Romanian soldier fires rocket propelled grenade at range near Bemowo Piskie Training Area, Poland, January 24, 2018, as part of multinational battle group comprised of U.S., UK, Croatian, and Romanian soldiers supporting NATO's Enhanced Forward Presence (U.S. Army/Andrew McNeil)

Ground Combat Overmatch Through Control of the Atmospheric Littoral

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The U.S. military is seeking disruptive innovations to sustain its technological advantage despite rapid advances by potential adversaries. The need is particularly acute in ground combat, where most U.S. casualties are sustained and where game-changing technical innovations have been less common than in other military mission areas.

The Search for Tactical Overmatch

In addition to increasing technological pressure, recent coalition combat experiences and defense studies suggest that the future battlefield will be more complex than in the past. Combat in built-up areas including megacities will become commonplace. As concluded by a recent report, "Urban operations in the 21st century are not just another type of operation; they will become this century's signature form of warfare."[1] The pivotal battles in Iraq and Syria have been urban fights for cities like Fallujah, Mosul, and Raqqa. Whether conducted in urban areas or elsewhere, battles will involve proliferating low-cost lethality used by adversaries, such as improvised explosive devices of increasing sophistication, man-portable weapons like advanced rocket-propelled grenades and explosively formed penetrator warheads, and weaponized commercial drones.[2] While roles exist for elegant technologies like hypersonic weapons and other long-range standoff fires, winning future conflicts will ultimately require tactical overmatch in close battles in the land domain.

The use of robotics and autonomy offers great but undefined potential. New innovations in this area could build on the U.S. military's early technological and operational lead in unmanned systems. They would also capitalize on U.S. advantages in battlefield networking, logistics, and technical training, and could help frustrate enemy attempts to bleed away American political will by inflicting U.S. casualties. Most concepts to date involve straightforward substitutions of unmanned or manned platforms within current concepts of operations—for instance, unmanned strike fighters to serve as "wingmen" to manned strike aircraft,[3] explosive ordnance disposal robots,[4] robotic "pack mules,"[5] autonomous trucks[6] for carrying supplies, and armed ground robots to provide remote-controlled gun firing positions.[7] These are all ways of better enabling existing military capabilities. However, they may not provide decisive overmatch for U.S. forces. Could the inherent capabilities of robotics and autonomy bring entirely new operational concepts to the battlefield? Looking beyond immediate technical limitations, what new capabilities and combat doctrine could these technologies enable to provide disruptive tactical overmatch in the battles to come? One example is proposed here.

Atmospheric Littoral Operations

To date, official U.S. military thinking regarding future direct application of robotics and autonomy to the land domain has focused largely on unmanned ground vehicles. This emphasis is seen, for instance, in the *U.S. Army Robotic and Autonomous Systems Strategy*, which envisions a ground vehicle–centric approach extending through the far-term horizon of the 2030s and beyond.[8] However, these vehicles will face the physical complexity of the future battlefield, in particular, the environment in which they need to navigate. The most advanced contemporary autonomous ground robots have had mishaps navigating relatively simple terrain. At the Defense Advanced Research Projects Agency Robotics Challenge in 2015, autonomous robots in complex environments struggled at length to accomplish the most basic tasks that humans find trivial, like moving over uneven ground and opening doors.[9] In another example during 2017, a security surveillance robot toppled into the fountain in an office park plaza.[10] The terrain of an urban battlescape, as seen in recent battles in Iraq and Syria, can be vastly more complex—a jumble of obstacles including barricades, debris from damaged structures, craters, and wrecked vehicles. Even with navigation using artificial intelligence (AI) generations beyond that of current self-driving cars, or with continuous remote control by a human operator, the physical obstacles are likely to impede any ground robot.

Elevate the plane of movement perhaps 10 meters up, however, and all is nearly as smooth as the floor of a laboratory. Flying drones can operate at this level but remain intimately engaged in ground combat. They are effectively ground forces, but they operate in the air with the tactical advantages of airpower. They operate in what can be called the *atmospheric littoral*, the portion of the atmosphere adjacent to the Earth. In terms of future military operations, it is where the following conditions apply:

- Operations are conducted in the air, high enough that most ground obstacles are of no consequence and forces can move, concentrate, and disperse without hindrance, much like aircraft but on a local scale.
- Operations are conducted low enough that the forces are in close and intimate contact with ground forces, able to attack enemy ground forces or support friendly ones in ways that other ground forces cannot.
- Operations are conducted low enough that the forces can use large features such as buildings, hills, or large trees as cover and concealment.

