INTRODUCTION

As noted earlier, it is our judgment that most urban operations will fall at the lower end of the spectrum of conflict. Although there are improvements that the USAF can make in its ability to conduct urban operations against conventional foes, we see the major shortcomings as being in the ability to detect and attack unconventional foes.

It may be possible in future limited operations to identify and attack critical adversary centers of gravity or key nodes. However, historical experience suggests that this possibility will be the exception, not the rule. Rather, in most limited operations, strategic objectives are more likely to be achieved through the cumulative effect of persistent surveillance and strike than through the destruction of a small target set.

For example, in a notional peace operation that included an urban component, U.S. objectives might be to stop the violence, resettle the population, and achieve a return to normal in which routine civil and economic activities could take place without disruption. To accomplish these objectives would require, above all else, that friendly forces control the streets. The operational task of controlling the
streets would, in turn, require that a variety of tactical tasks be accomplished. Among the more prominent tasks are the following:

- Stop movement of combatants, vehicles, equipment.
- Provide rapid, high-resolution imagery for target ID.
- Detect and neutralize adversary ambush positions.
- Detect and neutralize snipers.
- Monitor high-priority targets.
- Resupply isolated friendly ground forces.
- Provide close support to friendly ground forces.

The most robust solution to any of these tasks involves the combination of air and ground elements working in harmony. As we look to the future, unmanned ground-sensor networks may be able to reduce the number of ground personnel put at risk, just as unmanned air vehicles are doing for air operations. Nevertheless, it will likely always be the case that it is better to have some personnel on the ground to supplement unmanned ground sensors. This chapter presents new concepts of operation to accomplish the above tasks. For each task, we discuss the nature of the challenge, then suggest a new concept of operation to accomplish it.

STOP MOVEMENT OF COMBATANTS, VEHICLES, AND EQUIPMENT

Peace operations often require that friendly forces control the city’s streets. The amount of control may vary by situation; at the least, militias, irregulars, and various combatant forces must be denied the

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1We also believe that the detection and neutralization of adversary manportable surface-to-air missiles will become increasingly important as more-advanced versions of these proliferate. These weapons could seriously impede all urban air operations, both rotary and fixed wing. A related task is the insertion and extraction of personnel, equipment, and supplies in the urban environment. MANPADS, AAA, heavy machine guns, and small arms are all capable of downing rotary-wing aircraft. It would be valuable to have counters to these common weapons or alternative means to move personnel, equipment, and supplies. As the October 1993 shootdown of U.S. Army helicopters in Mogadishu, Somalia, showed, even simple weapons (in this case, RPGs) can down aircraft that are flying low and slow.
freedom to mass, move, and operate, whether on foot, in modified civilian vehicles, or in armored vehicles.

For operations in which the control of the city is contested, it is vital that adversary forces not be allowed to act as a governing force (e.g., collecting taxes, arresting people, patrolling with visible weapons). Such activities undermine the legitimacy and credibility of the local government the United States is supporting and present the adversary force as an alternative. U.S. forces may not always be able to prevent adversary forces from moving covertly, but they can readily detect and stop overt operations (roadblocks, weapons displays, vehicle convoys).

Not confined to peace operations only, detecting and stopping combatant movement may be necessary in noncombatant evacuation operations, hostage rescues, and other special operations. A traditional approach to this problem would put friendly ground forces throughout the city, manning observation posts and roadblocks, patrolling, and generally making it difficult for adversary forces to move without detection.

Both ground sensor networks and airborne platforms have the potential to reduce the manpower demands and risks to friendly forces associated with these operations. Although friendly ground forces are likely to still be required, they could be more effective if cued to problem areas by unmanned sensors. In some cases, such as a NEO or hostage rescue, airborne platforms (e.g., an AC-130) might operate independently to detect and interdict hostile forces. In Bosnia, JSTARS aircraft accomplished the surveillance task in rural areas by ensuring that the Bosnian, Serb, and Croatian forces lived up to the terms of the Dayton Agreement and kept their armored and other combat vehicles in holding areas. In some urban situations, JSTARS may have a role to play also; however, in urban core areas, building shadows and the commingling of adversary vehicles with civilian traffic (e.g., as Somali “technicals” were) will make it difficult to monitor vehicle movement, and JSTARS is unlikely to be able to distinguish between them. In our judgment, a distributed sensor system

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2 *Technicals* were pickup trucks and jeeps with machine guns mounted on the back.
will be necessary to detect combatant movement under these conditions.

A distributed sensor system could combine imaging and non-imaging sensors on both air and ground platforms. The imaging sensors would look for military vehicles, “technicals,” and other, more-overt displays of weapons. Non-imaging sensors would look for hidden weapons or explosives or use pattern analysis to detect anomalous vehicle or personnel movements. Initially, these sensors could supplement ground-force monitoring in the more dangerous or problematic parts of the city.

If unmanned ground sensors prove to be effective and some of the more exotic technologies become cheap and reliable, sensors could be placed throughout much of the city. These sensors would alert a weapon controller, who would then direct airborne sensors or ground patrols to take a closer look. When adversary ground forces could be clearly identified (e.g., massing at a militia leader’s compound as they did in Mogadishu), airborne strike platforms could be used to destroy them; or ground forces could be alerted to investigate further.

