Mini-UAVs for Convoy Protection

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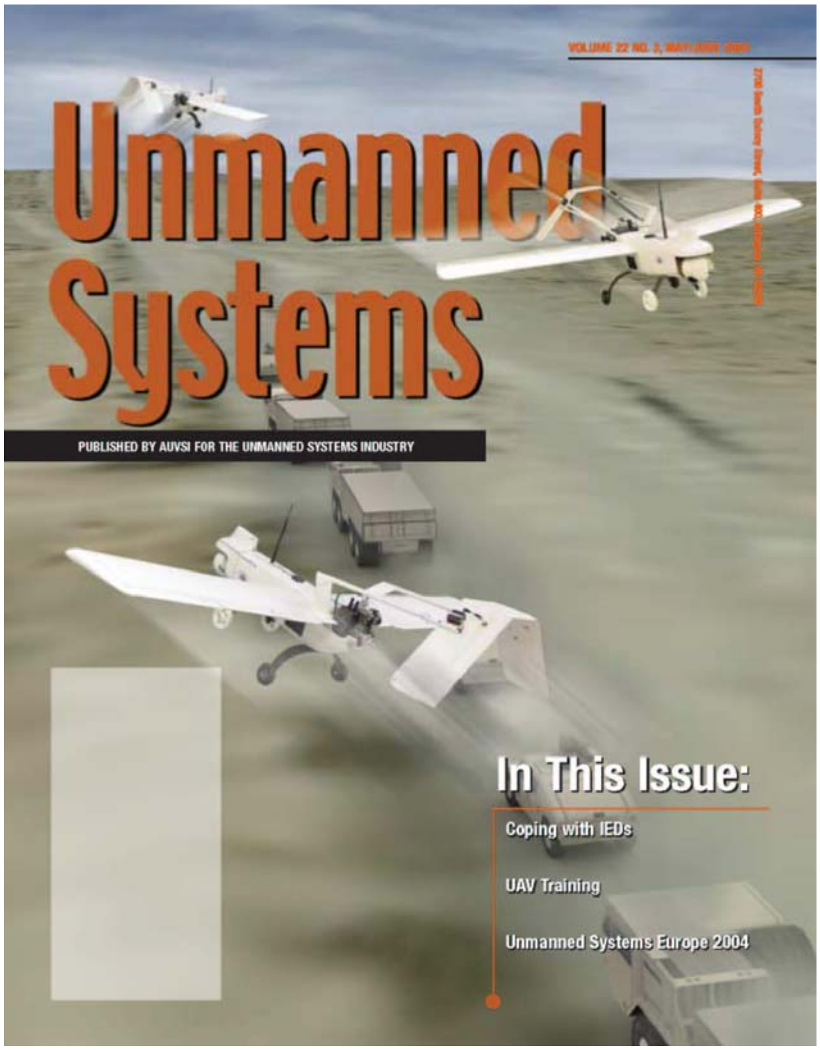

MLB Bat Mini-UAVs help protect a convoy

A U.S Marine is killed and two others are wounded in an attack on their re-supply convoy traveling east of the Iraqi town of Falluja, a U.S. military spokesman said. Insurgents detonated a crude bomb close to the truck convoy before pouring rocket-propelled grenades and small arms fire on those who survived the bombing.

The news stories are now all too familiar – American ground troops killed during convoy or patrol operations due to mortar attack, small arms fire, and detonation of rocket propelled grenades and roadside improvised explosive devices (IEDs).

Hundreds of truck convoys are on the move every day in Iraq and the growing number of fatalities have not gone unnoticed at the Pentagon or in cities and towns across the nation.

Operational experiments conducted by MLB Company and others indicate that mini-UAVs can help protect the soldiers traveling the dangerous dusty roads of Iraq.

Three types of convoys require protection:

- Bulk transport. Up to one hundred large transport vehicles (semi trailers or their military equivalent) that may stretch a few miles in a lightly protected convoy at speeds from 50 to 65 mph.
- Unit convoys. Ten to twenty-five military logistics vehicles for brigade support (or five to twenty vehicles for battalion support) moving at 60 to 75 mph. These convoys are high-priority targets for the insurgents. Aerial and ground protection is sometimes available, but the primary defense mechanism for these convoys is speed.
- Special purpose convoys. Two to five non-tactical vehicles (often converted civilian SUVs) traveling at 85 to 90 mph act as fast couriers of personnel and materiel.

Typical routes for all three convoy types vary in length from thirty to three hundred miles, last from four to six hours between convoy stop times, and take place almost always during daylight hours and in sand-blown conditions. Speed is the best way of staying alive.

The interest in transforming standard operational procedures for protecting convoys has reached the highest command levels of the services, and formal doctrinal and organizational changes are being proposed.

