ROBOTICS: AUGMENTING THE SOLDIER?

ROBOTIC SYSTEMS WERE FOUND TO BE USEFUL for the future force concepts described throughout this book. In fact, bomb disposal robots, mine-clearing devices, tactical UAVs, and other simple, radio-controlled applications have emerged recently to take over more and more functions normally assigned to soldiers. The stumbling blocks to more sophisticated use of such robotic systems have included processing power, communications limitations, control time delays, myopic machine vision, and bulky components. Many of these problems have been resolved recently with breakthroughs in microchips, miniaturized sensors, automatic target recognition programs, GPS/INS navigation systems, and broadband communication links. DARPA and the services quickly recognized the opportunities with these innovations and have included robotic systems in all of their concepts for future forces. Some of these systems are intended to essentially replace the human operator in risky or difficult situations, while others extend the capabilities far beyond what a human can perform.

We should note that there are different characterizations or definitions of robotic systems, and that many of the concepts described in earlier chapters might be considered some form of robotics. Unattended ground sensors such as the ADAS acoustic array and seeded microsensors have many of the characteristics of robotic systems. They incorporate multispectral sensors, onboard processing, and coordination with other automated systems. They may even trigger actuators (fire weapons, change field of view, etc.), but they do not exhibit mobility, an aspect we include in our specialized definition of a robotic system. In a similar manner, automated planning and rehearsal systems perform difficult computational tasks and even provide extensive visualization of options, but they are not mobile.

UGVs and UAVs do have all the characteristics of robotic systems, and they operate in several different modes. They may operate under continuous supervision by human operators (much like radio-control systems), they may be semi-autonomous with occasional operator commands, or they may be fully autonomous, sent off to achieve objectives without supervision. Examples of the important, intermediate level of semi-autonomy are vehicle-following systems, low-speed self-driving vehicles with manual override, and unmanned ground and air vehicles with limited autopilot capability. It is expected that most military systems will have some degree of human control or overwatch.

Over the past seven years, DARPA has managed a significant military UGV program concentrating on partially or fully autonomous ground robotic vehicles. This pro-

Image provided by Lockheed-Martin.

Figure D.1—HMMWV-Based UGV Used in DARPA Demo II Program

gram has demonstrated a wide variety of new technologies and systems in a series of laboratory and field exercises. The initial series (Demos A, B, and C) focused on vehicular movement and coordination, demonstrating many technologies needed for operational UGV application: obstacle recognition and avoidance, information sharing, position location, path replication, and others. These exercises culminated in Demo II, conducted in June 1996.[1] This large-scale operational demonstration was executed as a Battle Lab Warfighting Experiment, or BLWE, and illustrated many new technologies. These included dynamic path planning (taking into account enemy positions and line of sight), cooperative navigation among multiple robotic HMMWVs, multispectral imaging (with IR, visual, and acoustic sensors), and automatic target recognition under both stationary and moving conditions. The work currently continues as Demo III, in which the HMMWVs have been replaced with smaller, more agile vehicles (see Seffer, 1998). Also, Demo III has changed the focus from one of replacing soldiers in hazardous tasks to one of taking over entirely new functions.

RAND's role in Demo II was to provide analytic support, assessing the military utility of UGVs using high-resolution force-on-force combat simulation. To accomplish this, several different missions and scenarios were explored, which generally paralleled the DARPA Demo II field exercises. We also attempted to determine the level of capability needed, beyond that demonstrated in the field, to achieve mission success.

Missions Explored

Three different missions were explored in Demo II: a deep attack mission, a reconnaissance/counter-reconnaissance mission, and a MOUT operation. These three missions were selected to exercise the full range of robotic activities, including sensing, hiding, maneuvering, and engaging the enemy. The deep attack mission, for example, involved a HMMWV-based UGV acting in a largely autonomous mode, where it self-navigated to a location, conducted surveillance, acquired targets, and subsequently called for indirect fires (mortar volleys). A wide range of basic capabilities associated with a deep attack mission were demonstrated. In the test itself, though, the UGV was slow to get into position (making it vulnerable to enemy detection and fire), and it was equipped with a sensor too limited in range for this difficult task.