In this more-ambitious vision, the role of ground forces shifts to that of quick-reaction force for situations where a person on the ground is needed because of problems with target identification or because combatants are too intermingled with noncombatants for attack with standoff weapons. This concept might allow for a reduction in the number of required ground forces; if a small number were deployed, they would need some means to move quickly to the site of the problem. One advantage that ground forces have over most airborne platforms is their ability to detect and fire on fleeting targets. The longer the time of flight of the weapon, the harder it is to engage targets moving quickly in and out of cover.

Figure 5.1 illustrates the basic concept. On the left, a UAV with an EO/IR camera detects an insurgent roadblock and relays this information to the controller. The controller identifies the personnel as hostile and directs an AC-130 to take them under fire. On the right side of the figure, a “ground sensor” (located on the top of a building)
equipped with radio-frequency (RF) resonance-detection equipment detects what appears to be a load of assault rifles in a parked van. In this case, friendly ground forces (in the armored vehicles on the right) are sent to investigate.

**PROVIDE RAPID, HIGH-RESOLUTION IMAGERY FOR TARGET ID**

As the USAF discovered in Kosovo, from medium altitudes it is often impossible to distinguish between various types of vehicles or between adversary and friendly dismounted personnel. To aid in situations in which ground observers are not available to assist in target ID, it would be enormously useful if combat aircraft (whether F-16s or AC-130s) had access to offboard sensors flying at lower altitudes. If Predator or other UAVs are on-station, they may be available for this role. However, the limited number of such platforms and concern
about their survivability at lower altitudes may mean that combat aircraft cannot always count on UAV assistance.

In addition to these surveillance platforms, we propose the development of a set of air-launched disposable sensors for target ID in urgent situations. It would be possible for the parent platform, either a fighter, AC-130, or larger UAV, to drop a miniature glider with a small, low-light-level TV camera, GPS receiver, auto-pilot, and data link. The mini-glider could be folded into a container until deployed. However, a system like this would take many minutes to glide down from 15,000 or 20,000 ft to low altitudes—less than 500 ft—where its camera could provide the high-resolution images necessary for target identification. During that time, many things could happen. For example, the target could move away or, in an urban environment, move into a building. Therefore, it is important that any disposable identification sensor arrive at low altitude near the target very quickly.

One possibility would be for an F-16 or other fighter aircraft to carry a mini-UAV in a canister on one of the wing weapon stations. When the F-16 detected a situation requiring target ID and some endurance was desired, the UAV canister would be released and fall quickly to lower altitudes. A drogue chute would slow the canister and, at a few thousand feet altitude, a folding-wing UAV would be deployed. That UAV would fly at low altitudes, providing imagery back to the friendly aircraft for up to a few hours to allow confident target identification, attack, and battlefield damage assessment (BDA) or, as in the Kosovo example, to avoid accidental attacks on civilians. This kind of endurance over the target would often exceed that of the fighter deploying the UAV and would allow a UAV deployed by one fighter to provide imagery to its replacement on-station.

Another possibility is to build a container for the sensor package. The container would be shaped like a lifting body, with small control surfaces. Once dropped, the container would fall rapidly to low alti-

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3RAND colleague Randall Steeb points out that this is similar in concept to the videointerimaging round that the U.S. Army experimented with a few years ago. One version used the spiraling of the shell to produce a scanned image; another version used a parachute-dropped, GPS-equipped camera.
tude, but would generate enough lift to allow it to maneuver to coordinates anywhere within a few miles of the launch aircraft. However, a shape that is well adapted to rapidly maneuvering to a given set of GPS coordinates at low altitude is poorly suited for taking even a brief close-in look at whatever may be of interest there. It would not be capable of maintaining level flight or circling a target at close range without rapidly depleting its airspeed, which would result in an almost equally rapid aerodynamic stall and crash.

Therefore, we envision the lifting body deploying a small, controllable parafoil as it passes about 1,000 ft AGL. By the time it reaches 500 ft AGL, the parafoil should be fully unfurled, slowing the container. At about this altitude, it would begin a slow spiral around the GPS coordinates of interest. The diameter of the circle might be selectable before launch to allow the operator to tailor the resulting view, somewhat, to the suspected target and environmental conditions. Something as simple as “Near,” “Medium,” and “Far” circle diameters (determined through empirical tests during sensor development) might be sufficient.

The container could be suspended so that the camera looks to the inside of the descending turn. In its simplest form, a system like this would just continue to fly descending circles about the target coordinates, sending back images to its parent craft all the while, until it hit the ground. More-sophisticated versions might allow operators to steer the parafoil to change the camera’s azimuth view and include some means of controlling camera elevation view. These more complicated schemes would probably require a human to control the expendable camera once the parafoil deployed. This might make them more appropriate for multi-place (i.e., two or more crewmembers) aircraft or large UAVs, such as F-15Es, AC-130s, or Predator, so that crewmembers or operators can dedicate their full attention to operating the expendable camera for a short time. However, the simpler autonomous version would still be a valuable target-identification tool for single-seat fighter or attack aircraft operating at medium altitude.

In Figure 5.2, we illustrate how this GPS-guided parafoil might be used to accomplish a key operational task. In this concept, we envision an AC-130 or other combat aircraft patrolling an urban environment. The AC-130 detects a suspicious gathering of vehicles and
personnel but cannot positively identify them as hostile. Strict ROE prohibit engaging them without positive ID, and no friendly ground forces are available to investigate. Instead, the AC-130 crew deploys the lifting-body-shaped camera that flies to GPS coordinates programmed by the crew.

