Technologies Over the Near and Far Term for Light, Rapid-Reaction Forces

THROUGHOUT THIS BOOK, WE HAVE DISCUSSED many different technologies that light forces may employ. Here we assemble information about the systems, describe their development cycle, and show images of many of them in operation. These systems span the range of concepts from Rapid Force Projection to Army After Next, and include technologies for MOUT. Table C.1 summarizes the systems by function and by time period.

Table C.1—Near- and Far-Term Light Force Systems by Function

	Systems	
Function	**Near Term (Present to 15 years out)**	**Far Term (15 to 30 years out)**
RSTA (reconnaissance, surveillance, and target acquisition)	• RST-V (reconnaissance, surveillance, targeting vehicle) • COVER (commander's observation vehicle for elevated reconnaissance—a tethered UAV) • Close-range unmanned aerial vehicle (UAV) – High altitude endurance UAV – Unmanned ground vehicle (UGV) • Improved remotely monitored battlefield sensor system (IREMBASS) • Remote sentry • Air-deliverable acoustic sensor (ADAS) • Joint surveillance target attack radar system (JSTARS)	• Video imaging projectile • Microelectromechanical (MEMS) sensor net • Acoustic imaging system – Thru-wall imaging radar – Ground and foliage penetrating SAR radar
C2 (command and control)	• RFPI C2 • Light digital TOC – Sensor fusion system	• Battlefield visualization tools
Direct fire	• Javelin • Armored gun system (AGS) • AGS with line of sight antitank (LOSAT) – Follow-on to TOW (FOTT)	• Comanche/Longbow • Smart target-activated fire and forget (STAFF) • Guardian/directed energy • Electromagnetic/ electro-thermal (EM/ET) gun

Continued

Table C.1 Continued

Indirect fire	• Precision-guided mortar munition (PGMM) • Lightweight 155mm howitzer • High-mobility artillery rocket system (HIMARS) with MLRS rockets and ATACMS missiles – Sense and destroy armor (SADARM) – Damocles – Brilliant anti-tank submunition (BAT) – Fuel-air explosives	• BAT improvement (MMW) • Scramjet MLRS missile and 155mm round • Low-cost autonomous attack submunition (LOCAAS) • Advanced fire support system (AFSS) • Advanced robotic engagement system (ARES)
Obstacles	• Wide area munitions (WAM) • Aqueous and sticky foams • Anti-helicopter mines	• Super-lubricants • Controllable obstacles
Multifunctional	• Enhanced fiber-optic guided missile (EFOG-M) • Intelligent minefield (IMF) • Hydra (remote-controlled obstacle)	• Unmanned combat aerial vehicles (UCAVs) • LongFOG, Polyphem
Nonlethal weapons	• Anti-personnel – Foams – Nets – Calmatives – Acoustic weapons – Soft projectiles • Anti-materiel – Combustion inhibitors – Foams – Laser dazzlers	• Anti-personnel – Energy weapons – Airbags – Advanced calmatives • Anti-materiel – EMP (electromagnetic pulse) devices – Laser optics crazing/ retro-reflection
Airlifters	• C-130 • CH-47 • UH-60 • MI-26	• JTR • Tilt-rotor • SSTOL • Aeroship • Fast ship
Self-protection	• Multispectral smoke • Active protection system (APS)	• 3rd generation smoke • Laser air defense • Laser APS • RF bombs

RSTA

The light force will rely on a wide variety of systems for its eyes and ears. These don't have to be big or expensive to gather information on the battlefield, and it is sometimes even essential for them to be small and proliferated to assure coverage and avoid losses. The smallest sensors currently envisioned are scatterable microdevices the size of a seed or smaller. Figure C.1 shows a recent DARPA concept for seeded microsensors with multiple forms of sensing.[1] Because processors, power supplies, and communications devices have become so tiny, the limiting factor for MEMS (microelectromechanical system) sensors is often the aperture size for the wavelength being sensed—sound, visual, IR, radar, and so forth. MEMS sensors down to the size of dust particles have even been postulated, at least for the shorter-wavelength applications. These tiny devices, generally on the order of a few centimeters across or smaller, could be hand-emplaced or de-