We used a deep attack scenario in our simulation to extend the results of this first mission in the BLWE. The scenario was similar to the East Europe, close-terrain one used for recent RFPI analyses. Recall from Chapter Two (see Figures 2.3 and 2.4) that there is a Red heavy division (–) attacking a tightly packed Blue defensive position with two light battalions from the 82nd DRB. There are advanced weapon systems in the Blue force: EFOG-M in most cases, 155 SADARM and HIMARS with Damocles in others. We made several excursions with UGVs (eight HMMWV-sized platforms) added to the force and placed well forward (some 10–15 kilometers from the main Blue force). Recall that in the original runs with this scenario reported in Chapter Three, Blue needed special reconnaissance assets to locate and engage the Red force successfully.

The second BLWE scenario, a recon/counter-recon mission, involved three UGVs coordinating in a series of probing operations, attempting to locate enemy forward elements and pass on information. This demonstrated that UGVs can potentially take the place of manned scouts in high-risk missions and save lives, but at the expense of own losses. In fact, two of the three were lost to enemy fire in the BLWE.

The simulation scenario for the recon/counter-recon scenario was developed especially for this project. As shown in Figure D.2, both Red and Blue are conducting a meeting engagement on rough, close terrain. Both forces send out recon elements to move to contact. The Red commander opts to break off two mechanized armor com-

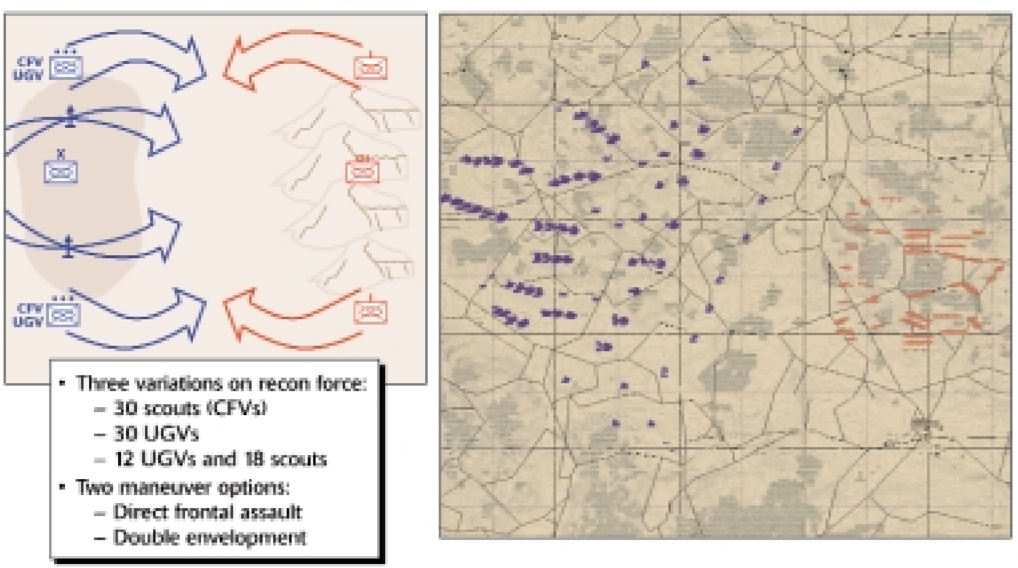


Figure D.2—Recon/Counter-Recon Scenario Emphasized UGV Maneuver panies from his regiment to conduct a recon mission. At the same time, the Blue commander has the same idea and breaks off two recon squads of cavalry fighting vehicles (CFVs) accompanied by helicopter air support. This recon mission attempts to flank the Red force and is seen as being very high risk. The excursions examine the potential benefits of replacing or complementing CFVs with UGVs.