In shorthand, it can be thought of as "the air between the buildings" and may extend to an altitude of a few hundred feet. Contemporary helicopters often operate in the atmospheric littoral but tend not to remain there for long in combat because they are vulnerable to enemy fire at that altitude, and their size—required for carrying human pilots and passengers—prevents them from maneuvering safely or effectively between buildings and trees or along streets. Once they are high enough to be out of danger from enemy small-arms fire, they are, tactically speaking, out of the atmospheric littoral.

Advantages of the Atmospheric Littoral

Combat operations in the atmospheric littoral may provide disruptive new military capability and overmatch for ground forces. They effectively expand the ground combat battlespace at the small-unit level from two dimensions to three. This could open up a whole new dimension of tactical maneuver. For instance, instead of flanking an enemy force on the next street by moving down side streets, the force could send elements "up and over" an intervening block to flank an opposing force from above.

The ability of atmospheric littoral forces to maneuver in the third dimension, and the freedom from ground obstacles that this enables, could provide several pervasive advantages:

- Speed. As with air forces, movement through the air is fast and unobstructed, so forces could be sent quickly to achieve time-sensitive objectives, like cutting off a withdrawing enemy's route of escape.

- Concentration. As with air forces, the ability to move independently of terrain and other ground forces enables the commander to concentrate combat power at the decisive time and place within the battlespace, even if physically separated from other friendly forces.
- Persistence. As with ground forces, atmospheric littoral forces could seize and control terrain. Operating in close contact with the ground, they could land and remain in place for long periods to physically occupy objectives and deny their use to the enemy.
- Mass. Unlike other forces, they could be arbitrarily arranged in space, enabling a unique concentration of firepower. For instance, arraying forces in the third dimension could enable a range of platforms at different altitudes to all have sustained direct-fire solutions on the enemy at the same moment.

A further advantage of atmospheric littoral operations is that they are expected to be complementary to, and integrate with, other ground unit operations. Littoral combat forces could be attached to other ground units under the same commander to serve as an organic force multiplier in combined-arms operations.

Doctrinal concepts for atmospheric littoral operations are influenced by several sources, considering their multidomain nature. These include airpower theory, small-unit tactics from the land domain, and air-mobile/air assault doctrine.

Characteristics of Weapons Systems

Operations in the atmospheric littoral have not been possible in the past because no suitable platforms have been technically possible. Characteristics of a capable atmospheric littoral combat platform include the following:

- Three-axis maneuverability. Ability to maneuver in the air up to an altitude of several hundred feet, move along multiple axes, or remain stationary. This effectively rules out fixed-wing aircraft.
- Small size. Small enough to maneuver effectively between buildings, trees, and other tall obstacles like cell towers and power lines. This effectively rules out human-piloted vehicles.
- Usable payload. Large enough to carry light infantry, man-portable–class weapons with significant lethality.
- Control. Equipped with sensors and communications to be able to sense their environment, report their circumstances, and accept command and control.
- Autonomy. Autonomous enough to manage their own stability, navigation, and other functions without continuous human control. Capable of collective control of many platforms by a single "operator," including coordinated action as a group.
- Endurance. Sufficient endurance to conduct meaningful combat operations on the timescale of small-unit engagements and return to a logistics point before running out of energy. About 30 minutes may be a practical minimum, with an ability to return immediately to operations after visiting the logistics point.

A large contemporary quad-rotor or hex-rotor drone is the first platform with the basic characteristics suitable for atmospheric littoral combat. Drones of the required size are being demonstrated today, for instance as part of the Army Research Laboratory's Joint Tactical Aerial Resupply Vehicle technology program, which targets a cargo capacity of 200 pounds or more.[11] Future platforms with different modes of propulsion and other qualities could offer greater capabilities in the future.

The Basic Unit of Operations

An individual drone of this type has limited survivability and lethality. Being small, the individual platforms may be vulnerable to small-arms and other direct fires such as laser and high-power microwave drone defeat weapons, and will therefore rely on cover and maneuverability for their survivability.[12] This includes flying at very low altitudes (~ 10 meters). Being too small to carry a human pilot, they will be able to carry light weapons loads comparable to those of an individual soldier—for instance, an assault or squad automatic rifle and/or compact tube-launched direct-attack munitions. An individual platform therefore may be comparable to one or a few infantry soldiers in combat power.