Unmanned aerial vehicles (UAVs) are among the technologies being considered in these new operational scenarios. Detailed operational plans for UAVs in convoy protection are being formed through field trials.
The most publicized threat to convoys is roadside IEDs, and some form of IED plays a part in the majority of attacks. Sensors suitable for detection of IEDs, which can be very small **(see Figure 1**) and can be hidden in common local objects (e.g. brush, garbage, rock piles, culverts, animal carcasses), are not available.

UAVs may best contribute to convoy protection by maintaining a persistent presence over known areas of activity and detecting the enemy technicians when they are installing the device. As much of this activity is at night, adequate low-light and IR sensors for the task are required for the UAV platform.

Concepts of Operations

The biggest open question for UAV operations for convoy protection is that of ownership - are the UAV assets organic to the convoys, or are they managed by a centralized organization? This issue is being addressed by a variety of experiments underway throughout the U.S. armed services.

One of the lead advisors on this topic, Dr. Jeff Cerny, Advanced Systems /

Figure 1. Example roadside improvised explosive device

Army Missile Research and Development at Redstone Arsenal, says "We are working the question of how to deploy small UAVs through a combination of spiral development with industry and live field experiments of systems that are working today." The decision criteria are complicated, and it is likely that an array of UAV capabilities will be needed to address the variety of particular mission requirements.

For centralized operation, the UAV resources are controlled, operated, and maintained from a central location and their sensors are monitored at this location as well. Deployed UAV assets such as the AAI Shadow 200 tactical UAV and the Northrop Grumman Hunter UAV are able to carry out this task in the current environment. However, the day-to-day coverage of convoys by these existing UAV assets has been intermittent and of varying utility.

Two different applications are possible given a centralized operation – route surveillance and convoy escort.

For route protection, the primary use of UAVs is as a persistent patrol platform that covers as much of the route for as much time as possible. This is ideally conducted by multiple UAVs for a single route, working together to provide the most effective coverage. Depending on route size and UAV capability, this may be accomplished by sending UAVs along the entire routes, or by giving individual UAVs responsibility for certain Named Areas of Interest (NAIs) where they then loiter.

In the route protection role, existing UAVs appear to be most useful for detection of large groups of people, blocked routes, and significant changes in infrastructure (e.g. bridge closures). A persistent and visible UAV presence

UAV Operations Type	Positives	Negatives
Centralized	Concentration of interpretation capability Easier airspace deconfliction Straightforward repair and maintenance	Non-LOS communication required Longer information loop times Difficult coordination
Organic	Short communication ranges Real-time information loop times Coordinated directly by convoy	Limited interpretation capability Minimal airspace deconfliction Limited repair and maintenance

Table A. UAV Operations Types

may also be the best deterrent for IED installation.

The second application of centralized UAV operations is as a direct convoy escort. In this use, the convoy commanders must be in constant contact with the UAV operators. This requirement is a significant one, as current convoys have struggled to maintain uninterrupted communication for existing needs and are unlikely to get better equipment to make communication to a central base more reliable.

Consequently, the level of coordination between convoys and UAVs should not be expected to exceed the current levels possible for coordination with manned air assets. In addition, most non-line-of-sight communication uses satellite systems, and this bandwidth is scarce enough to make ubiquitous convoy protection via a centralized hub unlikely.

As shown in Table A, there are significant positives and negatives for centralizing operations. UAV control from a single point enables active airspace deconfliction, an issue that has the potential to greatly restrict all in-theater UAV operations. In addition, the necessary operational, maintenance and repair expertise and resources can be developed more aggressively due to dedicated personnel and facilities.

On the other hand, centralization will require UAVs that are capable of safe operation beyond the line of sight of their operators, which has a tendency to significantly increase the cost of operation. Centralization will also increase the total information loop time as sending centrally-controlled UAV data directly to the convoy is unlikely without tools to place the UAV data in context for proper situational awareness.

An alternative to centralized operation is organic convoy deployment of the UAV assets. Such a setup reverses the positives and negatives of centralized operations presented in **Table A**.

Two roles are apparent for organic deployments – convoy protective escort and convoy coordination aid. For protection, the UAV would fly out ahead of the convoy, providing a look ahead at the route before the convoy arrives. As potential attackers are likely to have spotters on the route, low signatures are not particularly important.

Figure 2. Bat on ground

Given the time constraints and current sensor processing ability, the UAV would be mostly useful for spotting obstructions, groups or people, or infrastructure changes. For any scenario in which video is sent directly to the convoy, the final product should include substantial hardware or software stabilization to minimize motion sickness for the sensor user.

The oft-overlooked role for organic UAVs is as an eye in the sky for the convoy commander to monitor the whereabouts and integrity of his convoy. Communications breakdowns and confusion during route reporting can undermine the convoy commander's situational awareness.

