Chapter Five

TOWARD A SWARMING DOCTRINE?

Although the current FORCE XXI modernization effort is well under way and the Army hopes to complete the digitization of its first Army XXI Corps within a few years, the basic doctrine and division-based design of the ground force will not be changed radically. Any proposal (such as swarming) that calls for dismantling the Army division or the reinforced Marine battalion as the basic organizational building block will need to recognize that 60 years of doctrinal and institutional history present formidable obstacles. The service institutions themselves would have to change, as would joint doctrine.

For example, in *Breaking the Phalanx: A New Design for Landpower in the 21st Century* (Westport, CT: Praeger Publishers, 1997), Douglas MacGregor (of the Center for Strategic and International Studies in Washington, DC) proposes a new organization for the future army and argues that the division should be disestablished in favor of the brigade task force. MacGregor suggests that combined-arms "combat groups" will be effective, given the technology and missions of the future. His thought-provoking book provides detailed command, organization, and equipment tables that deserve serious consideration.[1] But even MacGregor did not stray too far in changes to equipment.[2]

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[1]It is not clear that MacGregor's changes to doctrine and modernization are feasible in the short term (before Army After Next), nor is it clear that his combat groups would be effective across the threat environment, especially in peace operations. He probably did not include a large enough support structure.

[2]MacGregor lowered the number of tanks and infantry fighting vehicles required for his battle groups, but he did not replace them.

A doctrine based on swarming calls for more-radical changes in equipment and organization. Abrams tanks and Bradley fighting vehicles are not mobile enough for swarming operations, because they require major refueling and maintenance support. Tanks are designed for massing fires, not for dispersed operations with long-range fires.

Any doctrine that calls for such a drastic reduction in heavy vehicles will encounter a lot of resistance. A major shift in doctrine is risky. DoD is also currently spending billions every year to maintain a "warm" tracked-combat-vehicle industrial base.[3] The U.S. Army has bought about 8,000 Abrams tanks and 6,500 Bradleys since 1980. Plans are under way to field a future tank around the 2015–2020 timeframe.[4]

At the same time, the Army recognizes the need for a lighter force that can deploy rapidly and stand against heavy ground forces. That force does not exist. Because of their weight, U.S. heavy forces are not rapidly deployable.[5] DoD is already seeking a solution. Ongoing research initiatives such as the Rapid Force Projection Initiative (RFPI) Advanced Concept Technology Demonstration (ACTD) are investigating new technologies that enable light airborne forces to

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[3]Recent government studies of the Tracked Combat Vehicle Industrial Base (Abrams and Bradley production) have estimated that, to keep the tank industrial base *warm*—capable of producing new tanks and expanding production within a short time (about 2 years)—the minimum necessary production activity would be to upgrade 120 Abrams tanks each year at the Lima, Ohio, tank facility (this is, in fact, what the Army currently does). In 1993, the procurement cost to maintain a warm production base was estimated at $650 billion. See Congressional Budget Office, "Alternatives for the US Tank Industrial Base," CBO Papers February 1993; Office of the Under Secretary of Defense, Industrial Capabilities and Assessments, *Industrial Assessment for Tracked Combat Vehicles*, October 1995.

[4]Both the Army and Congress are interested in preserving the current industrial base and maintaining an armor and ballistic structure production capability, but a debate exists over which tank-modernization path the Army should follow. The Army Science Board (ASB) argues for an "evolutionary" path to the next-generation tank: an Abrams block upgrade (M-1A4) between 2008 and 2020, which would ensure a warm tank industrial base. The Armor Center at Ft. Knox, Kentucky, favors a "leap ahead" approach to the Future Combat System (FCS), which precludes any M-1A2 production beyond 2003.

[5]Abrams tanks must be shipped to their destinations, a process that takes weeks. Once there, they usually need heavy-equipment transporters to move them far from the shoreline.

face advancing enemy armor.[6] In the fall of 1999, Army Chief of Staff General Eric Shinseki announced plans to redesign two combat brigades into a mobile force that can be rapidly deployed to any crisis spot in the world. Lighter alternatives to the Abrams tank and the Bradley IFV are currently being sought for this new "Strike Force."[7]

Because of these constraints, this monograph recommends that a doctrine based on swarming is more appropriate for future light or medium forces. History suggests that swarming works when an army possesses standoff capability, the ability to elude its opponents, and superior situational awareness. Ongoing technological development suggests that light Army or Marine units may enjoy these fundamental advantages in the future. Assuming that technological solutions are developed, a swarming doctrine may not only be feasible, it may be more appropriate than the currently organized division-based forces for certain light force missions. It is hoped that this survey has demonstrated that swarming has worked well in the past when certain advantages obtained; it is reasonable to assume that it can do so again if future forces enjoy those same advantages.