Combining multiple platforms, however, yields an aggregate that can provide significant survivability and lethality. The loss of a single drone would only marginally degrade the capability of the whole, and the ability to mass the firepower of a group could bring substantial combat power to bear.

In current usage, a group of unmanned systems operating together is called a *swarm*. This implies a loose aggregation with a lot of random positioning, like an insect swarm, and may be consistent with public experience of small drones for pre-programmed light shows and similar entertainment.[13] However, in military tactics it is unusual to speak of a swarm of soldiers, vehicles, or aircraft. To provide a sufficient level of discipline and control for combat in close coordination with friendly forces, a degree of order at least comparable to that of other ground forces is needed. In this context, a term such as *array* may be more accurate, indicating an ordered type of swarm where each element occupies a controlled position. Like other forces, a drone array can assume different tactical formations depending on the task it is performing. This degree of multiplatform coordination has been demonstrated using small commercial drones in controlled environments, including complex behaviors, such as quickly forming and reforming highly ordered formations and cooperating to move formations through constrictions such as doorways and reform them on the other side.[14]

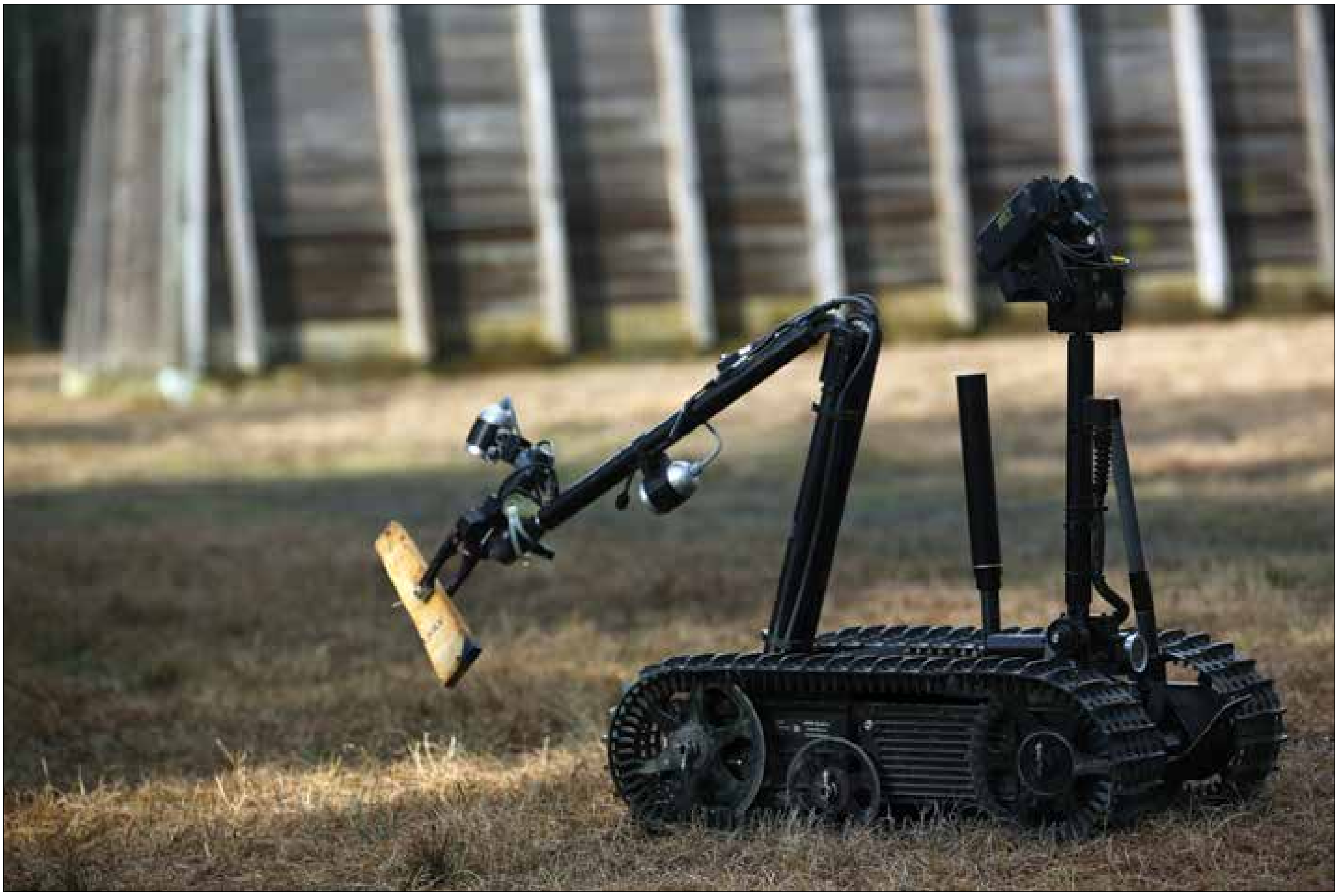
RoboSimian from Jet Propulsion Laboratory exits vehicle during DARPA Robotics Challenge, June 5, 2015, in Pomona, California (U.S. Navy/John F. Williams)