High-resolution low-light TV or IR images are relayed back to the AC-130. The parafoil can spiral all the way down onto hostile forces or can carry the camera clear of them. Either way, very high-resolution images should be obtainable as the parafoil passes below 500 ft, perhaps passing tens of feet over the target. The AC-130 by this point has made the determination that the people are in fact hostile forces being resupplied and attacks them with 40mm or 105mm rounds.

Such a capability would be enormously valuable in a host of situations in both rural and urban terrain. As advanced MANPADS proliferate around the world, it is likely that manned platforms will increasingly avoid loitering at lower and medium altitudes near threat forces. Air-deployable offboard sensors would give combat aircraft all the surveillance advantages of loitering with none of the attendant
risks and many of the capabilities of more-expensive surveillance platforms in a package they control.

DETECT AND NEUTRALIZE ADVERSARY AMBUSH POSITIONS

The ambush is a common technique that adversary forces are likely to use against friendly forces. Although their size and the type of weapon used can vary, classic infantry ambushes involve a small unit (squad or platoon) surreptitiously taking up hidden positions (often under cover of darkness) and waiting for an adversary patrol, convoy, civilian vehicles, or other targets to enter the kill zone. The ambushers use assault rifles, machine guns, antitank weapons, grenades, and mines to create a horrific volume of fire, often at very close range, against the victims. Careful siting of weapons is used to put fire down and across the road or trail so that there is no cover for the ambushed force. The suddenness and volume of fire can wipe out a patrol in seconds. The ambushers may take weapons and intelligence materials off the bodies or simply cease fire and leave.

If the ambush is badly sited or executed, adversary forces may be able to return fire and maneuver against the ambushers, particularly in ambushes against forces that are too large to be contained entirely within the kill zone. In those cases, the forces not in the kill zone are likely to maneuver around the flanks of the ambushers to bring fire on their positions and to cut off their escape. Also, nearby forces may come to the aid of those caught in the ambush. To avoid these dangers, ambushers do not linger. A well-executed ambush may be over in under a minute and rarely extends to more than a few minutes.

Weak forces may use ambushes to maintain the initiative, control territory, demoralize adversary forces, or gather intelligence (from maps, radio codes, and other operational information taken from the bodies of ambush victims). In an urban setting, adversaries may use ambushes to inflict heavy casualties and, thereby, so intimidate friendly forces that they are afraid to patrol particular sectors of the city. These areas could then come under the de facto control of, for example, insurgent forces or criminal elements. Alternatively, adversaries may seek to inflict casualties, on a peacekeeping force for example, as a way of undermining international support for the inter-
vention. Since patrolling is essential in many operations, U.S. forces need to find ways to better protect small units from ambushes.

Ideally, we would like to be able to detect and neutralize ambushes from standoff. As the above discussion illustrated, there are four components to an ambush: movement to the site, hiding at the site, the ambush itself, and escape. In urban operations, the ambushers may move to the site overtly; however, in the kind of operations we envision predominating, they probably will move in a more covert way. Thus, visual observation will probably not allow them to be singled out from the background civilian traffic. One exception would be if they attempt to move covertly at night but are detected by airborne or ground-based low-light TV or IR sensors. Even if their weapons were hidden, their movement could stand out if the streets were deserted and they were moving in rushes to minimize visibility from street observers. Also, environment-shaping measures such as curfews can help by making any activity at certain times or places suspicious. Alternatively, unmanned ground sensors might detect the ambusher’s body heat, weapons, or explosives if the ambushers passed by them. This would require either a large network of sensors or careful siting to maximize the probability of the ambushers passing by the sensors.4

A more difficult problem is detecting the ambushers once they are established in their attack positions. Airborne or ground-sensor platforms may be able to detect some ambush positions on streets, balconies, or rooftops, perhaps even inside of structures. Once detected, they could be attacked using traditional air or ground weapons or some of the more-specialized munitions discussed later in this chapter. Generally, detection of ambush positions will require fairly high-resolution IR or visual sensors, although other sensor types, such as radars that can detect weapons, might play a role. It is unlikely that airborne platforms randomly observing the urban land-

4In many situations, particularly those relating to defense of key installations, it will be possible to site ground sensors at choke points through which adversary forces would have to pass. For example, USAF security police described to one of our researchers a few years ago how security forces were able to use ground sensors to count adversary personnel. During air base defense exercises in Korea, security forces were able to put ground sensors on likely aggressor avenues of approach. As the aggressors passed by in file, USAF security forces at the remote monitoring site were able to count them and direct a quick-reaction force to the scene.
scape will detect ambushes, because either their sensor resolution will be too low (in the case of higher-flying aircraft with high coverage rates) or the coverage rate will be too slow (in the case of lower-flying aircraft taking close looks at individual streets and structures).

For this reason, ambush detection will need to be focused on specific streets or buildings for specific periods of time. For example, each foot or vehicle patrol could have an unmanned sensor platform (ground or air) precede it in search of suspicious activity, which would focus the sensor on the area of primary concern to the patrol and at the critical time. Such a platform could be controlled either by the patrol leader or at a rear command post. To the extent that more-exotic sensors such as chemical sniffs (to detect ammunition and explosives), weapon-detecting radars, etc. become feasible, this platform might be able to detect the actual ambush positions. The positions might also be detectable by IR, visual, or multispectral sensors.

If the ambushers are hiding inside of buildings (probably just below or beside windows), they will be very difficult to detect, requiring more-intrusive approaches. These approaches might include rifle-launched sensors that would fly through a window and attach to a wall, micro-UAVs doing essentially the same thing, or perhaps sensors that could be rolled or thrown into a room.

