A ROBOTIC SYSTEM CONCEPT FOR PARTIALLY AUTOMATING THE SECOND ECHELON OPPOSING FORCE AT THE NATIONAL TRAINING CENTER

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ABSTRACT

The paper reports the results of feasibility study investigating the potential of applying robotics to partially automate the second echelon opposing force (OPFOR) at the National Training Center (NTC) at Fort Irwin, California. A general robotic system concept approach is developed in the context of a generic unmanned robotic vehicle model. Training Wheels, a particular implementation of the generic robotic system concept, is overviewed. The Training Wheels system concept consists of a command post,manned by 1 or 2 persons, for monitoring the movement of multiple vehicle company convoys composed of multiple unmanned vehicles following the path set by a lead vehicle manned by 2 persons. The concept appears to be technically feasible as it makes effective use of key operational constraints, operator personnel, and a supervised autonomous control schema for controlling the unmanned convoy vehicles.

INTRODUCTION

This paper reports the results of a recent study performed to determine the feasibility of applying unmanned vehicle technology (robotics) at the US Army's premier combined arms training facility, the National Training Center (NTC) at Ft. Irwin, CA. The goal of the effort was to effectively represent (via robotics) a Warsaw Pact style second echelon force with significantly fewer operator personnel.

Following the introductory section, the paper is organized in four sections. First, the background for and requirement for the study problem is discussed. Second, five unmanned vehicle technology concepts are introduced and a generic robotic system model is defined to provide a framework for the discussion of the Training Wheels concept in the next section. Here the Training Wheels concept is introduced/overviewed and characterized in terms of the generic robotic system model defined in the previous section. In the final section conclusions from the study are summarized.

BACKGROUND/REQUIREMENT

In January 1987, the Chief of Staff of the Army approved a plan to "ramp" to brigade operations at NTC. The plan called for a phased approach beginning with the evaluation of the brigade support "slice", allowing limited brigade operations with two maneuver battalions in the force-on-force engagement exercise.

Initially, the plan called for a third maneuver battalion, to be added eventually, to bring NTC up to "full" brigade operation. But, as a result of changing mission needs and costs constraints it was recently decided not to add a third heavy maneuver battalion. The need for additional OPFOR is still considered valid since the current OPFOR cannot portray doctrinal force ratios for some missions against the two battalion/task force brigade.

The senior Army leadership recognized that full BLUEFOR brigade operations would necessitate an increase in the size of the opposing force (OPFOR) from a motorized rifle regiment (MRR) to a motorized rifle Division (MRD) in order to maintain doctrinal force ratios. Figure 1 depicts how these units would be distributed on the NTC Battlefield in terms of the first and second echelon areas of operation. The direct approach for achieving the increase in the OPFOR, e.g. total replication of men and equipment was proposed and deemed to be unaffordable. As an alternative, it was decided to energize industry to look for technological solutions (e.g. artificial intelligence (AI), and robotics) that would allow the OPFOR to grow to an MRD without a linear increase in personnel and equipment.

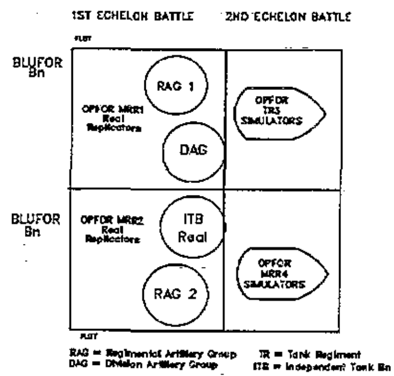

Figure 1. NTC Expansion Concept

Subsequently, in May 1987 a NTC Industry Day was held at Ft. Irwin. The following February (1988) PM TRADE issued a Broad Agency Announcement (BAA) seeking innovative technological solutions to several NTC specific problem areas. In the BAA, the OPFOR problem was characterized in terms of first and second echelon components which have distinctly different operational requirements, as summarized in Table 1, suggests two different technological approaches, i.e., manned vehicle/reduced crew technology (first echelon), and unmanned vehicle/robotic technology (second echelon).

First Echelon:	*Second Echelon:*
Overall veh/crew performance should not be either enhanced or degraded significantly.	Min manpower required (<1) man/vehicle.
	Convoy column mobility
Veh/crew must be capable of engaging multiple moving & stationary targets out to 3km.	Instantaneous path selection for real time responsiveness.
Veh/crew's ability to execute evasive maneuvers cannot be compromised.	Human presence in column req'd.
	Evasive maneuver capability: speed up & vary interveh space.
Role of tank cdr in selecting & prioritizing targets must be maintained.	Veh speed: 20-30 km/hr on rd. 10 km/hr max off rd
Safety cannot be compromised.	Inter veh spacing: 50-100 m variable.
	MILES detection capability.
	Interface convoy to CIS.