This discussion of historical swarming and the feasibility of using swarming in the future serves as another step in the process of proposal and debate about future U.S. military doctrine. The next step is to further flesh out the details of organizational design, the specifics of weapon platforms, and the feasibility of dispersed battlefield logistics without traditional lines of supply. Swarming scenarios have already been used in some high-level wargaming exercises.[8] Further

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[6]RAND has a long history of exploration, analysis, and modeling of weapons and sensors for light forces, with both direct- and indirect-fire capabilities. One indirect-fire concept is the "hunter/standoff killer" concept, whereby assorted manned or unmanned hunters sense the enemy and communicate target coordinates back to either C2 nodes or indirect-fire assets (killers). See R. Steeb, J. Matsumura, T. G. Covington, T. J. Herbert, and S. Eisenhard, *Rapid Force Projection: Exploring New Technology Concepts for Light Airborne Forces*, Santa Monica, CA: RAND, DB-168-A/OSD, 1996.

[7]Ed Offley, "Fast Strike Force Being Developed at Fort Lewis," *Seattle Post-Intelligencer*, November 3, 1999.

[8]The Office of the Secretary of Defense (OSD) and U.S. Army Deputy Chief of Staff for Operations and Plans (DCSOPS) have conducted wargames that explore a swarming operational concept (at the Dominating Maneuver Game VI, 30 June–2 July 1997, U.S. Army War College, Carlisle Barracks, PA). Their view of swarming is that maneuver forces allow enemy forces to advance fairly unaware until they are attacked from all

study is needed to determine whether computer simulations, gaming, and testing might offer insights.[9] Eventually, an experimental force (EXFOR) could be created from an existing battalion, trained and equipped for swarming, and sent to a combat training center such as the Joint Readiness Training Center (JRTC) at Ft. Polk, Louisiana, for force-on-force training with an opposition force (OPFOR). Practical field experiments would help demonstrate whether swarming is feasible.

Since a future swarming doctrine is still very much a concept in progress, additional detail is offered here on the tactics, logistics, command and organization, and technology of a possible swarming doctrine. Limitations of and situations conducive to swarming are also described. This speculative discussion is based as much as possible on the historical conclusions from the ten cases.

TACTICS

Swarming can be conceptually broken into four stages: locate, converge, attack, and disperse. Swarming forces must be capable of sustainable pulsing: Swarm networks must be able to come together rapidly and stealthily on a target, then redisperse and be able to recombine for a new pulse.[10] It is important that swarm units con-

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directions simultaneously. The swarm concept is built on the principles of complexity theory, and it assumes that blue units have to operate autonomously and adaptively according to the overall mission statement. The concept relies on a highly complex, artificial intelligence (AI)-assisted, theater-wide C4ISR architecture to coordinate fire support, information, and logistics. Swarm tactical maneuver units use precise, organic fire, information operations, and indirect strikes to cause enemy loss of cohesion and destruction. Swarming blue units operate among red units, striking exposed flanks and critical command and control (C2), combat support (CS), and combat service support (CSS) nodes in such a way that the enemy must constantly turn to multiple new threats emerging from constantly changing axes. Massing of fire occurs more often than massing of forces.

[9]The Center for Naval Analyses has already started computer simulation of swarming behavior by modeling combat as a complex, adaptive system with a set of simple, multi-agent "toy models" called ISAAC/EINSTein. These models assume that land combat is a complex adaptive system—essentially a nonlinear dynamic system composed of many interacting semiautonomous and hierarchically organized agents continuously adapting to a changing environment. Patterns of behavior may be observed from the decentralized and nonlinear local dynamics of the agent-based model.