The drone array, not the individual platform, would be the basic unit of atmospheric littoral operations. Command and control would be feasible with one human operating an array, with the many details of individual drone navigation, object avoidance, and so on handled autonomously. The array would move, attack, or change formation as a unit under human direction. When sustaining battle damage, the array would remain mission-capable despite the loss of some of its elements. It would simply reassemble its formation and conduct its operations using the remaining elements. It could undergo attrition gracefully. Due to its distributed nature, it would be hard to defeat with a single attack, no matter how forceful.

Tactical Employment

Drone arrays operating in the atmospheric littoral may offer ground forces a powerful and flexible range of new options that provide decisive tactical advantage in both high- and low-intensity conflicts, suited to the complex environments expected in (near) future campaigns. The basic concept of operation envisions attachment to company- or battalion-level units operating in built-up areas, similar, for instance, to today's Stryker Brigade Combat Team infantry rifle companies or Marine infantry battalions. Roles can also be envisioned for arrays operating with a range of combat forces from special operations forces to heavier maneuver forces. The roles are applicable in both conventional and irregular warfare. Some examples of tactical employment for drone arrays include the following small-unit maneuvers:

- Movement to contact. Due to their high mobility and immunity to the effects of terrain, drone arrays may be a highly effective covering force during movement to contact. They provide real-time intelligence, surveillance, and reconnaissance (ISR) information to the command unit. If a meeting engagement occurs, an array's mobility could enable it to react more quickly than the enemy to seize the initiative and fix the enemy forces to help shape the larger engagement. Friendly forces retain the option to disengage, since the array's mobility and attritability prevent it from being decisively engaged. It could withdraw at will.
- Shaping engagements. During an assault, a drone array could enter a built-up area before the arrival of follow-on forces in order to find and engage prepared enemy positions, provide suppressive fire, and drive enemy forces away from open



TALON robot, operated by Marines with Explosive Ordnance Disposal Platoon, Combat Logistics Battalion 2, scouts area for improvised explosive devices during field exercise at Camp Lejeune, North Carolina, March 2, 2016 (U.S. Marine Corps/Paul S. Martinez)

areas. It could also identify potential ambush locations and lay smoke screens. Because an array contains no human soldiers and is attritable, this could greatly reduce hazards to the assaulting forces and speed the engagement.

- Vertical envelopment. Operations in the atmospheric littoral provide tactical dominance because they allow friendly forces to maneuver in three dimensions while the enemy is confined to two. In addition to flanking envelopments, a drone array could move over the top of intervening buildings, hills, or other obstacles and conduct a vertical envelopment. This is particularly valuable when an enemy is in defilade—sheltering behind an obstacle or in a trench—but is without strong overhead cover. Unlike traditional air support, the array could maintain an enveloping position, fix the enemy, and subject him to continuous fire.
- Infiltration and interdiction. An array is a dissociable unit and has the ability to concentrate or disperse at will. Because it can move without regard to terrain, its elements could move through or into locations that would ordinarily be inaccessible to friendly forces. Drones can filter individually through terrain and concentrate over enemy rear areas to conduct rear attacks, interdict enemy supplies or reinforcements, or attack command elements. They can disperse and reinfiltrate back to friendly locations or, if desired, be left engaged until all the elements are expended without incurring friendly casualties.
- Decisive engagement. Atmospheric littoral operations provide the ability to concentrate firepower in three dimensions to provide maximum lethality. When called for, a drone array could assume three-dimensional tactical formations to bring a unique number of converging direct fires into play. This could be done through vertical echeloning, for instance—by forming the elements into vertical ranks in a “wall” formation, or even taking a hemispherical formation to concentrate fire on a discrete target such as a fortified building.
- Area defense. Atmospheric littoral forces, like other ground forces, could help take and hold ground objectives. A drone array could land, thereby conserving power, and remain on station indefinitely to observe and defend a location and deny its use to enemy forces. If attacked, it could take to the air to engage in combat. Future drone