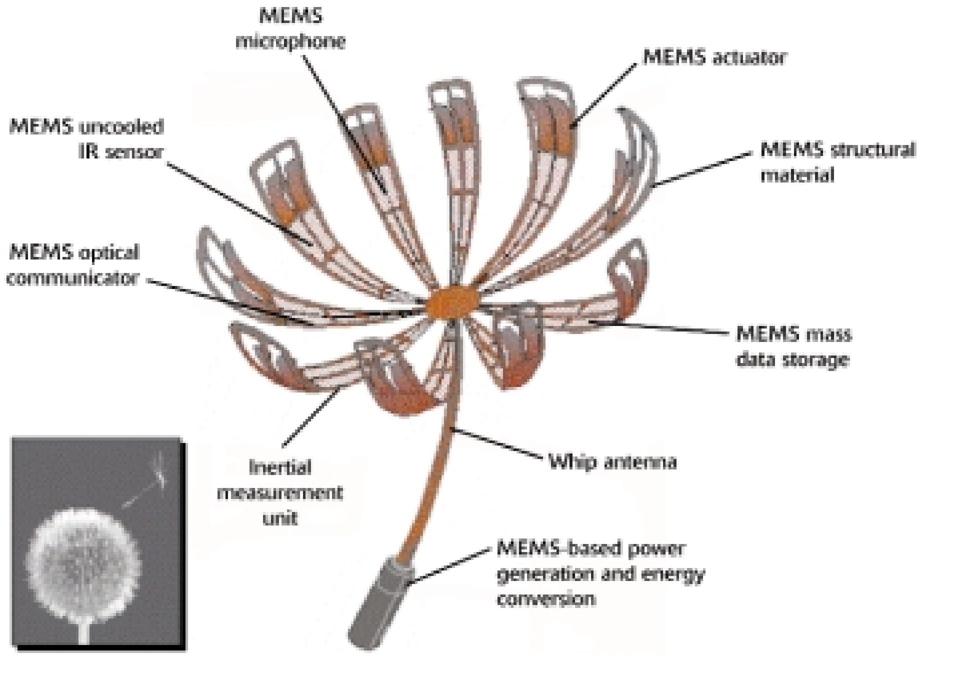


Image courtesy of Defense Advanced Research Projects Agency.

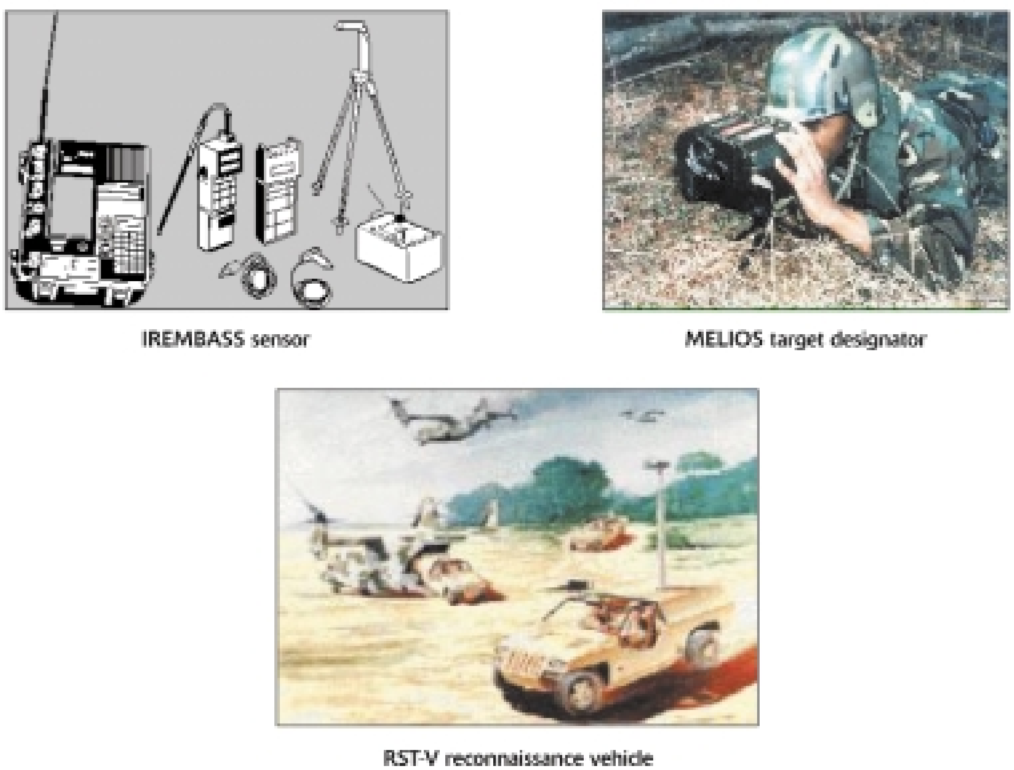
Figure C.1—Example of Seeded Microsensor Concept