[10]Arquilla and Ronfeldt, 1995, p. 465.

verge and attack simultaneously. Each individual swarm unit is vulnerable on its own, but if it is united in a concerted effort with other friendly units, overall lethality can be multiplied, because the phenomenon of the swarm effect is greater than the sum of its parts. Individual units or incompletely assembled groups are vulnerable to defeat in detail against the larger enemy force with its superior firepower and mass.[11]

Because of the increasing vulnerability of massed formations on the ground to airpower and WMD, the Dispersed Swarm maneuver is more appropriate for the future. More-dispersed operations are a natural response to the growing lethality of modern munitions.

Lightly armored and dispersed units must use elusiveness as a form of force protection. Lawrence of Arabia evoked the swarm philosophy of elusiveness when he compared the tactics of his Arab forces with those of his conventional Turkish opponents. Lawrence knew the Arabs needed a mobile force that would form "an influence, a thing invulnerable, intangible, without front or back, drifting about like a gas."[12]

In the past, some swarming units enjoyed what could be called "direct standoff fire," the capability to inflict damage on the enemy without receiving punishment in return, using weapons such as the composite bow or Mauser rifle. Today, swarm units can use indirect standoff weapons (both *organic*—carried on their persons—and *nonorganic*—a remote asset that has to be called to) such as missile-launched "brilliant" munitions or offshore naval platforms deep in

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[11]For example, the Chechen tank killer teams that preyed upon lone Russian T-72 tanks on the streets of Grozny in 1995 accomplished their kills by arriving at (or attacking) the target at the same time. Piecemeal RPG attacks by teams arriving at different times might have been suppressed or defeated in turn.

[12]Lawrence of Arabia's guerrilla campaigning on the Arabian peninsula during WWI is similar to swarming. Lawrence's Arab forces did not swarm; they conducted hit-and-run attacks. Nevertheless, his tactics relied on superior mobility and intelligence just as swarm tactics do. Lawrence sought to avoid direct battle and exploit the immense open space of the desert to cut the Turkish lines of communication—a strategy he could afford to employ (there was no political pressure to defend cities) and one of the major differences between swarming and guerrilla warfare. The peculiar political conditions of Lawrence's Arabian campaign enabled him to employ a Fabian strategy whereby he could abandon major cities, whereas swarming does not. See Asprey, 1994, p. 184.

the rear. Because of this ability to apply force against a target with assets located far away, light units will potentially be much more lethal than their counterparts from the past. Swarm tactics aim to leverage this shift from direct-fire to indirect-fire weapons to some degree in order to improve the mobility of the individual unit on the ground and reduce its signature.

LOGISTICS

Before the proven WWII division structure will be dismantled, the following questions must be addressed: Which combat service support assets should be organic to swarm units and which assets should be prepositioned? To what extent is aerial resupply possible? How can information technology ease logistics demand?

Superior mobility will require substantial fuel resupply, barring some revolutionary development in chemical propulsion technology. Without the typical main support battalion that is normally present in a division area of operations, swarm units will require a new way to repair and maintain their vehicles.

Since swarming requires vehicles that are either mobile or stealthy, Abrams tanks and Bradley fighting vehicles are not ideal. New generations of light strike vehicles (LSVs)—which require far, far less logistics support, less fuel, and no heavy-equipment support vehicles[13]—may prove more practical.

A swarm unit could also use more indirect-fire assets rather than organic direct-fire weapons, limiting its ammunition load. It would also have a smaller tail of support personnel (compared with that of a division-based force), which would lower logistics demand.

Another way to possibly reduce the demand for supplies is to use *focused logistics*, the U.S. Army's operational concept to leverage

[13]The Army's RFPI ACTD is looking at heavy HMMWVs to evaluate hunter/standoff killer operational techniques. The sensors of these light vehicles will include second-generation Forward-Looking Infrared Radar (FLIR) with embedded aided target recognition, acoustics, daylight TV, laser rangefinding, color digital maps, image compression/transmission, GPS, and secure communications. The goal is to transmit digital targeting reports plus imagery in near-real time to "killer" indirect-fire assets in the rear.

information technologies and thereby rapidly provide supplies such as food, fuel, equipment and ammunition.[14] The Marines call this *anticipatory logistics*, but it is basically the same thing. The notion here is that information-management systems allow constant visibility of all supplies to be maintained so that no unit need stockpile for emergencies. Smaller logistical tails result when ground combat units carry exactly those supplies they need, never more than necessary. Greater speed will help agile units maintain a faster tempo of operations. Considering both the frictions of war and the certainty of an adversary's trying to exploit dependence on such finely tuned logistics, how far the Army and Marines will be able to go is as yet unclear.