Sometimes, adversary forces will be able to set up an urban ambush without local civilians detecting it; other times, locals will be aware of the ambush because it is being set up in the building they live or work in. To the extent that local civilians are at odds with the adversary force, they may warn authorities of the ambush. Even when the locals are supporters, perhaps even involved in helping set up the ambush, they may take steps to protect themselves or family members, or otherwise engage in nonroutine behavior that can be observed.

An experienced operator (either a member of the patrol or rear-area sensor operator) may detect changes in the social and physical landscape that suggest there is something wrong, although he cannot see the actual ambushers. For example, an infantry patrol leader might notice changes in people’s behavior, number or location of vehicles, whether shop windows or doors are open or closed, presence or ab-
sence of children, dogs barking, unusual silence, or other signs that would indicate danger. The more experience the patrol has with a particular patrol route, the more likely they will be to detect such changes. Many combat infantrymen and policemen have reported detecting such anomalies and being saved from imminent attack, sometimes without being conscious of what exactly is wrong with the picture. Unfortunately, these signs are not always clear and the patrol may not detect them until it is too late.

Rather, what we need is a way to observe these patterns safely from standoff and in a more systematic and reliable way. The UAVs discussed above could be used to extend the vision of the patrol or other observer. Using experience or a database of photos taken at similar times and days of the week, the patrol or observer could compare the current picture with the baseline. There is some danger that the appearance of an unmanned platform would be recognized by adversaries as a precursor to the arrival of the patrol, but this seems a small price to pay for the increased security. Also, there are a variety of techniques that could be used to make the UAV more covert.

An alternative method (illustrated in Figure 5.3) that has utility beyond this particular task would be to use a network of ground sensors to continuously observe locations of interest, which might include major roads, marketplaces, town squares, trouble spots, and likely ambush locations on patrol routes. The network could use IR or visual sensors, but unless some technique were developed to automatically analyze the images, this approach would be feasible only for small networks. If, however, seismic, acoustic, sniffing, magnetic, and other sensors could be developed, it might be possible to rely more heavily on computers to do pattern analysis. For example, automated analysis of vehicle- or foot-traffic patterns might be possible. These or other sensors might be used to alert sensor operators or intelligence analysts to anomalies. Operators and analysts could then use imagery to delve deeper into the mystery, comparing stored images from similar days of the week and times.

From a force-protection perspective, it would be best to have both the wide-, or at least wider, area surveillance associated with the ground sensors and a small UAV (perhaps even multiple UAVs) providing imagery and other data directly to the patrol.
DETECT AND NEUTRALIZE SNIPERS

Snipers are a perennial problem in urban military operations. Threatening civilians and military personnel alike, snipers can shut down civil activities, hurt morale, cause politically significant casualties, perhaps even stop a NEO from an urban embassy. Snipers armed with the increasingly popular .50-caliber rifle (using incendiary or armor-piercing bullets) can threaten lightly armored vehicles and hovering or landing helicopters.

For our purposes, a sniper is a single combatant (sometimes teamed with an observer) who selectively engages targets from a location that offers superior fields of view. He may be a specially trained sniper, a regular infantryman, or a civilian irregular.

An untrained sniper may fire from a balcony, rooftop, or window with a standard assault rifle such as an AK-47, using either the weapon’s iron sight or a scope. Most sniper casualties in recent civil conflicts (e.g., in Bosnia and Somalia) were probably the work of untrained snipers, either irregulars or soldiers with only basic marksmanship training. U.S. forces encountering such snipers
during operations in Somalia found that countersniper teams flying in helicopters or on the ground were able to routinely detect and dispatch these threats because the snipers failed to use cover or tended to fire too many times from one location.5

In contrast, professional snipers rarely fire from open positions.6 Instead, they will covertly enter a hide and take substantial time preparing their firing site. In an urban setting, a well-trained sniper will use windows, small holes through shingles or walls, or other small openings for observation and fire. They often will build a firing platform in the back of a room hidden by netting.7 Although this cover limits their field of view, it also masks muzzle flash and makes them extremely difficult to detect. Professional snipers typically use special bolt action or semi-automatic rifles,8 scopes and match-grade ammunition, spotting scopes, and camouflage (e.g., “Ghillie suits”), and they are trained in ballistic calculations and other tradecraft.

The U.S. practice, for both police and military snipers, is for snipers to operate in pairs, rotating between shooter and observer duties. The observer uses a spotting scope to help adjust fire and provides security. He typically is armed with a semi-automatic weapon. Adversary snipers may operate as individuals or in pairs. Finally, the professional sniper will take only a few shots from his position before

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6What constitutes an open position will vary with the situation. For example, a police sniper on a rooftop, while visible to airborne platforms, typically is only concerned with remaining hidden from his criminal target in a building or at street level. In contrast, in a combat situation, a sniper going against U.S. forces would have to worry about detection from airborne platforms. Even a professional sniper might fire from the open under these conditions if the mission required it. The point here is that U.S. forces should not count on snipers routinely being detectable through simple visual observation of open spaces.
8Sniper rifles include the Russian SVD and Mosin-Nagant, the U.S. Remington 700 and McMillan .50-caliber, and the British Parker-Hale M85. However, trained snipers have been quite effective with less-sophisticated weapons. For example, Irish Republican Army (IRA) snipers have been very successful over the years using AR-15s with basic scopes.
leaving the area or moving to an alternate firing position.\textsuperscript{9} For this reason, a sniper should be considered a time-critical target.