elements may even be able to change geometry when landed to optimize them for observation, energy harvesting, ground movement, or weapons employment while landed.
- Mobile defense and retrograde. The same capabilities provided for offensive maneuvers could provide overmatch in defensive situations. For instance, the ability of atmospheric littoral forces to rapidly move and concentrate makes them a potent reserve force. They enable defending friendly forces to quickly bring combat power to bear in response to an enemy attack at any point, even one separated by difficult terrain. Drone arrays may also provide effective defensive covering forces during retrograde movements, allowing the human forces to disengage, and then exfiltrating themselves at will.

Technical Challenges

Current platforms may be sufficient to start conducting limited experiments in atmospheric littoral operations. Making drone platforms more durable and mounting weapons are fairly straightforward challenges. But in order to be combat effective, the drones will need a number of new technical capabilities related to command and control, AI, and logistics. Military-specific research and development will need to be directed toward maturing these capabilities.

A common denominator to these challenges is the need to reduce the burden on human warfighters. Current unmanned systems can serve as high-value assets—for instance, as ISR platforms—but require too much human intervention for widespread use in ground combat. A soldier, or a combat vehicle including its crew, has to be able to carry out orders, feed or refuel, care for itself when it stumbles or suffers minor injury, and otherwise carry out basic functions without constant outside oversight. The same applies to drone arrays. The following challenges may be overcome with relatively near-term advances in autonomy, but all will require some military-specific investment.

Command, Control, and Communications. Challenges in command and control include guiding multiple drones within an array and enabling effective human control of arrays. The technology has reached the point where many of these functions are feasible in the near term.

Autonomous swarm control has advanced to the point that external aids such as global positioning systems are no longer required for complex array behavior.[15] Drones can navigate through complicated environments using visual and range data collected by miniature cameras, radar, and light distance and ranging sensors being commercialized for self-driving cars.[16] This includes navigation through indoor environments including autonomous avoidance of obstacles[17] and through outdoor environments as complex as forests.[18] Recent advances, driven by applications like drone-based package delivery, include the ability to travel city streets and take navigational data from other vehicles.[19]

An array must be able to accept and interpret high-level commands similar in detail to those that might be given to a soldier or squad leader, such as "move to this intersection" or "attack this target until it is destroyed." For the time being, it is likely to be easiest to give these commands electronically—for instance, by clicking on locations and objects on a live map of the battlespace. This level of control is already familiar and intuitive to a generation of real-time strategy gamers.

Human operator situational awareness, however, will require new development. Contemporary ground warfare, instead of becoming more automated and push-button, has seen the rise of the *three-block war* where decisions with delicate ethical, political, and even strategic consequences are required at the lowest ranks.[20] It will not be practical in the foreseeable future for arrays to understand the full complexity of their environment, and they may encounter unexpected obstacles or situations. They certainly cannot understand the nature of the conflict, exercise good judgment, or uphold U.S. military values and laws of armed conflict on their own. Human control at a high level will remain essential, both to carry out their military missions effectively and to avoid mishaps, especially when weapons are being used. A human controller must be able to maintain positive situational awareness and control over the array as a whole. Therefore, interfaces must be developed that allow an operator to see what the array sees, to "look over its shoulder" and give it direction. A human controller may need to quickly switch his or her viewpoint from one array element to another as needed. Early technologies of this kind are being tested for operator control of multiple military ISR drones.[21]

All the command and control functions will require information-sharing and data fusion. Information will need to be shared between elements of the array in order for it to act as a single unit and for all the elements to see what any one sees. Similarly, it will be necessary for the array controller to work with a current version of the battle map and for the real-time information on the drones and their observations to update the battle map seen by the commander and other parts of the unit. This *combat cloud* is required with or without drone arrays. Secure encrypted data links and data fusion would be critical enablers of collective atmospheric littoral operations and could evolve along with other combat cloud applications.