The MOUT demonstration, finally, involved the use of different UGVs ranging from HMMWV-based ones for exterior surveillance to small tele-operated platforms for penetration into the town. It was evident that the current state of the technology was not up to the level of stealth or agility of a soldier, but the test showed that UGVs could nevertheless contribute well to situational awareness and tactical presence.

The MOUT simulation vignette (see Figure D.3) was adapted from an existing scenario based on a Sarajevo mission. Blue is escorting a resupply or humanitarian convoy of trucks through the downtown area. Blue leads with HMMWV scouts equipped with .50 caliber machine guns, and changes routes if an enemy ambush is spotted in time. Red has prepared an ambush partway through the town, with cratering charges along the road and infantry in the nearby buildings. Red waits until most of the convoy is in the killing zone and opens fire. Typically, the lead vehicles are hit and the convoy is halted. When Blue UGVs are present, they lead the convoy and periodically stop to scan the buildings and find Red units. These UGVs are presented with many problems specific to urban operations: fratricide issues, short lines of sight, need for agility, and so forth.

The field tests in Demo II served to demonstrate that UGV technology can assist in various missions, but it did not show what improvements might be needed to ensure op-

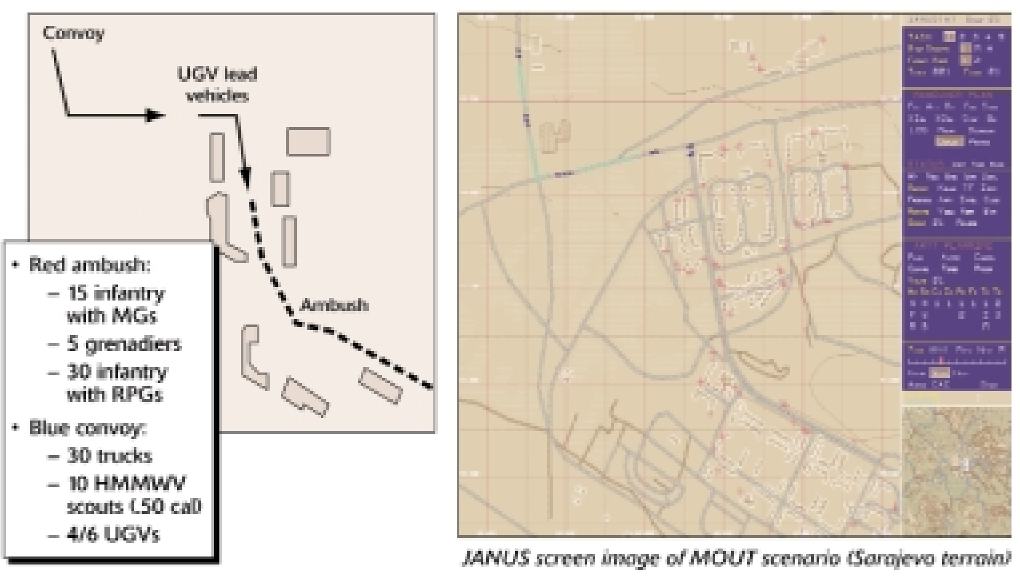


Figure D.3—MOUT Scenario Highlighted High-Risk "Pointman" Function erational utility. The intent of our work was to use simulation to extend Demo II scenarios to larger engagements, explore the effect of changing system characteristics and technologies, and provide some recommendations for further work. Specifically, we posed two key questions. First, can UGVs improve RSTA coverage and situational awareness? It was expected that UGVs, with similar sensor capabilities as manned systems, may be used more aggressively—with greater risk and potentially greater return. Second, can UGVs improve overall battle outcomes? Given that they offer added RSTA benefits, is this benefit meaningful and does it translate into greater force lethality, force survivability, or both? In particular, can UGVs save lives and, if so, at what cost?