Table 1. Key OPFOR Operational Requirements/Constraints

In 1989, separate study contracts for first echelon (manned vehicle technology), and second echelon (unmanned vehicle technology) were awarded. The results of the first echelon feasibility study are described in (1), and (2) and will not be discussed further here.

The rest of this paper will provide an overview of the second echelon (unmanned vehicle technology) feasibility study performed by Alliant Techsystems.* A detail technical report (3) describing the Training Wheels concept is available to government agencies through the Defense Technical Information Center.

CONCEPT DEVELOPMENT

The second echelon robotic system concept developed (as will be seen in the next section) was guided by the five broad unmanned vehicle concepts highlighted in the 1988 NTC BAA and summarized in Table 2. Examination of Table 2 reveals all concepts have a "man" presence, some more and some less. In addition, all concepts result in systems that can be less manpower intensive than the "full" crew implementation.

(1) Autonomously operating vehicles occasionally monitored & controlled by mobile and/or fixed based operator and/or operator teams.

(2) One operator controlling at least a squad-sized element.

(3) One operator controlling at least a platoon-sized elements.

(4) A two-man operator team controlling squad and/or platoon-sized elements.

(5) A three or more man operator team controlling company sized elements.

Table 2. Unmanned Vehicle Concepts

The process of selecting a concept is iterative and involves always keeping the goal in view while considering the system issues summarized in Table 3, and the key second echelon requirements and constrained summarized in Table 1. Results from this analysis clearly leads to concept 5, "a three or more man operator team controlling company sized elements", in Table 2.

This concept can be characterized at some high level of abstraction as a system composed of three major subsystems, i.e., manned and unmanned subsystems connected by a communication link, see figure 2. The components of the model are briefly described next.

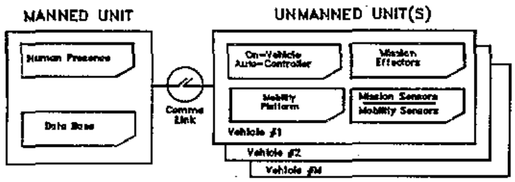

Figure 2. Generic Unmanned Robotic Vehicle System Model

ISSUES

o The number of unmanned vehicles to be controlled.

o Distribution of the Control Task (man vs machine).

o Intelligence/automation that can be cost effectively embedded on the unmanned vehicle.

o Type of training scenarios to be executed.

Table 3. System Issues

The major functions included in the unmanned subsystem are (1) on-vehicle auto-controller, (2) mobility and mission sensors, (3) mission effectors, and (4) mobility platform. These functions working collectively and in concert with "off" vehicle functions permit the unmanned vehicle to interact with and affect the environment to accomplish the mission. The manned subsystem is characterized by a manned presence and data bases to augment the man functions. The manned presence maybe distributed over both fixed and mobile platforms, and will in general form a command, supervise, and/or operate control schema of the unmanned subsystem(s). Communication between the manned and unmanned subsystems is essential. The characteristics of the link are a function of control schema, the operational environment, and the particular application. This model is quite general and provides a convenient tool for framing the discussion in the remainder of this section and the next section where the Training Wheels concept is introduced.

For the selected robotic system concept to be viable, it must support the efficient and effective execution of at least the key system functions shown in Table 4. These functions are discussed next in the context of the functional components of the generic robotic system model shown in Figure 2.

* In July 1989, the feasibility study contract was awarded to Honeywell Advanced Systems Center (prime) who teamed with Kaman Sciences Corporation (Sub). In October 1990, the Advanced Systems Center became part of Alliant Techsystems.

- o Command and Control
- o Maneuver
- o Execution of Mission Specific Functions

Table 4. Key System Functions

Command and control of the unmanned robotic vehicle system is effected through the on-vehicle auto-controller, mobility and mission sensors, and the reliable exchange of data between the unmanned and manned subsystems. Effective execution of this function is essential for safe and precise movement of the unmanned robotic vehicle, and operation of mission equipment.

Maneuvering the unmanned robotic vehicle is accomplished by the mobility platform responding to heading and speed commands from the on-vehicle auto-controller. The on-vehicle auto-controller receives guidance and instruction from the lead vehicle via the communication link. Safe and effective maneuvering of the unmanned robotic vehicle is affected by terrain, accurate position location, route planning and selection, and driving.

Execution of mission specific functions are effected through mission sensors, effectors, and the on-vehicle auto-controller all operating directly or indirectly on instructions from the human via the communication link.

The difficulty of performing these functions varies greatly across application domain. It is clear that there are at lease two keys to success, human presence, and the amount of autonomy obtained by the unmanned robotic vehicle. The OPFOR second echelon training application is an exemplar of this as we shall see in the next section.