As with all unmanned concepts, the security of communications is a consideration. Atmospheric littoral drone arrays could be subject to the same kinds of electronic warfare attack as other unmanned platforms. If communications are cut, they could return autonomously to their home location. However, due to their coordination with ground forces, the arrays could have an additional option. In the event of loss of a secure radio data channel, local communications with their controlling unit could be maintained using high-bandwidth, low-probability-of-intercept line-of-sight means, such as laser optical datalinks.[22] Drone arrays will likely operate within a few kilometers or less of the base station, within line-of-sight range. Commands such as "move here" or "destroy this target" could even be given by nearby forces using readily available laser target designators with the addition of optical encoding. In urban areas, optical datalinks could be directed around corners by relay drones hovering in intersections. Such drones would be relatively simple compared to the combat drones they support.

Combat Artificial Intelligence. Combat by semi-autonomous drone arrays will involve some specific AI challenges, even with the tougher issues of human judgment and decisionmaking handled by an operator. In order to accept and execute operator commands in a way that is predictable and understandable, at the speed of combat, several capabilities will be needed:

- Target acceptance. Automatic target recognition is the ability of a sensor system to recognize and flag potential targets based on predefined characteristics. Drone arrays will need a related but distinct ability to accept the designation of a target by the operator and understand the target's boundaries and what it consists of: a static object, part of a static object (for example, a window of a building), a moving vehicle, an area, and so on.
- Target keeping. Drone arrays require the ability to keep the designation of a target despite movement or aspect changes, changes in lighting or weather, brief obscuration of the target behind an object or smoke screen, or the effects of weapons use. Without this ability, drones may constantly "lose lock" on the target or fall for simple tricks intended to confuse them. This is similar to the appreciation of object permanence, which is a key step in cognitive development for human infants.[23]
- Target assessment. After attack, drones need the ability to determine whether their target has been destroyed so that attacks are not continued needlessly on an already neutralized target or stopped before the target has been neutralized.
- Incoming fire awareness. Drone arrays will come under attack by enemy forces. To survive, they will need to be able to detect when a drone is under attack or has been destroyed and take appropriate defensive action, such as evasive movement, while alerting the operator.

When adversaries are able to field their own drone formations, combat AI will need to incorporate drone vs. drone combat. This may be simpler than ground combat in some ways, as the need for human judgment will be reduced and target recognition and assessment may be more straightforward. Academic researchers have already demonstrated autonomous swarm vs. swarm "dogfights" using simulated weapons.[24]

Logistics

Drones in an array will eventually run short of fuel, whether liquid or electric, and be depleted of ammunition. Autonomous combat logistics will be essential to keep the burden off the rest of the combat unit. Otherwise, efforts to support a drone array in sustained combat could absorb the attention of much of the rest of the unit that the array is supporting.

Like soldiers and manned vehicles, drone arrays need to be provided with replenishment locations, but otherwise they should be expected to refuel and rearm themselves, as common floor-sweeping robots recharge themselves today. One way this could be done is by providing pods, reservoirs of fuel and ammunition that could be dropped in locations close to the battle area but with some degree of sanctuary. In an urban combat scenario, they could be located a few blocks to the rear or in a physically inaccessible location like the roof of a building. They could be placed by large supply drones, similar to the current Joint Tactical Aerial Resupply Vehicle prototypes. The pods could be simple, such as a pressurized fuel bladder with a docking port on top or a frame covered with full weapon magazines and rocket/missile tubes. The individual drones in the array could navigate to the appropriate pod, perhaps following a radio frequency or infrared beacon. Self-refueling could be achieved by deploying a fuel probe from the bottom of a drone, which could then hover atop a fuel pod, docked with the port, until its onboard tank is full. Self-rearming could involve discarding depleted magazines and rocket tubes and snapping new ones into place by landing on the ammunition pod.

At a modest speed of 30 miles per hour, in one minute a drone could be the distance of seven large city blocks to the rear, refueling and rearming at a logistics node, and in another minute be back in the fight. With this capability, the endurance of atmospheric littoral drones could be practically unlimited, as is the case today for combat aircraft provided with air-to-air refueling.