As a last area of interest, we also asked "What might be some other ideas (besides those shown in Demo II) for exploiting UGVs on the battlefield?" To a large extent, we focused on possible applications in which the UGVs augment or complement manned systems rather than replace them.

Research Findings

Can UGVs Increase Surveillance Coverage?

In general, we found that UGVs could be emplaced much deeper and provide more extensive coverage than manned sensor systems. This was found in both the deep attack and recon/counter-recon missions. The sensing ranges in the MOUT scenario were so short that no range or coverage advantage was present with UGVs.

Figure D.4 shows cumulative "detection images" that accrue during the course of a simulated battle. The left image in the figure shows detections for the forward observer (FO)-only case (some detections are from EFOG-Ms also). The middle image shows detections with UGVs and FOs present, and the right image shows the extreme

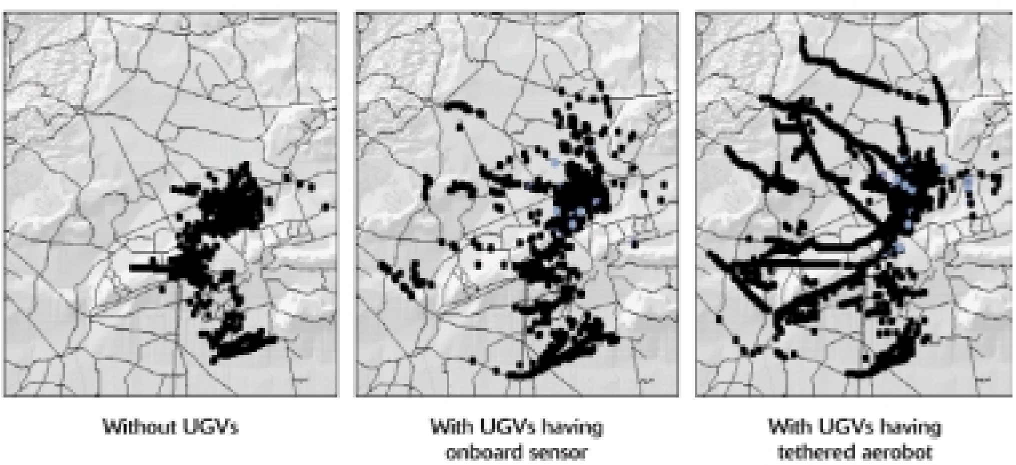


Figure D.4—UGVs Were Found to Greatly Increase Situational Awareness in Deep Attack Scenario case of UGVs with tethered aerobots (a sensor-carrying hovering device flying above the vehicle at the end of a power and data cable). As more RSTA assets are added, detections occur earlier and deeper and are more complete. Of course, the commander is not able to see the entire scene; even in the best case only a third or so of the enemy force is visible at any one time.

In the recon/counter-recon mission, UGVs provided a significant share of the total recon force detections. Because the terrain is very close and the scenario involves a considerable amount of movement, sensor height and range did not strongly influence performance. Instead, reduction in the UGV size turned out to be a more significant factor. By reducing the UGV to half its size, almost twice the number of detections occurred, mainly because the UGV was harder to detect and to kill. Even further size reduction improved the detections yet again.

Can UGVs Result in Improved Battle Outcomes?

Here we see how this added situational awareness and forward presence translates to battle outcomes. In the deep attack scenario, with UGVs out forward and FOs back, kills by EFOG-M increased by about 20 percent, overall Blue losses decreased by about 20 percent, and loss-exchange ratio increased by about 25 percent compared to the FO-only case. The dynamics of the battle change also. With UGVs calling in deeper fires than the FOs, more of the attrition takes place farther out, and the close, direct-fire battle becomes more manageable for Blue.