ployed using artillery rounds, missiles, or manned or unmanned ground and air vehicles. The sensors would be inexpensive enough to scatter and leave behind. They should be able to wake up when disturbed, and intercommunicate back to a collecting node. Of course, without big improvements in battery life or duty cycles in which they sleep most of the time, they would likely have a short operating life.

The next step up in sensing would be unattended, shoebox-sized and larger sensing arrays. Some of the first of these unattended ground sensor (UGS) were widely used in Vietnam under the name REMBASS (remotely monitored battlefield sensor system). These were simple sensors which detected noise sources, ground vibrations, or hot objects and radioed back their presence. They gave no information about direction or range, only an indication that something had passed within some short distance of the sensor. Recent versions (called improved REMBASS or IREMBASS) were smaller, more sensitive, and had better position location. Nevertheless, detection, identification and location of targets require more capable systems. Two of the more important of these are the air-deliverable acoustic sensor (ADAS) and remote sentry, both described previously in Chapter Three. ADAS consists of an array of systems, each with five microphones and associated processing, which can detect and triangulate moving vehicles based on their distinctive signatures. These sensors don't require line of sight to the targets, but they are affected by noise, wind, and thermal effects. Remote sentry goes one step farther by using the microphones to cue a TV/FLIR imaging sensor toward the target. (For a good overview of UGSs, including REMBASS and remote sentry, see

Hewish (1998).) This is not always successful, because the acoustic sensor can hear targets over the hill, while the imaging sensor requires LOS. If well positioned, though, this should not be a problem. Detection ranges up to 2 kilometers for the acoustic sensor and 4–5 kilometers for the imaging sensor are reasonable. Future versions may be equipped with laser radar or MMW radar to give more information about vehicle type and status. Figure C.2 illustrates some of the tactical sensors and designators available to the soldier.

Hand-held sensors are especially important for MOUT and low intensity operations. Soldiers need to know if a person is carrying weapons, if booby traps are present, or if a room is occupied. Dissimilar metal detectors are claimed to be able to determine if a person is hiding a weapon, at least at close range. At longer ranges, radio frequency systems are said to be able to resonate and detect characteristic metallic structures such as the barrel of a rifle. Through-wall radar can take several different forms, from a hand-held radar "flashlight" to a vehicle-mounted synthetic aperture radar. Depending on the wavelength being emitted, these systems can penetrate one or several walls (un-



IREMBASS image courtesy of U.S. Army CECOM. RST-V image courtesy of Defense Advanced Research Projects Agency

Figure C.2—Some Tactical Sensor Systems

Image courtesy of General Dynamics Robotics Systems.

