, Lane Keeping Assist, Adaptive Cruise Control Assist, Automatic Wiper Assist, Emergency Brake Assist, Hill Descent Assist, and Hill Hold Assist.

Tethered Remote Control (TRC) Mode – This mode provides manual control of vehicle ignition, steering, braking, and throttle with a COTS gamepad controller.

AUTONOMY KIT MODES

The Autonomy Kit Modes include the following:

Wireless Remote Control (WRC) Mode – This mode provides the capability for personnel to use one AMAS system to remotely and wirelessly control the actuation of another AMAS vehicle. This mode does not provide video to the remote AMAS station, requiring the operator to have a line of sight to the vehicle in order to control the remote vehicle.

Teleoperation (TO) Mode – This mode provides the capability for personnel to use one AMAS system to remotely and wirelessly control the actuation of another AMAS vehicle. Teleoperation mode provides video to the remote AMAS station, allowing the operator to control the remote vehicle without a line of sight.

Waypoint (WP) Mode – This mode provides the capability for an AMAS vehicle to follow a path of pre-defined GPS waypoints.

Leader / Follower (LF) Mode – This mode provides the capability for an AMAS vehicle to lead other autonomous follower vehicles, and/or to become an autonomous follower behind another AMAS vehicle.

This paper will now focus on the OD conducted and the resulting MUA. A short description of the OD will be followed by evaluation methodologies and findings, and will conclude with the lessons learned in preparation for future Operational Demonstrations and improvements for obtaining data that is more readily usable by the developer, requirements and acquisition communities. A summary of the prior program Technical Demonstrations can be found in Appendix A.

Figure 2: AMAS JCTD Team.

OPERATIONAL DEMONSTRATION DESCRIPTION

The AMAS JCTD OD was conducted at Savannah River Site (SRS), Aiken, South Carolina (SC), from 28 July to 27 August 2014. In the OD, Soldiers and Marines operated the AMAS JCTD equipped vehicles (Figure 2) in a series of vignettes developed to present all of the AMAS modes and functions in operationally realistic scenarios to allow the test conductors to gather data for an MUA.

OD participants consisted of nine US Army Soldiers from 101st Airborne Division and the 3rd Infantry Division and three US Marines from the II Marine Expeditionary Unit. Users had military specialties aligned with the anticipated users of AMAS. The participants provided demographic information on their background and levels of experience. Each participant completed their assigned tasks based on the operational scenarios and gave subjective feedback via end of day debriefs, questionnaires, and interviews.

The Naval Facilities (NAVFAC) Engineering and Expeditionary Warfare Center, Systems Experimentation Division (SED) executed the OD to determine the military utility of the AMAS JCTD and to demonstrate the maturity of the integrated off-the-shelf BWASK and A-Kit technologies on six vehicle variants. The following modes of the system were assessed: Manual Driver (MD), Driver Warning (DW), Driver Assist (DA), Tethered Remote Control (TRC), Tele-operation (TO), Waypoint Navigation (WP) and Leader/Follower (LF).

The Operational Demonstration consisted of a series of vignettes designed to capture each of the modes of operation. The vignettes were designed through collaboration between the SED, US Army Combined Arms Support Command (CASCOM), US Marnie Corps Warfighting Laboratory (MCWL) and US Central Command (CENTCOM) and modified to fit the terrain and operational constraints imposed by Savanah River Site and US Army Test and Evaluation Command (ATEC). The vignettes were put together into missions which were briefed to the Convoy Commander, who directed the Soldiers and Marines to accomplish the mission.

Each mission was run several times and varied to encounter threats that increased from peacetime humanitarian, semi-permissive humanitarian, up to non-permissive/combat environments.

In addition to Warfighter testing additional cyber security testing was performed by the Army Research Lab (ARL) Unique Mission Cell Joint Vulnerability Assessment Branch (JVAB). Overall, the system proved resilient to radiofrequency, optical and computer network attacks. Several of the initial potential vulnerabilities were changed to lower levels from a previous assessment.

EVALUATION METRICS AND METHODOLOGIES

The MUA team developed three key metrics or Critical Operational Issues (COI) and sixteen objectives to assess whether AMAS improved the effectiveness of convoy operations, is operationally suitable and supportable, and is interoperable across convoy tactical vehicles.

Figure 3: Warfighter Survey System.

Both objective and subjective data was collected on a daily basis and data collection forms were completed for each mission or primary mode being executed during the mission. Electronic files were copied to electronic storage media and archived for analysis. Subjective questionnaires were administered at the end of each assessment event to obtain user feedback on AMAS capabilities. A web-based tool (Figure 3) was used to collect user comments on a daily basis. During the OD, the Task Lead ensured data collection requirements were met and identified any shortfalls to the Operational Manager (OM).