In short, the logistics problem of supplying widely dispersed units without traditional CSS battalions present is a difficult problem that will probably need to be addressed by a package of fixes. Additional fixes include the following:

- Spread the burden. Networked units can coordinate their supply needs, using situational awareness to transfer and share between units.
- Use common parts and systems. The organization of a swarming force will naturally be flat, with homogeneous unit types. Instead of ten battalions of Abrams and Bradleys, there might be 40 swarm units equipped with LSVs. With commonality of parts, there are fewer different types of systems to repair.
- Use precise aerial resupply when possible, including unmanned delivery systems such as GPS-guided parafoils.

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[14]Focused logistics uses a Velocity Management approach to battlefield distribution, wherein the speed and control of logistics material is more important than the mass of stockpiles. By re-engineering logistics processes, Velocity Management can reduce the long material flows that help create massive stocks of supplies. Eliminating non–value-added activity (such as obtaining an extra signature from a middle manager) and maintaining in-transit visibility (or knowing where every logistics item is at all times) decreases the logistician's response time to warfighter demands. In the past, U.S. inventories have typically been large because warfighters hoarded supplies "just-in-case" the items they ordered either took too long to arrive or never showed up. Rather than "just-in-case," focused logistics seeks to respond to real-time battlefield demand and move in the direction of a "just-in-time" philosophy. Rapid response to the needs of dispersed maneuver units will provide logistics support in hours and days rather than weeks.

- Use prepositioned supply depots.
- Create combat service support units that operate with particular clusters of swarm units. These CSS units remain mobile but carry no combat capability and are devoted to support functions.

Alternative ways to treat and evacuate casualties, such as telemedicine, need to be perfected. If casualties cannot be air-evacuated, swarm units must either carry the wounded themselves or consolidate them at temporary field hospitals.

COMMAND AND ORGANIZATION

The organization of a standard armored division includes not just four mechanized and six armored battalions, but other division support units such as an engineer battalion, a signal battalion, a chemical company, a brigade of artillery, an air defense battalion, and the division support command.[15] All of these support units provide critical functions. Finding an alternative way to provide that support—if it is needed for a swarm unit—is one of the next steps of a serious consideration of swarming. However, it is beyond the scope of this monograph to detail what a table of organization and equipment for a swarm unit should look like.

Organization and command are directly related. Organization determines the number, position, and responsibilities of noncommissioned and commissioned officers. Whenever a force of any size is divided into many parts, the problem of coordination between units becomes more difficult. The complexity of the command problem grows with the number of units, the power and range of their weapons, the speed at which they move, and the space over which they operate.[16]

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[15]Although the division structure has evolved somewhat since 1917, the major issue of Army force development has remained establishing the numbers and types of support units that should be in the echelons above division. As weapons have improved in lethality, the proportion of the army devoted to combat has decreased and the proportion devoted to support has increased.

[16] Van Creveld, 1985, p. 6.

Improved C4I technologies may provide part of the answer by increasing the supply of command, but a swarming doctrine will have to provide other ways to reduce the demand for command.[17] One way is to adopt a decentralized system of command in which orders flow from the bottom up rather than from the top down. The other way is to address training.

The extreme decentralization of a network organization with semi-autonomous units calls for the mission-order system of command (the German concept of *Auftragstaktik).* In the mission-order system, small-unit commanders are granted the freedom to deal with the local tactical situation on the spot while following the overall commander's *intent*.[18] Historically speaking, those armies that have allowed tactical commanders considerable latitude have been very successful. Roman centurions and military tribunes, Napoleon's marshals, and Mongol *toumen* commanders all demonstrated how the initiative of a subordinate leader initiative can minimize the complexity of hierarchical, top-down control.[19] Swarming would never work with a hierarchical command structure, because an extremely flat organization would place too much demand on the overall commander.

Achieving superior situational awareness may tempt higher-level commanders to exercise more control over tactical commanders on the scene—an urge that should be resisted. There is a natural tension between the decentralized system of *Auftragstaktik* and the very centralized command possibilities of the all-encompassing C4I system the U.S. Army is heading toward in its modernization effort. Even though high-level commanders may have unprecedented awareness of the battlefield, they should avoid micromanagement. Carl von Clausewitz's "friction" of war usually finds a way to ruin the best-laid

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[17]For example, personnel could remain in swarm units for the duration of their enlistment in order to improve unit cohesion (and thereby reduce the demand on command).