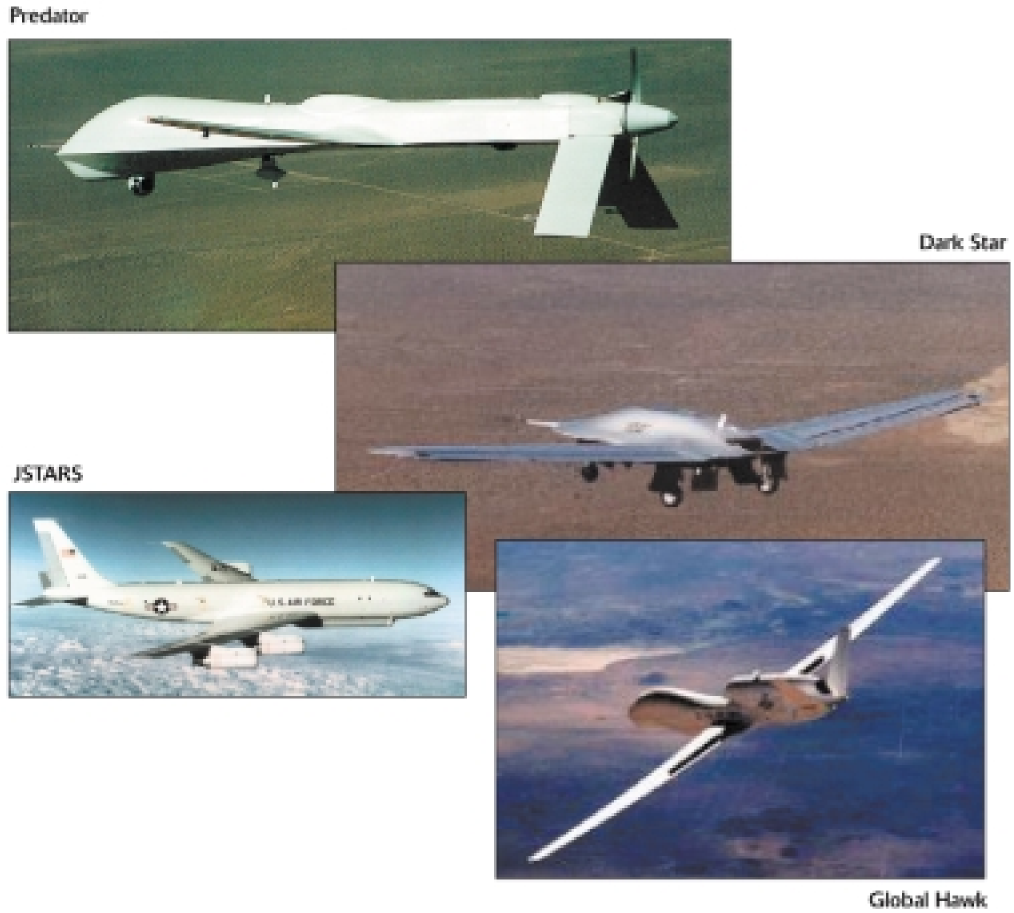
Figure C.3—Small (2000-pound) MDARS Robotic Vehicle

less metal shielding defeats them), detect moving entities, or even resolve images to a few inches, perhaps enough to tell if a terrorist is holding a weapon on a hostage.[2]

Ability to move is also important for the sensor network, particularly if the rapid-reaction force is maneuvering. Even if the force is stationary, the commander may need to orient reconnaissance assets on a particular area during times of risk or opportunity. Sensor mobility may follow many of the patterns in nature—the platforms might crawl, run, hop, fly, or hover. In fact, demonstrated systems for robotic platforms have been legged, wheeled, tracked, winged, and bladed. There have even been prototypes of biobots (insects and other animals equipped with sensors and control mechanisms).

Some larger mobile sensors include robotic scout vehicles, such as the 2000-pound MDARS platform shown in Figure C.3, the fully autonomous HMMWV exercised in DARPA's Demo II program (see Appendix D, Figure D.1), and the future scout vehicle (RST-V, shown in Figure C.2) proposed by DARPA. All of these systems provide detailed targeting information at the ground level, using large-aperture, long-range IR and visual imaging systems, many of which are mounted on extensible masts for best coverage and concealment. Typical detection ranges for these systems are 2–8 kilometers when searching for armor vehicles, and 1–3 km when looking for dismounted infantry.

Occupying the next layer up in the realm of sensor platforms are overhead assets, such as tactical and strategic UAVs, aerostats, JSTARS, and satellites. Overhead assets typically cannot see into areas covered by foliage, buildings, and camouflage, but they do cover large open areas quickly. Figure C.4 shows a variety of systems that may be available to the light forces. These include JSTARS (a manned aircraft standing off more



Predator image courtesy of General Atomics-ASI; Global Hawk image courtesy of Northrop Grumman Aeronautical Center; and Dark Star image courtesy of Lockheed Martin Skunk Works.

Figure C.4—Manned and Unmanned High Altitude Sensing Aircraft

than 100 kilometers from the force), high-altitude, overflying UAVs such as the stealthy Dark Star and the long-endurance Global Hawk, and low-altitude close-range UAVs such as Outrider and Predator. All of these can carry sizable payloads, including long-range SAR radars. Some of these radars can range out to hundreds of kilometers and even penetrate foliage and light cover. Real-time correlation of images from Predator and JSTARS was also recently demonstrated (see Kegan, 1999).

A special type of sensor under development is the video sensing projectile. Several different versions of this have been proposed, including one in which the round spins over the area of interest and the onboard TV camera scans the area, sending back images. Another design is targeted at an area then billows out a parachute, stabilizes, and scans the ground as it descends.