There are three situations in which U.S. forces are likely to need to counter snipers:

- The first is in the defense of U.S. or allied facilities or ground-force positions. U.S. embassies, air bases, airports, ports, barracks, allied governmental buildings, television, or other public facilities might come under attack from snipers. At best, such attacks are a nuisance; at worst, they have the potential to cause serious loss of life or damage to high-value assets such as parked aircraft.

- A second situation is when friendly patrols come under sniper fire. Routine sniper attacks on patrols could seriously disrupt their ability to interact with the local populace, observe activities, and collect intelligence. Force-protection concerns could limit patrol frequency, locations, and duration; undermine morale; and cause the patrols to be so defensive that they were ineffective in their primary mission.

- Third, civilian populations can be harassed and intimidated through sniper attacks on foot traffic, marketplaces, parks, and other places where civilians congregate. For example, during the Bosnian civil war, Serbs in the suburban hills surrounding Sarajevo routinely fired into the center of Sarajevo, particularly down "Sniper's Alley," a road near the Holiday Inn.

U.S. forces have traditionally used their own snipers to stalk and kill adversary snipers.\textsuperscript{10} Although manpower-intensive and time-consuming, this is an effective way to counter professional snipers. U.S. countersniper teams are even more effective against untrained snipers but can quickly be overwhelmed by sheer numbers. These teams are simply too few to effectively counter irregular and other


\textsuperscript{10} See Plaster, 1993, pp. 365-394, for a discussion of countersniper tactics.
forces deploying many infantrymen or even untrained militias as snipers throughout a city.

To supplement infantry countersniper teams and allow them to focus on priority missions, DoD has been exploring other countersniper concepts. Acoustic, radar, passive IR, and scanning lasers have all been tested for their applicability against snipers. The Stingray scanning laser system on the Bradley Fighting Vehicle, for example, can be used to detect sniper optics (telescopes or night-vision devices) and alert the gunner; in automatic mode, it can engage and neutralize optics.\textsuperscript{11}

We propose a two-track approach for expanding countersniper operations in the urban environment, as illustrated in Figure 5.4.

For fixed facilities and known problem areas, unmanned ground sensors would be deployed by ground forces or air.\textsuperscript{12} Scanning lasers, acoustic arrays, and passive IR systems all hold promise for this mission. Since scanning lasers can potentially detect the sniper before he has fired, they should be used wherever possible; the other approaches, particularly passive IR, should be used in combination with scanning lasers to increase the probability of detecting and destroying sniper threats after they have fired.

In our concept, we use an unmanned sensor equipped with a scanning laser, laser designator,\textsuperscript{13} and EO/IR camera. When the scanning laser detects optics, the camera would automatically slew to that location and a controller would be alerted and automatically provided with three-dimensional (3-D) coordinates for the


\textsuperscript{12}An important shortcoming is the current inability to implant urban ground sensors from the air. Past aerial-delivery sensors were either high-speed spikes that implanted themselves in the ground (primarily seismic sensors) or acoustic sensors dropped by parachute. These approaches are viable for operations in undeveloped areas but have limited utility in urban settings. Rather, what is needed are small, difficult-to-detect sensors that can be covertly implanted on building tops or sides. One concept that we recommend exploring would use small VTOL UAVs to implant such sensors.

\textsuperscript{13}A \textit{laser designator} is a device that illuminates a target with laser energy so that a weapon equipped with a laser receiver can guide in on the beam.
location. Automated decision support software would compare these coordinates to a 3-D database to determine whether the location was known to house friendlies or noncombatants. Using this information, what he knows about friendly operations, and what he sees remotely through the camera, the controller would then make a determination on the next step. If it appears to be a legitimate target, the controller could send ground forces to the location or preemptively use nonlethal or lethal weapons against the site. We envision equipping at least some of the sensors with a grenade launcher. The launcher would fire laser-guided grenades with sufficient accuracy to go through an average-sized window and have sufficient lethality to take out a sniper without harming noncombatants in adjacent rooms or on adjacent floors.

All of our concepts assume that the USAF will acquire the ability to do near-real-time three-dimensional imaging of urban environments and that this imaging will be used to produce a three-dimensional coordinate system for navigation, battle management, and weapon-system guidance.
To deter random sniper attacks on civilians or attacks on friendly patrols, we propose supplementing the fixed sensors with a passive IR system like Lawrence Livermore’s Lifeguard system, on a UAV. The UAV would also be equipped with an EO/IR camera, concentric-coded laser\textsuperscript{15,16} designator, and mini–glide bombs with small warheads. When the passive IR sensor detects a hot bullet against the cooler background of the air, it uses a ballistic model to backtrack to the firing location. Separate calculations are done for each bullet fired, enabling the sniper’s location to be determined with sufficient accuracy for counterfire. When used in the fixed ground mode in the line of fire, the Lifeguard system slew a camera to the sniper location, allowing a friendly sniper or other weapon operator to engage.

For an airborne platform it is possible that the sensor would have line of sight to the bullet in flight, but not to the firing location, which might be blocked by another building. Thus, slewing a camera to the sniper will not always be possible. Rather, the UAV fire-control computer would need access to the 3-D city database so that the ballistic track could be compared and the likely firing location determined.\textsuperscript{17} If it were not already in a position with line of sight to the sniper’s location, the UAV would maneuver so that it was. The EO/IR camera

\textsuperscript{15}A circular laser puts energy around the window but not on it. The weapons would be programmed to fly through the middle of the laser circle. Concentric-coded lasers would put several laser rings around the target, using different frequencies of lasers to convey information about target location to the weapon.