Sensor quality on the robotic systems had a profound effect on battle outcome, even though the UGVs were only a small part of the force in the deep attack scenario. As shown in Figure D.5, we considered a low-, moderate-, and high-quality sensor (cor-

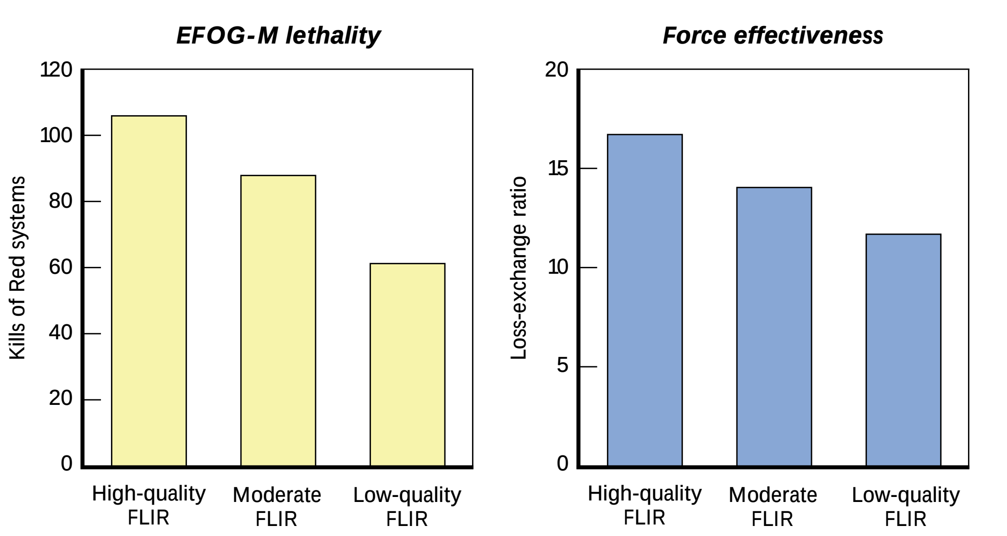
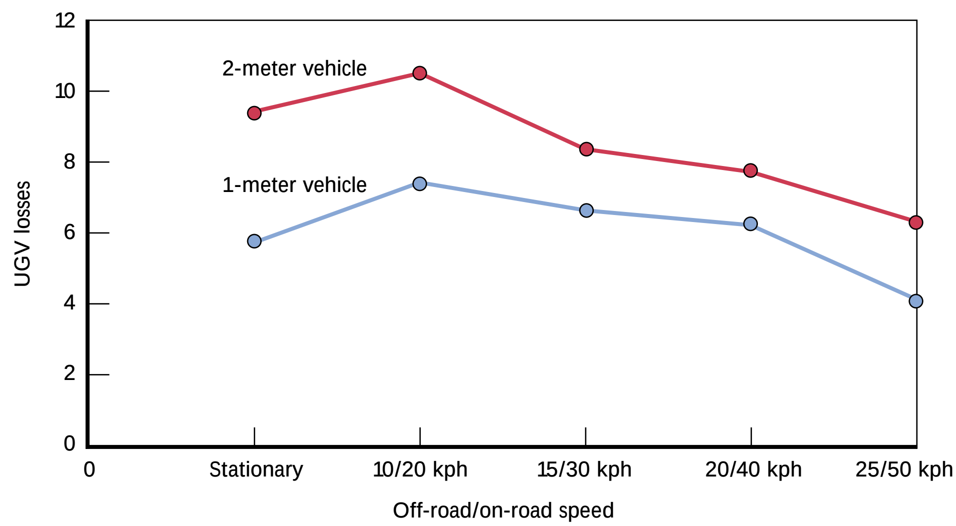


Figure D.5—Quality of Sensor Had Major Impact on Outcome of Deep Fires Scenario responding roughly to 2-, 4-, and 6-kilometer maximum detection ranges for tank-sized targets). Generally, as the sensor was improved, the number of target detections increased, which increased the number of calls for fire and ultimately allowed a larger volume of fires to be placed over deep targets.