C2

Command and control refers to the presentation of information, planning courses of action, decisionmaking about options, and coordination of actions of the force. C2 is sometimes extended to C4, for command, control, communications, and computers. An honest appraisal of how it has historically been done would take it to C6, for confusion and collapse. This is where the term "fog of war" really sets in. Light forces have to rely on situational awareness, fast decisionmaking, and decisive action to survive. Unlike heavy forces, they cannot just depend on overwhelming firepower and armor to defeat the enemy. Thus, they are extremely sensitive to the proper orchestration of sensing, maneuver, and fires from a variety of scattered assets, and when things go wrong, they can go very wrong indeed.

Most concepts for future light forces envision (1) some form of communications network that can pass information throughout the force, (2) a fusion capability that can combine inputs from multiple sources, and (3) an automated tactical operations center subject to human operator override. The communication function can be low bandwidth, such as SINCGARS and the prototype soldier's radio, it can include high-bandwidth links such as satellite and surrogate satellite repeaters (UAVs and aerostats acting like more expensive satellites), or it can be multimode, such as the tactical internet. These options range from a low of perhaps 2 kilobits per second for SINCGARS to many megabits for some satellite and high-capacity links. Time latencies are similarly diverse, ranging from milliseconds to minutes. Figure C.5 illustrates several of the key systems. The diagram on the upper left of the figure shows the links present in the Forward Area Air Defense Command and Control (FAADC2) system. Here inputs from as-

Diagrams and images courtesy of Fort Sill.

Figure C.5—Examples of Command, Control, and Communications Systems sets such as E2-C aircraft are downlinked to filter centers that then send targets to missile launchers. Tactical fire control is somewhat simpler, as shown by the AFATDS (Advanced Field Artillery Tactical Data System) components. Forward observers (or TACFIRE radar systems) input target sets with portable entry devices, and the data is passed to fire direction centers and then to missile launchers or cannon batteries. Individual soldiers and teams, finally, use SINCGARS to communicate voice and data messages. There are many problems with this system in hilly, vegetated, or urban areas, and other communication devices are being fielded for these areas.

Fusion and presentation of information for future rapid-reaction forces has been envisioned in the form of small, HMMWV-mounted command centers. Visualization and decision-aiding systems such as ARDEC's virtual reality mission planning model and CECOM's battle planning and visualization tool can show target and friendly locations, age and confidence of the information, planned actions, and expected outcomes. These systems are essential for such functions as deconfliction of targets (making sure multiple shooters do not fire at the same target), deconfliction of the airspace (ensuring friendly missiles and aircraft do not collide), synchronization of fires and maneuver, projection of nonlethal effects, and coordination of logistics. The intent is to have each user supplied with a tailored, up-to-date common picture.

Direct-Fire Weapons

Direct-fire systems are typically weapons that engage targets in direct line of sight. Modes include rounds fired using chemical and electrical energy, guided and unguided missiles, and laser beams. These destroy things in very different ways: kinetic energy is essentially a spear that produces penetration and spalling, shaped-charge weapons result in a directed explosive burst, top attack typically fires an explosively forged penetrator (EFP) as the weapon flies over, and lasers produce burning and crazing. The simplest weapons are main guns firing APFSDS (armor-piercing, fin-stabilized, discarding sabot) rounds and HEAT (high energy anti-tank) rounds. APFSDS rounds are Mach 5, very dense (depleted uranium) long-rod penetrators that have enough energy to pierce thick armor and pass through enemy vehicles. HEAT rounds use explosive power and are very good against soft targets (e.g., trucks and BMPs) but typically cannot penetrate as much armor as APFSDS rounds. Both types of rounds typically have a maximum range of 3–4 kilometers (although some kills in Desert Storm were at around 5 kilometers). No guidance is present and little is needed, as the round is downrange in 2–3 seconds and accuracy is a few feet. Because of their weight and recoil, these large conventional guns are usually found only on main battle tanks. Because of improving protection on tanks, even larger guns (140mm and above) have been proposed for future systems. (For a good overview of planned improvements in both weapon systems and protection, see Ogorkiewicz (1997).)