A UAV patrolling the convoy can aid the commander when en route and when under attack. Commanders must currently drive their vehicle among the convoy vehicles, sometimes turning back against the direction of travel, to get eyes on potential problems. An organic UAV could be directed to the problem faster and with less impact on the commander.

The value of short communication ranges, given the communications difficulties currently faced by convoys in Iraq, cannot be overstated. A UAV beaming data directly and only to the convoy can carry a smaller and simpler communications system than one required to use a satellite link. The direct connection also reduces the information loop delay time down to almost zero, but at the cost of requiring personnel in the convoy to do the data interpretation.

The UAV operator for a convoy is unlikely to be fully trained in airspace issues, so in the near term there will likely be a restriction on convoy UAV flight areas to reduce airspace confliction.

In the future, deployed forces should begin to think of convoys in three dimensions and recognize that a convoy may have a "little bird" over it at 500 or 1000 feet. The UAV can always be

Figure 3. Sample still imagery of IED area in the desert

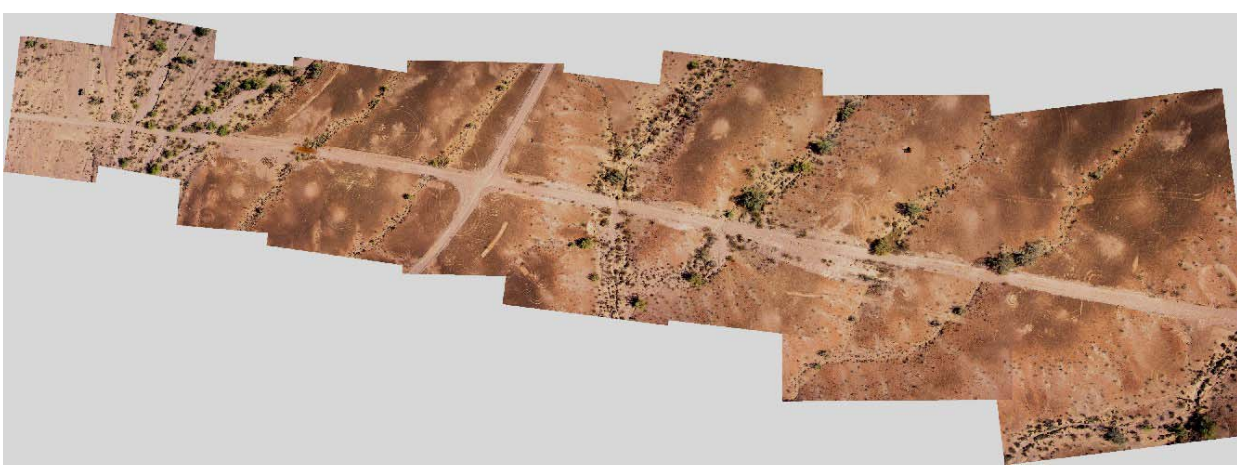

Figure 4. Mosaic of still images in a desert setting

Figure 5. The small footprint of the MLB Bat allows organic deployment

landed, crashed, or sent home if a serious airspace conflict arises.

As a final obstacle to organic convoy operation, someone in the convoy must be responsible for maintaining the UAV amongst a set of already lengthy equipment maintenance tasks.

Convoy Protection Experimentation

The MLB Company has been conducting experiments with a mini-UAV, the MLB Bat **(see Figure 2 and Table B)**, in a variety of convoy protection scenarios, concentrating on centralized route patrol and organic deployments.

The Bat is a small UAV with a six-foot wingspan, 15-pound takeoff weight, six-hour endurance, three-axis automatically aimed gimbaled video camera, and bungee-powered catapult.

A centralized real-time route protection capability is greatly simplified when an automatically aimed three-axis gimbaled camera is available. Otherwise, the operator task load is too high for too long for manual aiming and fixed cameras require a stabilization/ mosaicking software suite that cannot ensure complete data over the area of interest. In addition, the automatic aiming allows the operator to specify NAIs that the UAV can then spend extra dwell time on without requiring operator intervention each time it passes over.

An alternative to live video of the route is the collection of high-resolution still imagery **(see Figure 3)** that can be processed on the ground to look for potential hazards. A mosaic of the route created from these images **(see Figure 4)** can be provided to the convoy commander for planning.

Mini-UAVs like the MLB Bat have very small operational footprints even when compared to slightly larger "small UAVs" like the Shadow. Mini-UAVs do not require a runway for takeoff and only need a road or small field for recovery, yet can maintain extended flight times and a range of a couple hundred miles. These qualities allow the centralized operation to be moved to the battalion level if so desired.

Mini-UAVs thus compete with larger-class UAVs and manned aircraft to carry out the persistent route protection mission. The main benefit of mini-UAVs is their operational footprint and low cost, though they suffer from limited sensors due to payload constraints.