\textsuperscript{16}As noted in Chapter Four, one problem with laser designation in urban environments is that the laser energy may reflect off window glass or, where windows are missing, go into a structure but not reflect enough energy out to guide a weapon. One possible solution would be to put laser energy on less-reflective surfaces around the window, perhaps in concentric circles. The simplest near-term concentric coding might involve a purely spatial code that could be traced using technology similar to that employed in laser light shows. For example, the pattern closest to the target might be two nearly concentric circles with slightly offset centers, so that the distance between them appears to be larger at the top of the circles than at the bottom. As the seeker scans across the pattern, the amount of separation would indicate whether the seeker is approaching high or low but, also, by virtue of the number of circles, would indicate the distance to the target. In the future, a more advanced laser could be used to provide similar data by varying the laser frequency or by modulating the laser signal.

\textsuperscript{17}A simple algorithm could rule out interior spaces and windows on the far sides of buildings, identifying the most likely firing position along the ballistic track.
would then be directed at the sniper location so that the controller could put eyes on target before releasing a weapon.

At this point, a mini–glide bomb would be released, flying a course over and between buildings using enhanced GPS signals and the 3-D database to navigate to a position in front of the target building (see Figures 5.5 and 5.6). A high-flying UAV would act as a GPS pseudolite, increasing the accuracy of the signal and rebroadcasting it at a frequency that can be received in the urban canyons. The concentric-coded laser designator on the mother UAV would illuminate the

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18 Other possibilities would be to use ground-based systems such as optically guided Enhanced Fiber-Optic Guided Missile (EFOG-M) or perhaps maneuvering mortar rounds.

19 Pseudolites are ground-based or airborne transmitters that supplement or replace GPS for navigational purposes. See the discussion in Chapter Six.

20 See Chapter Six for a fuller discussion of GPS use in urban settings.
target, providing terminal guidance for the glide bomb. The glide bomb would maneuver and ignite a small rocket motor to give it sufficient energy to penetrate a window or other minimal obstruction if necessary. A laser proximity fuse would then detonate the small warhead once it had entered the sniper-occupied room.\textsuperscript{21} By using a small, light platform, flying a level course, and bursting a small warhead inside of the room, this concept should allow for effective counterfire without putting noncombatants at risk in adjacent rooms or on adjacent floors.

**MONITOR HIGH-PRIORITY TARGETS**

In addition to more-general surveillance requirements, urban operations—particularly counterterrorist, counterdrug or WMD-related—may require continuous monitoring of a building or fairly

\textsuperscript{21}We envision not only a lethal fragmenting warhead of roughly grenade size, but also incapacitating gas, a stun grenade, or other nonlethal weapons as other possibilities.
small area. There may be a need to observe or listen to activities in a particular room; to monitor personnel, equipment, or vehicles entering or leaving a building; or to otherwise observe activities at a town square, park, or other fixed site.

Most of the time, AC-130s, Predators, and other existing platforms using EO, IR, or radar sensors have sufficient resolution to accomplish these missions covertly\textsuperscript{22} from medium to high altitudes. If, however, the mission requires identifying a particular person, small piece of equipment, or small package entering or leaving a building, imagery equivalent to that provided by a police stakeout squad in a vehicle or nearby building would be necessary. Larger platforms operating at standoff distances do not have sufficient resolution to accomplish these extremely demanding tasks. In the following discussion, we explore the possibility that low-flying UAVs or unattended ground sensors could achieve this very high level of resolution.

Mini- and micro-UAVs (with wingspans from 8 ft or so down to bird size) have much utility in urban settings. They can fly down into urban canyons, thereby gaining excellent viewing angles through windows and of streets, alleyways, and other narrow passageways. However, it does not appear that they can conduct enduring covert surveillance with EO or IR sensors. The problem is the mismatch between what the UAV needs to do to monitor the site and what a human observer at the site needs to do to detect the UAV. The UAV sensor would need resolution on the order of inches to identify specific individuals or very small packages. To get this resolution requires that the UAV either carry a camera with a long-focal-length lens or get very close to the target.

In exploring various combinations of UAV size, associated payload, and sensor range, we could not find one that would allow the UAV to get sufficiently close to identify a human and still remain undetectable to the adversary observer. For example, a typical slow-flying UAV with a wingspan of 8 ft can carry roughly a 5-lb payload. A standard 5-lb optical-sensor package has sufficient resolution to identify

\textsuperscript{22}That is, they would be difficult or impossible to detect with the naked eye. If the adversary had radar coverage or advanced IR systems, these aircraft would be detectable.
a specific person (e.g., Osama bin Laden as opposed to Saddam Hussein) in daylight at a distance of about 1,400 ft.\textsuperscript{23}

At this distance, not only could the UAV be spotted but it could easily be shot down. The adversary human observer needs only to detect the UAV and identify it as an aircraft, and the UAV is moving, which makes detection much easier. Resolution of 1 ft will probably be adequate to determine that the UAV is not a bird. To make matters worse, the UAV can be detected acoustically, and it is difficult to make them very quiet. Whether flying a racetrack offset pattern or an orbit around the surveillance target, the regularity of the movement would make the UAV stand out as a man-made object after only an orbit or two.