Electromagnetic and electrothermal (EM and ET) guns do about the same thing as conventional tank rounds but use electric energy (in ET this is supplemented with chemical reactions) to provide the propelling force. The problem here is sufficient energy storage. A typical shot might consume 10–20 megajoules of energy, which requires the use of very large flywheels, supercapacitors, or jet engines to provide more than a few shots. Potential velocities are higher than for conventional guns, however, and may provide greater range and lethality for the same size weapon. If the energy storage problems are solved, these weapons may be mounted on medium or even lightweight vehicles.

Missiles can also reach Mach 5 speeds and above. The hypervelocity missile, also known as the kinetic energy missile (KEM) or line-of-sight antitank (LOSAT) weapon, uses a powerful solid propellant rocket motor to accelerate a "spear" or long-rod penetrator to 1,600 meters per second or more. The operator in the vehicle can then control the missile by sending infrared signals to sensors on the tail. Vehicles as light as the HMMWV have been proposed as firing platforms for the KEM (see Figure C.6). A light tank version has also been prototyped, carrying six missiles in each of two pods. It can engage targets at intervals of 2-3 seconds and at ranges of 5 kilometers or more. A long-range, farther-future variation proposed for AAN has ranges more than twice that of KEM.

Images courtesy of ASA(ALT).

Figure C.6—Direct-Fire Munitions Come in Many Forms

Slower missiles include TOW (tube-launched, optically-tracked, wire-guided), Javelin, Hellfire, and Maverick. All of these use some form of control to guide the missile to the target. Hellfire has gone through many improvement cycles and now has special variations for shipboard operations, low trajectories, cloud conditions, and reactive armor (Lange, 1998).

Laser weapons appear to be much farther in the future. Here chemical or solid-state lasers place energy directly on the target and attempt to burn or blind the vehicle.

Indirect-Fire Weapons

Indirect fire typically means that the target is engaged beyond line of sight, using a high trajectory to place munitions in the area. Targeting may be from reconnaissance assets in the air or on the ground, and the indirect-fire platform itself can be tens or even hundreds of kilometers from the target area. The sequence of engagement is much more complex than for direct-fire systems, and it typically includes stages involving target sensing, decisions by fire direction centers, actions by launch platforms, flyout by missiles or projectiles, and ejection and activation of submunitions over the target area. The simplest examples are mortars and towed howitzers. These are exemplified by the M-113 mounted 120mm mortar vehicle and the M-109 155mm self-propelled howitzer. Variations of the M-109 have been around for over 30 years. The latest, called Paladin, weighs 32 tons and fires up to four rounds per minute up to a range of almost 30 kilometers. A future, heavier system called Crusader has greater range, protection, and firing rate. These platforms are somewhat heavy for rapid-reaction airliftable forces, however. Lighter-weight systems include the 9,000-pound lightweight towed 155mm howitzer and the 4,000-pound towed 105mm howitzer.

Missile systems typically provide greater range and payload compared to the cannons and mortars, but they are usually much more expensive on a per-round basis. MLRS (Multiple Launch Rocket System) can fire MLRS rockets up to 32–50 kilometers (the longer range depending on planned improvements), and ATACMS missiles up to 300 kilometers. The launcher can load, arm, and ripple fire a 12-missile load in 5 minutes.[3] This system is also too heavy for most rapid-reaction forces. A much lighter (28,000-pound instead of 53,000-pound) HIMARS launcher carries a half-load of six MLRS missiles or a single ATACMS missile, and can be loaded on a C-130. Two of the indirect-fire systems are illustrated in Figure C.7, including the Copperhead laser-guided 155mm round.

Obstacles

These are devices to slow or attrit the enemy force, but they usually must be emplaced before the enemy's advance over the area. Conventional land mines are cheap and nondiscriminating—hence the number of treaties outlawing their use. Recent variations focus on armor vehicles or helicopters only, can be turned on and off, and do not have to be stepped on or rolled over to activate. A prime example is the wide area munition (WAM), termed Hornet. This system is capable of sensing and engaging combat vehi-

Figure C.7—Some Exemplary Indirect-Fire Systems

cles out to a 100-meter range. It uses a small microphone array to detect nearby armor vehicles and lofts a smart submunition over the target in the direction of nearest approach. Even if many targets are missed, these weapons have a disruption effect. The enemy column slows down or has to maneuver around burning hulks, and is susceptible to other fires.