Mini-UAVs appear to be well suited for organic deployment due to their small ops footprint, low cost, and capable endurance and range. **Figure 5** shows the full extent of equipment necessary to operate the Bat from a convoy vehicle.

The UAV is launched from a convoy vehicle and is commanded to loiter about a GPS point sent up by the UAV command vehicle. This point moves at some distance ahead of the convoy on its route to provide an early warning of trouble ahead (e.g. 30 seconds warning at 60 km/h = 500 meters in front). The calculation of this point may vary in complexity from an analysis of the entire route beforehand to simply slaving the UAV to the motions of a convoy vehicle.

Figure 6. View of convoy vehicle from automatically aimed video

Figure 6 shows a video capture from the airplane while automatically looking at a convoy vehicle.

Most mini-UAVs can be re-tasked at any point during their flight, and a UAV operator within the convoy would be able to alter the UAV mission to achieve the best information. Video from the UAV can be sent to any number of vehicles in the convoy as in-vehicle resources permit.

MLB has demonstrated a "zero operator" mode of convoy protection in which the Bat mini-UAV is put in an autonomous flight mode that coordinates UAV motion and camera aiming with convoy movement. The aircraft flies at a specified lead and offset distance from the convoy commander’s vehicle location and automatically alters its flight path to an appropriate loiter trajectory when the convoy is moving slower than the UAV's stall speed. A 3-axis gimbaled camera system with EO and IR sensors is automatically steered to the specified aim point by the UAV's flight computer throughout the entire mission, thus eliminating the need for a fulltime sensor operator. The UAV focus point is then controlled by the convoy commander’s vehicle direction and velocity, effectively making the ground vehicle's steering wheel the UAV operator interface. From launch through landing, the UAV requires no input from the operator and thus achieves a large amount of utility in a fully autonomous manner.

A dial or keypad could be added to change the offset distance while the UAV is in flight without requiring a full operator control station. The experiments to this point have proven very successful, with significant increases in ease of use and situational awareness for the convoy commander.

What’s next?

Pending further experimentation with organic deployments, centralized operations are likely to be the norm for UAVs in the field. The route patrol mission, rather than close support of individual convoys, appears to be the best fit for current UAV capabilities.

Mini-UAVs will be a part of this mix, though they will have to find their place among the larger UAV platforms and manned aircraft. Organic deployments are a new paradigm for UAV operations in convoy operations, and more proof of the concept will be required before they are sent into the field.

The low cost of mini-UAVs and potential for ubiquitous coverage makes this paradigm attractive, but requirements for low maintenance, very low operator involvement, and safe launch/recovery operations must all be addressed. The goal for all systems is to make the convoy personnel feel safer and be safer.

According to Dr. Cerny, the Army is working the problem to close the gap between possibilities and capabilities: "Small UAVs have great potential to provide an eye in the sky over our transportation lines with reliability and persistence in a small footprint and at a cost that is acceptable. We are beginning to experiment to determine the best method of employment."

A draft Operational Requirements Document (ORD) would be the next step, but that is months if not years away.

For the troops on the road, fielding of mini-UAVs designed to locate and neutralize IEDs and other roadside threats would be a welcome sight indeed.

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To learn more about the Bat mini-UAV, go to www.spyplanes.com

Powerplant	1.2 cubic inch (23cc) 2-stroke engine
Fuel	Gasoline & oil mixture; diesel, JP-8, JP-5, and Jet-A fuels also possible
Wingspan	72 inches
Gross weight	15.0 lbs (maximum)
Payload	4.0 lbs
Speed	25 to 60 mph
Duration	2.5 hours (nominal); 6 hours (maximum)
Altitude	9000 feet (maximum operating)
Range	7.0 mile radius (telemetry limited); 180 mile fuel range
Sensors	Color CCD video camera with 45 deg FOV. Three-axis stabilized gimbal mount with 17 deg and 45 deg FOV color cameras. IR video and still cameras available.
Data Link	72 MHz uplink, 2.4 GHz downlink for video and 1200 baud flight data, 800 mw video transmit power.
Launch	Autonomous launch using bungee-powered catapult
Recovery	Automatic return-to-base with autonomous GPS landing on wheels
Guidance	GPS waypoint navigation using MLB flight controller with IMU. Aircraft operates autonomously from launch through landing. Waypoint changes can be made when aircraft is in telemetry range.
Ground Station	Video receiving and recording station for color camera. PC laptop with moving-map and flight data displays is used to monitor the flight and store data.
Support equipment	Engine starter, power supplies, antennas, shipping cases all included in standard system.
Training and Support	MLB offers support (flight operations, flight training, and repair) at additional cost. Travel expenses and parts are charged additionally.
Price	Standard Bat system with one vehicle, ground station, catapult, and basic training starts at $42,000 for US customers. Delivery date specified on receipt of order.

Table B. MLB Bat specifications