Alternatively, we could use micro-UAVs, insectoids, or a collection of ground sensors on nearby buildings to avoid detection. Micro-UAVs or insectoids (either flying, hopping, or crawling) would use their small size to get extremely close to or inside a target building. Once on or in the building, they might attach themselves to a wall and observe. Such sensors and platforms are being explored at Los Alamos and other laboratories, but a host of aerodynamic, power-supply, navigation, and communication challenges need to be overcome before they have much operational utility. These systems offer promise for some high-priority, specialized surveillance missions; however we view them as being unlikely to be practical for routine surveillance missions in the near term.

The only enduring, high-resolution covert sensor that is practical in the near term is either an unmanned ground sensor or a ground observation team. Even with these alternatives, there is some chance of discovery upon insertion or at some later point. Inserting ground sensors covertly is tricky and requires either ground personnel (perhaps disguised as maintenance workers) or a precise and quiet airborne mode. Also in cases where enduring surveillance is required, ground sensors may fail and have to be replaced and ground observers must be rotated or resupplied.

\textsuperscript{23}See pages 172–173 for more on these performance trade-offs.
In our concept, we envision deploying miniaturized ground sensors by VTOL UAV. These would be deployed at night by a small, quiet VTOL UAV. To avoid detection, the UAV would need to fly a profile that maximized masking by buildings or rooftop structures. For example, most multistory urban buildings do not have completely flat roofs. Typically, the roof space also contains a 1-story structure housing elevator, heating, or other machinery. A VTOL UAV could land on the far side of this structure to escape visual detection from the target while implanting the sensor, but doing so would put the sensor in an undesirable location. For this reason, the sensor would need some limited mobility so that it could crawl to the correct location on the roof. Once it was in position, a small telescoping arm would raise the optics or other sensor above the roof lip for viewing, minimizing its signature from the target building (see Figure 5.7). To minimize accidental discovery by people who might have occasion

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24 These would range in size from a shoebox down to a large coin.
to visit the rooftop, the sensor housing would need to be designed to blend in with the surroundings, masquerading as a piece of electrical equipment or other cultural artifact. Alternatively, sensors might be designed for emplacement on walls or other hard-to-reach places. In these cases, they also would need to be designed to blend in with the surroundings.

As Figure 5.8 illustrates, sensors on multiple buildings would provide continuous surveillance of all building entrances, selected interior spaces with windows, rooftops, and balconies as appropriate. In addition to surveilling this fixed site, it might also be necessary to follow a person or vehicle after he or it had left the site. We envision a VTOL UAV for this task. It would land on an isolated location on a nearby rooftop (perhaps on top of the machinery structure), where it would stand by. If a target person or vehicle left the structure, this UAV would take off and follow it. For this concept to work, the UAV would have to be partially powered up and able to achieve flight within a short period of time, most likely under a minute. To give the UAV a
bit more time to get airborne, it might be necessary to implant additional ground sensors along avenues of approach to the building. Another possibility would use a medium-altitude UAV to provide interim coverage until the VTOL UAV was able to take over, although lines of sight to the target would be sporadic in urban-core areas, particularly if the target made many turns.

The most robust concept would use some combination of ground personnel (on foot and in vehicles), unmanned ground sensors, and airborne platforms. USAF and joint exercises (as well as many years of law-enforcement experience) using airborne platforms and ground personnel have shown this to be a highly effective way to covertly follow vehicles.

RESUPPLY ISOLATED FRIENDLY GROUND FORCES

During urban operations, friendly ground forces may become isolated and need resupply from the air. We specify urban operations, because isolation is much more likely to happen in urban settings because of the difficulty of preventing adversary infiltration of friendly lines. Also, friendly patrols or special operations forces often will be operating in contested or adversary-controlled terrain. In many cases, adversary roadblocks, downed bridges, or rubble in roads will mean that such forces cannot be resupplied via ground routes.

This is exactly what happened to Task Force Ranger in Mogadishu when the operation went awry. Unable to withdraw or be reinforced by ground, the task force—in desperate need of ammunition, intravenous fluid bags (IVs), water, and other supplies—found shelter in a few small buildings. One helicopter did manage to hover over one friendly group and drop some supplies, but it was so badly shot up in the process that it barely made it back to the airport. No other attempts were made.25

In such situations, adversary fire will prevent helicopter resupply, and traditional fixed-wing airdrop from safer altitudes lacks the precision needed to put the supplies in the right hands.

In the concept illustrated in Figure 5.9, we propose developing GPS-guided resupply canisters. The isolated unit would transmit its supply request and GPS coordinates to a control center, which would dispatch an aircraft—fighter, transport, or rotary wing. A canister could be prepackaged with basic supplies or tailored to support specific mission needs. It could be released from a variety of altitudes and standoff ranges, depending on the local situation. The canister would be aerodynamically shaped, have control surfaces similar to a GPS- or laser-guided bomb, and would be programmed to fly to the GPS coordinates of the isolated unit. At a relatively low altitude (to prevent drift), a drogue chute would be deployed to slow the canister. Shortly before impact, airbags also would deploy to cushion the impact.

Basic engineering and field tests will have to be done to determine the feasibility of this concept. However, the combination of shock-protected compartments, air bags, and a drogue chute should allow precision resupply in urban settings.
Provide Close Support for Ground Forces

As noted above, it is easy for small ground forces to become isolated in urban settings. Urban structures limit both visibility and fields of fire, horizontally and vertically, making it difficult for ground forces to provide mutually supporting fire. Traditional fire support from artillery is often limited in urban areas because of its low-angle trajectory. Mortars, which fire at much steeper angles, are better able to get over buildings. However, both mortars and artillery are insufficiently accurate to use in situations where collateral damage must be minimized. Air forces can provide immediate and accurate fire support to friendly ground forces engaged in close combat.