Anti-helicopter mines are similar in nature to anti-armor mines, but they discriminate helicopter acoustic signatures (typically blade noise) and engage at longer ranges, out to 400 meters or so. These can be laid along ravines, next to ridge lines, and on other likely helicopter avenues of approach.

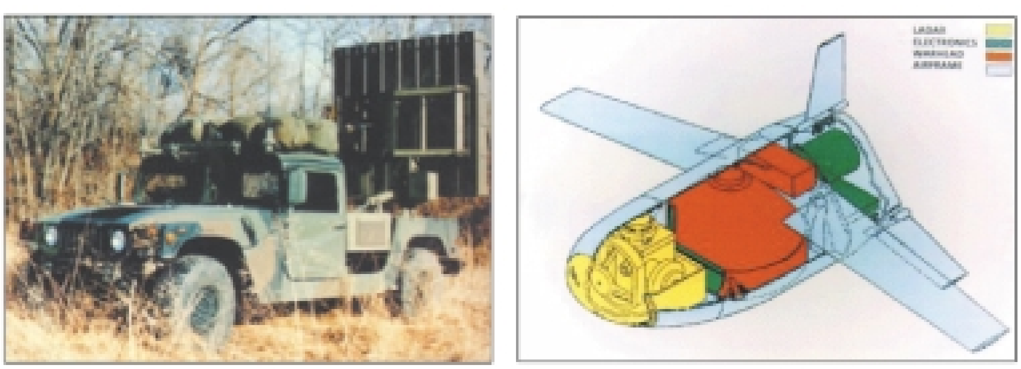
Controllable obstacles are command-activated lethal and nonlethal devices that can be left in place for long periods. Especially good for covering approaches to urban areas, these can release foams, erect vehicle barricades, fire explosively formed projectiles against armor, or eject lethal anti-personnel shrapnel or ball bearings (e.g., remotely controlled claymore mines). The Hydra system from Aerojet General is a good example of a controllable system, as it uses small video cameras boresighted with explosively forged projectiles. Up to six cameras can be linked back to a soldier by fiber-optic cable.

Multifunctional Systems

Multifunctional systems can act as both sensor and weapon. Good examples are fiber-optic guided missiles (FOG-Ms), loitering submunitions, lethal UAVs, space weapons, and intelligent minefields. Many countries are now developing FOG-Ms, with the primary ones being the U.S. EFOG-M and Euromissile's Polyphem. The EFOG-M missile has a 15-kilometer range and a speed of 100 meters per second; it has a GPS antenna/receiver onboard and an imaging sensor in the nose that sends back video to the operator along a fiber-optic link. Six EFOG-M missiles are mounted on a HMMWV platform. Polyphem is a larger FOG-M, with a 60-kilometer maximum range, a speed of 200 meters per second, and a very large (20-kilogram) warhead. EFOG-M is designed to attack armor and other mobile targets, while Polyphem seems more suited to high-value deep targets such as C2 centers, AD sites, helicopter FAARPS, and long-range missile batteries. Both systems can send back information about the battlefield as they fly out to their targets. Both systems have successfully completed initial demonstrations of their capabilities.

Lethal UAVs or UCAVs also send back video information and can attack targets of opportunity, but typically they have a much longer time on station than FOG-Ms. Two versions of UCAVs have been proposed: a low-cost, hit-to-kill concept based on a small airframe such as Exdrone, and a higher-cost concept which carries missiles onboard. UAVs such as Predator and Outrider should have the payload capability to carry sensor packages, communication sets, and air-to-ground missiles such as Hellfire, TOW, or Javelin. At the other extreme is the small LOCAAS (low-cost autonomous attack submunition), which can fly for 30 minutes or so, detect targets with its onboard laser radar, and dive in to attack them. Images of the developmental LOCAAS and FOG-M systems are shown in Figure C.8.

The intelligent minefield is a combination of the acoustic sensor array and wide area mine concepts described earlier. Here an array of mines and "gateway" fusion and com-



EFOG-M LOCAAS

Figure C.8—Enhanced Fiber-Optic Guided Missile and LOCAAS Loitering Weapon Systems munication nodes will detect targets and, when given the command, engage these targets at the opportune time. Because targets can be detected at a much greater distance than they can be engaged (often detection occurs at 2–3 kilometers for armor vehicles, but engagement is at 0.1 kilometer or less), the IMF may frequently be more important as a reconnaissance asset than as an obstacle.