Self-repair is likely impractical, so to ease the burden, drones would need to be built for damage tolerance. They will need to absorb damage gracefully, through redundancy and by automatically compensating for damage where possible. The inherent redundancy of drones with four or more rotors could help with this. The ability of a fail-safe control system to partially compensate for a lost rotor has already been demonstrated.[25]

None of the technical challenges described here are trivial. Much as with airpower and mechanized maneuver warfare, it may take many years of development before the technologies are fully able to realize operational hopes envisioned in the doctrine. But as in those cases, important military advantages could likely be gained with each step forward in capability.

Questions and Concerns

There are important concerns regarding the introduction of robotic combat systems. The doctrinal framework of exploiting the atmospheric littoral using drone arrays addresses several of these:

- Will they accidentally shoot the wrong things or run amok? Drone arrays have only limited autonomy, in keeping with a realistic view of

The DARPA Subterranean Challenge explores innovative approaches and new technologies to rapidly map, navigate, and search complex underground environments, Edgar Experimental Mine, April 2019 (DARPA/Colorado School of Mines)

the limitations of fully autonomous systems in complex environments. Authority to use weapons is provided and circumscribed by the human operators overseeing them and operating in coordination with them.
- Will they be a burden to operate in a combat situation? Autonomous logistics and the intuitive control of large numbers of platforms by a single operator are key aspects of the littoral operations concept. The burden can be even lower than with conventional weapons systems.
- Can other systems do the same things? Littoral drone arrays provide capabilities that are fundamentally unobtainable through existing means such as ground vehicles, manned aircraft, or large fixed-wing drones. The atmospheric littoral is a new tactical dimension open for exploitation.
- Will their communications be jammed? Relative proximity to friendly forces and to each other provides excellent fallback options if digital radio communications are unreliable. For instance, line-of-sight communications using laser datalinks could be both practical and intuitive and enable continued operations under the most severe jamming.

Next Steps

Realizing the military potential of autonomous robotics will involve more than just plugging unmanned systems into existing operational doctrine. It will likely involve a comprehensive set of changes similar to those that allowed the Army and Marine Corps to incorporate aviation starting in the late 1940s or to "own the night" starting in the 1970s. But the opportunities to force disruptive change on U.S. adversaries and secure a lasting source of tactical overmatch may be greater still.

Atmospheric littoral operations are one example of how the inherent capabilities of unmanned systems and autonomy could enable overmatch, particularly for close combat in the land domain, where many conflicts of the coming decades are likely to be decided. A doctrine of exploiting control of the atmospheric littoral offers tactical advantages that provide a driving force for the adoption of robotic systems into ground combat. To adequately explore the potential, the next steps would be to focus technical research and development efforts on the areas described above and conduct military experiments to advance tactical experience and methods.

The necessary hardware technology is essentially available, and the software is advancing quickly. Fully mature technology is not needed up front; small

Lattice Modular Heli-Drone flies during test run of Lattice Platform Security System, at Red Beach training area, Marine Corps Base Camp Pendleton, California, November 8, 2018 (U.S. Marine Corps/Dylan Chagnon)

numbers of prototype militarized drones should be procured for experimentation and the results of the experiments used to refine requirements for the next generation of drones.

Key military questions, such as how best to coordinate with other small-unit actions and how much autonomy to allow, should be worked out on the training ground. The possibilities can be explored gradually and at low cost. The Army, Marine Corps, and other Services should establish programs to bring together the latest prototype hardware and software, new doctrinal concepts, and forward-thinking warfighters and allow the best approaches to be developed iteratively in realistic field experiments. This approach was used successfully in the past—for instance, within the Marines' experimental helicopter unit, HMX-1, that started work in 1947 to explore the military possibilities of rotary-wing aviation.[26]

Since many combat advantages may be gained from the addition of a drone array to otherwise standard forces, advances could be seen with incremental changes to units or doctrine. Military forces could start small and increase their commitment as the possibilities are matured.

Soldiers and Marines are already encountering enemy forces fielding simple weaponized drones in urban combat. If U.S. forces do not master operations of this type, they may have to face enemies in the future who can fight in three dimensions. By pursuing a low-cost program of prototyping and experimentation, the U.S. military can lead the emerging combat capabilities offered by unmanned systems, avoid technological surprise, and enable a new era of sustained tactical overmatch. JFQ

Notes

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