Figure 5.10 illustrates one concept for providing fire support to a small ground element. In the illustration, a friendly patrol at ground level has become pinned down by adversary forces firing from fourth-story windows across the street. The friendly force uses a laser rangefinder/GPS receiver like the Viper system to determine the GPS coordinates of the adversary force. They also use a circular or
concentric-coded laser designator to illuminate the adversary force. The GPS coordinates of the adversary force are relayed, along with their fire-support request, to a friendly command facility. The controller enters the GPS coordinates into a 3-D map/urban database and receives basic information about the building. From this, the controller learns that the adversary force is firing from an apartment building occupied by noncombatants. Under these conditions, strict ROE must be observed to minimize civilian casualties. A controller directs a friendly aircraft equipped with armed mini-UAVs to provide fire support.

The aircraft—in this case, a fighter—releases the UAV, which uses GPS signals to fly toward the adversary’s position. At this point, its onboard guidance system determines the best approach route, using an onboard 3-D map to negotiate the city streets, and the UAV detects the laser reflection off the adversary’s position and flies a path directly in front of it, firing multiple grenade-sized explosives or perhaps a nonlethal incapacitating agent through the windows. The UAV would have a multiple-shot capacity and could return to fire again if necessary. Although such a limited-effects weapon might not disable or kill all the adversary combatants, it would probably produce sufficient shock to allow the friendly forces to escape.

Ideally, such weapons would carry variable-effect munitions, which allow the amount of explosive power to be adjusted for each mission. Again, the technical details of such a weapon have yet to be worked out, but the concept is fundamentally practicable.

To summarize, the key characteristics of this weapon are its small size and slow speed. Both characteristics enable it to maneuver in the urban canyons and to either fly by a window, firing a weapon as it passes, or to turn and fly through the window and detonate inside. The small size and weight and the slow speed of this weapon would minimize penetration and collateral damage in civilian structures.

THE ROLE OF THE JOINT CONTROL CENTER

In the type of urban operations we emphasize in this report, we think it is unlikely that sensor detection of weapons, adversary personnel, or vehicles will lead to lethal fires being put automatically on the target. Rather, we expect there to be at least one human servicemember
in the loop between the sensor and the shooter: a controller in the air or on the ground in the rear who has responsibility for a sector of the city in major operations in large cities or for the entire city in smaller operations. Controllers would develop situational awareness from ground-sensor inputs, communications with supported ground forces, airborne imagery, and background intelligence on expected adversary operations. They also would have knowledge of major civilian and friendly military activities planned for that day in their sector. For these concepts to work, the controller must have access to a 3-D database, be supported by sophisticated software that aids decisions by providing basic information about target coordinates (e.g., what building, what floor, who is thought to be there normally, where known friendly and adversary forces are), and have the power to authorize lethal fires. We illustrate this process in the following paragraphs.

Imagine a ground sensor detecting weapons moving through a building entrance, alleyway, or some other constricted feature. The controller’s console gives an alert with basic information about the situation. For example, the standard message might say something like “Alert: Weapons, Type: Long-barrel small arms, Count: five and counting, Location: Lat, Long, altitude.” The controller would select a database check (or perhaps this would be triggered simultaneously with the alert), and the coordinates would be compared to the urban database, providing additional information (Location: alley between Palms apartment building, 2100 East St, and abandoned warehouse at 2200 East St, Adversary forces: No current reports, Friendly forces: Foot patrol 5 blocks to east moving toward location, Civilians: Apartment building occupied, Recent operations: Friendly patrol ambushed 2 blocks west on 8/17/05).

Most ground systems would have multiple sensors to reduce false alarms and allow target ID. In this case, we envision a low-light TV or IR camera on the same system that detected the weapons. Alternatively, the camera might be located on a different system or airborne. The camera would be turned on and slewed automatically to the location where the weapons were detected. In this case, made simple for the sake of the illustration, the controller is able to observe the suspect personnel setting up an ambush in the alley. With many options at this point, the controller can request additional ground forces to surround and attack the ambushers or can bring in airborne
fire support. In this case, the controller alerts the friendly patrol and also an AC-130 or other fire-support platform orbiting over the city. The coordinates are uploaded to the AC-130, and a glide bomb is dropped on the adversary forces.

Precisely because of the complexity of these situations and the need for superior judgment, we see the controller playing a critical role in integrating airborne surveillance and fire support assets in urban operations. Many difficult command and control issues would have to be resolved before this system could be put in place. Such a control center would be a cross between a standard ground-element command center and a Combined Air Operations Center. Given the level of integration required, a joint operations center for urban operations would need to be staffed by airmen, soldiers, sailors, and marines to ensure that all the necessary expertise is available.

In this chapter, we presented new concepts to accomplish some of the more important and vexing operational tasks confronting U.S. joint forces in urban settings. We focused on capabilities that could plausibly be fielded within a decade rather than on long-term possibilities. Nevertheless, the capabilities envisioned here will not just happen; to be realized, they will require focused R&D and prototype development. The next chapter identifies and assesses the state of the art in six technology areas that have promise for improving the contribution of aerospace forces to joint urban operations.