To better understand the survivability issues, we next looked at the impact of speed and size on UGV survivability. As might be expected, the UGVs are better off in stationary, hide positions than when they are withdrawing slowly. Movements cue the enemy to the systems and draw fire. As the speed is increased to a level comparable to the speed of the attacking force, many of the UGVs are better able to maintain standoff (see Figure D.6).

In the recon/counter-recon mission, the impact of UGVs on saving lives was substantially different from that seen in the deep attack mission. When FOs are used here, they are generally dug in and bypassed, making them highly survivable. But as they are used more and more aggressively, for deeper coverage, they sustain more losses. And this is where the primary UGV benefit comes in. Because UGVs can reach farther out and be used more aggressively and with less reservation, they can extend the battlespace. Depending on the tactic taken with the FOs, UGVs can either save lives or improve battle outcomes in this scenario.

In this maneuver scenario, the UGVs' calls for indirect fire almost always took more time than the faster direct-fire weapons associated with the Red recon elements. Consequently, we explored the effect of adding a direct-fire weapon—mounted Javelins—to the UGVs with a very fast cycle time for response. The UGVs' overall survivability decreased because their firing signature resulted in much more return fire than against



NOTE: EFOG-M in force, moderate-quality FLIR on UGV.

Figure D.6—UGV Speed and Size Also Impacted UGV Survivability in Deep Fires Scenario unarmed UGVs, but their lethality increased dramatically. In fact, they produced far more kills than the accompanying manned CFVs. With armed UGVs, the overall LER rose 15 percent. Given that the recon portion of the battle is a small part of the overall battle, this is an impressive result. This initial exploration should be expanded to examine other weapons and tactics for lethal UGVs.

UGV speed had a moderate effect on mission outcomes in the recon/counter-recon scenario. At low speeds (characterized as 10 kilometers per hour off-road and 20 kilometers per hour on-road, with further reductions due to terrain slope), the UGVs were not able to keep up with the manned vehicles. They were also not able to get to the enemy artillery before it was able to fire several missions against Blue. As shown in Figure D.7, with faster speeds, UGVs have significantly lower losses and are able to kill rear area artillery much more effectively.

The recon/counter-recon mission most strongly showed the capability of UGVs to save lives. In this high-risk mission, savings were seen with both the frontal assault and the double envelopment tactics. In the frontal assault with only manned cavalry fighting vehicles (CFVs), over a third of these systems were lost. When these systems were replaced by UGVs, about the same number of UGV losses occurred, with the same overall performance. In the less risky recon mission (double envelopment), about 20 percent of the CFV losses were averted, again with similar overall battle performance.