OPERATIONAL DEMONSTRATION FINDINGS

The Critical Operational Issues were given green, yellow and red ratings corresponding to demonstrated military utility, demonstrated limited utility, and demonstrated no military utility respectively. Each of the Objectives supporting the COI were rated individually and corresponded to the overall rating of the COI in question. There were no objectives that were scored red. All of the objectives for the COI, “Does the system improve effectiveness of convoy operations,” were yellow and require additional development. All but two of the objectives for the COI, “Is AMAS operationally suitable and supportable,” were green. The two yellow were on reliability, which is to be expected given the prototype nature of the JCTD, and on training which will be discussed further in lessons learned. All objectives for the COI, “Is AMAS interoperable across vehicles,” were green.

US CENTCOM recommends that the US Army and US Marine Corps develop supporting Concept of Operations (CONOPS), facilitate the proposed transition of AMAS JCTD to the associated PORs and continue development and integration of this technology. Based on this recommendation US Army Training and Doctrine Command (TRADOC) Capabilities Manager – Transportation (TCM-T) has begun working on a Leader Follower Capability Production Document (CPD) and TARDEC developed a follow on AMAS effort called Automated Ground Resupply (AGR).

DEVELOPMENT LESSONS LEARNED

The following lessons were learned during development:

- Data logging should be designed-in to capture data that supports objectives, support analysis and have real time verification methodology
- Human factors is given more importance than it should be given, so the system is judged by other than objective means
- Safety interlocks cannot make the system hard to use e.g. during tethered remote control
- Keep the level of rigor appropriate to the development cycle. The JCTD was R&D, but had to produce artifacts that supported transition, which limited R&D
- More vehicles proved to be more burden than benefit
- Spirals should be sacrosanct, say what you are going to develop for a given spiral, complete that development and do true system verification testing, roll findings into new spiral
- The CAD were appropriate responses to our stakeholders, but had a negative effect on the baseline system

Figure 4: CAD1 vehicle on Boaz MOUT Site.

DEMONSTRATION DESIGN LESSONS LEARNED

The following lesson were learned designing the demo:

- Pick your site early and understand the limitations both in environment and what is permissible
- Safety must sign off on the site and articulate the limitations the site will begin with
- Subjective reviews from the Soldiers and Marines are just that and must be understood in that context
- Don’t tell your subjects that the system they are evaluating is going to replace them
- Development and requirements should be structured against the objectives from the start

SUMMARY

The AMAS JCTD was successful to the letter of a JCTD, however the program utilized the JCTD to develop a product in some senses, which had varying consequences. Certainly the community walked away with the feeling that technology is at a place where it has promise to meet the needs of military. There are modes that can be transitioned now and would show savings in accident avoidance, reduced injuries, and increased through put. There are other modes where capabilities where shown that informed stakeholders of where we can go, but need further development.

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Appendix A

PRIOR PROGRAM DEMONSTRATIONS

Technical Demonstration I

Overall the Technical Demonstration I (TD1) demonstrated the ability to integrate a reliable actuation system on a variety of tactical vehicles, along with a number of COTS based driver warning and driver assist functions. The demonstrated ability to reliably control vehicle actuation and integrate COTS functions was shown to sufficient enough degree to be able to confidently continue the JCTD through integration on additional platform variants, and the incorporation of an Autonomy Kit.

Technical Demonstration II

The objective of the Technical Demonstration II (TD2) was to demonstrate the technical feasibility and maturity of the integrated BWASK and Autonomy Kit technology on six vehicle variants, and identify the system's current status, progress, and readiness in the development process.

Capabilities Advancement Demonstration I

The purpose of the AMAS Capabilities Advancement Demonstration I (CAD1) was to demonstrate the capabilities requested in the III Corps Operational Needs Statement (ONS) (Memorandum for Commander, US Army Forces Command (AFOP-CS), Operational Needs Statement for Tactical Wheeled Vehicle Operator Assist and Leader Follower Capability Appliqué System, July 3, 2012) and to inform senior US Army Training and Doctrine Command (TRADOC) leadership of the current robotic capability.

The CAD1 (Figure 4) was conducted at the Boaz Military Operations on Urban Terrain (MOUT) site in Fort Hood, TX. The site provided an operations building for the team in addition to roadways, obstacles, and structures for course operations, and facilitated the full range of testing of the CAD1 objectives. CAD1 vehicles had the opportunity to negotiate intersections, encounter live traffic, obstacles and pedestrians throughout the demonstration.

Capabilities Advancement Demonstration II

The purpose of the AMAS Capabilities Advancement Demonstration II (CAD2) was to demonstrate a line haul mission with more vehicles at higher speeds than CAD1with additional autonomy. CAD2 took advantage of the same road network at SRS used for TD2.

The AMAS CAD2 (Figure 5) successfully demonstrated a seven vehicle robotic convoy performing a line haul mission at 40 mph; further demonstrating capability objectives from the III Corps ONS.

Figure 5: CAD2 Convoy on Road B at SRS.

The CAD2 demonstration included an unmanned lead vehicle. To achieve this, an additional sensor, a Velodyne 64, was installed on the lead vehicle. This allowed the lead vehicle to map the environment to a higher fidelity than the TD2 equipped vehicles.

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