TRAINING WHEELS CONCEPT

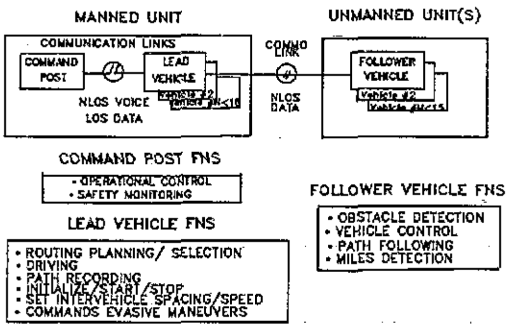

Figure 3. Training Wheels Concept

The Training Wheels system concept developed by Alliant Techsystems, see Figure 3 above, resulted from: a broad knowledge of robotics technology and its application; a understanding of how the NTC functions and the Army trains there; an understanding of the unique NTC environment; and a careful examination and understanding of the training and operational requirements. Specifically, the five key operational constraints, summarized in Table 5, were recognized and exploited to essentially "crack" the problem and lead to the potentially affordable and effective solution.

- o Very restricted operational domain.
- o Listed engagement requirement.
- o Restricted mobility (column formation, albeit, arbitrary paths).
- o Friendly RF environment (albeit restricted).
- o Obstacle detection for safety only, met navigation.

Table 5. Key Constraints

As can be inferred from Figure 3, the Training Wheel concept, is slight variation of the Concept presented in the last section. The three major subsystem structure remains with the following exceptions.

The Manned subsystem, characterized by a distributed man presence, consists of the three components: a command post (CP), manned by no more than two personnel, provides the command and control function. The CP will be physically located in the Core Instrumentation System (CIS) facility at NTC. The CP is connected to the lead vehicles through the second component, a global communication network which includes LOS data and NLOS voice links. The third component, the manned lead vehicle has, a crew of two, a driver and column operator. The driver selects the path and speed, and pilots the lead vehicle transmitting its path as series of way points over a local data network. The column operator monitors the unmanned follower vehicles status and controls intervehicle spacing.

The Unmanned subsystem consists of a unmanned follower vehicles which uses way points transmitted from the lead vehicle to navigate and execute accurate track-in-track vehicle following.* Since the follower vehicle accurately follows the path of the lead vehicle, only simple (relatively speaking) obstacle detection is needed.** The path is known to be clear except possibly for transient obstacles such as humans and animal crossing the column path after the lead vehicle passed. The obstacle detection system need only detect and report these types of problems to the column operator.

* In October 1990, USALABCOM's Team Program (Robotics) demonstrated an accurate (±18 inches) path retrace capability for a robotic vehicle at the AMC Technology show held at Aberdeen Proving Ground, Maryland.

**In June 1990, Alliant Techsystems demonstrated the viability of a obstacle detection system in a desert environment. Both vehicle and personnel type obstacles were tested.

Although there are hardware and software implementation issues remaining it seems reasonably to say the Training Wheels concept is capable of effectively executing the unmanned robotic vehicle essential functions discussed in the previous section. It achieves them through the innovative placement of operator personnel and the unique semi-autonomous vehicular navigation and control schema.

CONCLUSIONS

The Training Wheels concept appears to be technical feasible to accomplish the training mission envisioned at the NTC. The concept uses a form of supervised autonomy to control columns of 10 to 15 unmanned vehicles from a manned lead vehicle, thus achieving significant manpower reduction. This system performance relies upon several key operating constraints: very restricted operational domain; limited engagement requirement; restricted mobility (column formation); obstacle detection for safety not for navigation.

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SUGGESTED READING

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ACKNOWLEDGMENTS

The authors are indebted to the highly talented individuals, too numerous to list here, who composed the Government, Alliant Techsystems, Honeywell, and Kaman Sciences Technical teams performing on this effort. We especially want to acknowledge Vickie McDevitt, Sarah Gottschalk, Arlene Gregory and Aurelia Vallin for their collective contribution in typing the early drafts and final preparation of the paper for publication.

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Mr. Kraetz served as the principal investigator for the Training Wheels program with PM-TRADE to utilize robotic technology for the cost-effective insertion of a second echelon at the NTC.

With Alliant Techsystems (Honeywell) Ordnance Division for over 10 years, Mr. Kraetz is currently Technical Director of the Teleoperational Vehicles Area leading development efforts for reconnaissance and forward observation applications. He has been involved with numerous military systems in a lead engineer/technical director capacity, most notably the Howitzer Improvement Program (HIP), the Modular Azimuth Positioning System (MAPS), and as IR&D manager of Honeywell's Robotic Vehicle Test Bed program.

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