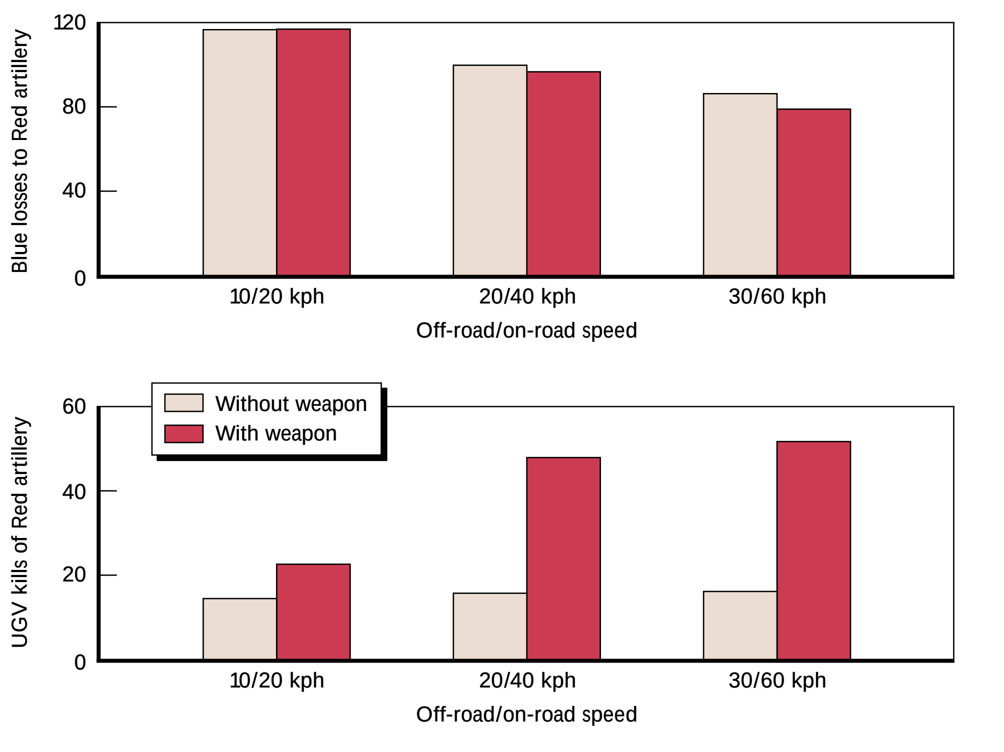


Figure D.7—In Recon/Counter-Recon Scenario, UGV Speed and Weapon Both Impact Outcomes

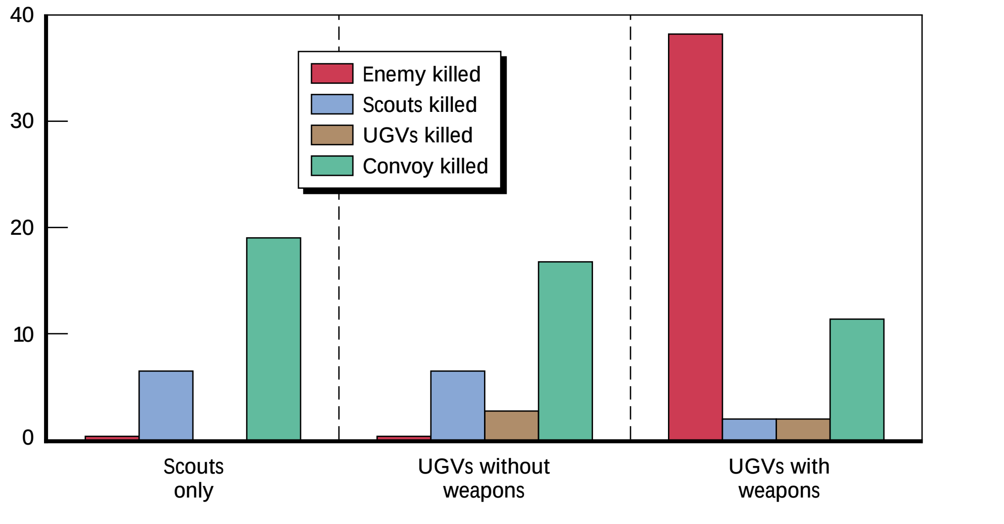


Figure D.8—MOUT Scenario Shows That Ambush Is More Survivable When UGVs Are Equipped with Weapons

The MOUT scenario illustrated two phenomena with the use of UGVs. The first is that unarmed UGVs in a convoy have the potential to dilute the losses of manned vehicles. This is seen in a comparison of the first two sets of columns in Figure D.8. With (manned) scouts only, few enemy are killed, and most of the scouts and convoy are lost. When unarmed UGVs are interspersed in the convoy, fewer elements of the convoy are lost, at the expense of the UGVs. The second phenomenon is that armed UGVs (.50 caliber machine guns) change the nature of the outcome: a large proportion of the enemy are killed, and fewer scouts, convoy vehicles, and UGVs are lost.

The MOUT scenario involved an intense, short-range engagement, with most detections and fires under a few hundred meters. Accordingly, most technology and packaging options for the UGVs had little effect. We did not run excursions in which the UGVs have greater protection against small-arms and/or missile fire. Such protection may add to the cost and bulk of the system, but could make the difference in a "pointman" situation.