Self-Protection

As vehicles in the rapid-reaction forces become lighter and smaller, they are able to carry less armor and must resort to other means of self-protection. These include speed, agility, firepower, stealth, and probably most important, use of active protection systems (APS). New advances in APS are cropping up around the world. These vehicle add-on systems are able to defeat a wide variety of weapons by detecting the incoming missiles or rounds and triggering smoke grenades, laser dazzlers, fragmentation grenades, and protective missiles. These systems may even be able to break up long-rod penetrators, by shearing them in flight with metal plates or altering their trajectory with explosives. The Russian Arena, Shtora, and Drozd systems, several of which are in production on export vehicles such as the T-72 and T-80 tanks, utilize many of these protective devices.[4] U.S. developmental systems, such as Boeing's SLID (small low-cost interceptor device), further enhance protection with a small, maneuverable hit-to-kill interceptor missile.

A special self-protection technique for urban areas is the use of "designer" multispectral smoke. This smoke would obscure all sensor wavelengths from visual to IR to millimeter wave, but it would have spectral windows at the sensor frequencies of the friendly forces. This would allow dismounted soldiers and vehicles to scoot from position to position while under cover of smoke. The difficulty is producing multispectral smoke with variably sized particles, some sizes of which are missing, thus producing the windows.

Airlift

Tactical airlift is now being performed by well-proven systems: UH-60 medium-lift and CH-47 heavy-lift helicopters and C-130 cargo aircraft. These craft have some survivability, speed, and range problems, though, as indicated in Chapter Five. A rapid-reaction force must be able to penetrate close to the enemy, carry both light and medium weight vehicles (sometimes up to 30 tons), and land and take off from either small open areas or short, unprepared airstrips. The only new tactical transport aircraft in recent years, the V-22, has good range and speed but little payload capability.

The next generation of lifters are expected to be more capable, and some are fast seacraft rather than aircraft. New rotorcraft include the proposed joint tactical rotorcraft (JTR), with up to a 10-ton payload and 170-knot speed, and the advanced airframe (AAF), with a 15-ton payload and 300-knot maximum speed. The JTR is configured as a conventional helicopter with special survivability packages, and the AAF is envisioned as a tilt-rotor, essentially a scaled-up and more expensive V-22. As planners have considered larger ground vehicles (up to 30 tons) for their rapid-reaction forces, designers have moved to the notion of SSTOL (super short takeoff and landing) aircraft. Such an aircraft is planned as a follow-on to the C-130, designed to be able to land and take off (fully loaded) on a 600-foot unprepared runway. Two versions have been proposed: a tilt-wing design with a very slow 40-knot stall speed, and a conventional fixed-wing aircraft with huge jet engines. Beyond these, the last two options are not true aircraft at all, but fast ships and hybrid aircraft. Ingalls Shipbuilding has proposed very fast ships with 60- to 80-knot capability and 10,000-ton capacity. Such a ship could carry a fully equipped brigade of light forces almost anywhere in the world in 4–5 days. Of course, such a ship might be vulnerable to attack at sea, so the disembarkation port would have to be secure. A hybrid aircraft concept is being developed by Lockheed Martin. This is a huge "aerocraft" that is half airplane and half blimp. It is designed for fast loading and unloading of up to a million pounds of cargo (Fulghum and Wall, 1999). With both commercial and military investment, the Hindenberg-sized aircraft could deploy forces at 125 knots, reaching most areas in the world in 2–3 days.

APPENDIX C ENDNOTES

1 For a summary of military applications of MEMS sensors, see Brendley and Steeb (1993) and the DARPA MEMS Web page, *http://www.darpa.mil/MTO/MEMS*. (Web site accessed and running on July 28, 2000.)

2 Images provided by Raytheon through-wall radars are reproduced in "Surveillance Through Walls and Other Opaque Materials," International Society for Optical Engineering (OE Reports), August 1995, pp. 1–3.

3 A good description of the MLRS system can be found on the World Wide Web at *http://sun00781.dn.net/man/dod-101/sys/land/m270.htm*. (Web site accessed and running on July 28, 2000.)

4 Even the small (18-ton) Russian 2S25 light tank is said to be fitted with the Arena defensive system, increasing weight by 300 kilograms, according to a short article in *International Defense Review*, May 1999, p. 14.