Summary

It is apparent that robotic systems have great potential on the future battlefield, both for saving lives and for carrying out missions that manned systems cannot accomplish. They can strongly improve a force's situational awareness. They can also achieve stealth and endurance, and they can operate with impunity in the face of biological, chemical, electronic, and nuclear effects. They can even deliver nonlethal weapons without being affected. In all of the missions we examined, future robotic systems would make strong contributions to the force. Improvements over the levels of speed, range, and survivability are needed over the Demo II prototypes, but these should be achievable in the next few years.

The types of missions open to autonomous or semi-autonomous robotic vehicles are expanding rapidly. Some of the newer ones are deception and feigned attacks, NBC surveillance, logistics support and forward area resupply, obscurant dispensing, and physical security. All of these missions require some level of mobility, environmental sensing, onboard processing, and payload capacity. Many of these functions can be accomplished very simply, just by adding special components to existing robotic systems.[2] More specialized applications that require special platforms are also in development, such as the robotic crab, a lobster-sized device that can scuttle over the surf zone, clearing it of mines and obstacles (see Cooper, 1995).

Microelectromechanical (MEMS) systems provide some revolutionary opportunities for robotic systems. Robotic vehicles (UAVs and UGVs) can seed centimeter-sized microsensors over the battlefield and interrogate them periodically. The robotic systems may communicate with the sensors using radio signals or a technique such as bouncing back laser signals from modulated corner reflectors (see Brendley and Steeb, 1993). The MEMS devices themselves can act as electronic disablers, be mounted as backpacks on insects (biobots), or (when loaded onto microaircraft) fly in restricted areas such as though buildings, across rooms, and even in tunnels.[3]

At the same time, there are limitations to robotic capabilities. Countermeasures may be more effective against these systems than against manned vehicles. If the robotic systems are of the type that must be continuously supervised, the communications may be detected, or the control commands and information feedback may be jammed or spoofed. If the systems are more autonomous, the limitations of automatic target recognition (ATR) may become evident if the enemy uses decoys and deception. Most robotic systems will also probably be slower than their equivalent manned systems, at least for the near future, and may thus be in exposed positions for longer periods.

All of these opportunities and shortcomings need to be examined using simulations, prototypes, field tests, and exercises. And the evaluation criteria are different for manned and unmanned systems. For example, it is not enough that an unmanned system be faster, more survivable, or more lethal than the equivalent manned system. It may not even be enough to provide a completely new function that a warfighter cannot do. Robotic systems have to work synergistically with the soldiers and show an improvement in overall battle outcome (they cannot be too costly or burdensome for the advantage they are providing), they must be robust against easy countermeasures, and they must operate under different rules than manned systems. This last point is exemplified by situations where some level of fratricide by human soldiers may be unavoidable and even acceptable, but the same loss of life caused by a robot is catastrophic. The use of microaircraft, miniature robots, and biobots to gather information may be an unacceptable invasion of privacy in any conflict short of mid- to high-intensity war. Finally, the recent images of Iraqi soldiers surrendering to a UAV in the Gulf War let us know that completely new cultural ground will be broken as robotic systems take over more of the fight.

APPENDIX D ENDNOTES

1 Gage (1995) ably summarizes this and other DARPA- and OSD-sponsored efforts. Further information and images are available at the Demo II Web site, *http://www.cis.saic.com/previous/demoII/demoII.html*. (Web site accessed and running on July 28, 2000.)

2 See *http://www.nosc.mil/robots/images/* for images of UGVs in development. (Web site accessed and running on July 28, 2000.)

3 Radio-controlled aircraft as small as 59 grams have been flown, as described on the Web at *http://www.ezonemag.com*. (Web site accessed and running on July 28, 2000.) Estimates of near-term microflight aircraft weights have dropped down to as low as 5 grams, including video camera, power supply, aircraft controller, motor, and communications system.