[18]Joint doctrine already embraces the general philosophy of commander's intent and the mission-order. See Joint Pub 3-0, *Doctrine for Joint Operations*, 1 February 1995.

[19]Van Creveld, 1985, p. 270.

plan.[20] A decentralized command system would be more adaptable to friction caused by a loss of communications.

The character of swarming conflict—dispersed operations conducted by numerous small units in close coordination—will require that small-unit leaders assume high initiative and responsibility. For example, the squad is the basic swarm element in the Marine Corps "Urban Swarm." The Marine command and control concept states that the squad leader at the point of contact assumes the role of On-Scene Tactical Commander until relieved, operating within the intent of the overall commander but remaining in command even as higher-ranked officers from adjacent units arrive during the course of the battle. A higher-ranked commander can assume overall command only after becoming fully acquainted with the tactical situation. Implicit in this type of command and control arrangement is the requirement that junior leaders be capable of much higher levels of command and responsibility (squad leaders with the knowledge of a platoon leader of today).

Future enlisted personnel will most likely have to undergo more-extensive training than in the past. Recruits may need to be of higher quality to begin with (score in the upper half of the Armed Forces Qualification Test). All too often, the human-capital side of a new doctrine does not get the attention it deserves. Even today, recruiting and retaining high-quality personnel in the military are increasingly difficult.[21] The linkage between doctrine and personnel quality standards cannot be ignored.

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[20]War is inherently a chaotic system where so many variables collide that a systematic breakdown of what actually occurs in any one battle is impossible. Clausewitz called this complexity and uncertainty the "friction" of war. *Friction* is used to represent all the unforeseen and uncontrollable factors of battle. In other words, friction corresponds to the factors that distinguish real war from war on paper. It includes the role of chance and how it slows down movement, sows confusion among various echelons of command, or makes something go wrong that has worked a hundred times before. See Carl von Clausewitz, *On War,* edited and translated by Michael Howard and Peter Paret, New York: Alfred A. Knopf, Inc., 1993.

[21]There are many reasons for this problem, including demographic trends, increased optempo and deployment overseas, a booming economy and a growing gap between civilian and military pay, and declining youth interest in enlistment while interest in attending college has grown (among high-quality youth).

TECHNOLOGY

The extent to which a swarming doctrine depends on superior technology is a key question. History demonstrates that technological advantage is *always* temporary. Technology alone will not suffice. Adversaries adapt to superior technology by either copying the technology or developing a countermeasure. In order for swarming to remain relevant, all the pieces of the RMA puzzle—doctrine, organization, and technology—must be fitted together properly.

That said, there are three critical functions that technology must enable for swarmer success: superior situational awareness, elusiveness (mobility and/or concealment), and direct and/or indirect standoff fire capability. The reader will no doubt note that these same capabilities, listed above, are already a major focus of the U.S. military's ongoing modernization effort.

Real-time situational awareness will require the integration of command and control systems, communication systems, and intelligence, surveillance, and reconnaissance systems.

The communication system for a dispersed tactical formation will have to be a mobile mesh communication network with high data throughput and survivability. Units must be capable of sharing information at all times, even in harsh electromagnetic environments.[22] Capture of nodes must not compromise system security. The Defense Advanced Research Projects Agency (DARPA) is already developing the kind of network communication systems essential for future swarmer units, especially dismounted swarmers.[23]

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[22]There are many kinds of threats to the tactical internet. Radio-frequency bombs, conventional jamming, information-warfare attacks, even high-altitude electromagnetic pulse attacks are possible. See Sean Edwards, "The Threat of High Altitude Electromagnetic Pulse (HEMP) to FORCE XXI," *National Security Studies Quarterly*, Vol. III, Issue 4, Autumn 1997.

[23]One goal of DARPA's Small Unit Operations program is to develop a mobile wireless communication system for widely dispersed tactical units. This equipment will be capable of supporting a tactical internet based on dismounted-soldier and mounted-vehicle nodes without having to rely on a fixed ground infrastructure—essentially a "comm on the move" capability. The most promising type of system would be a mobile mesh network of communication nodes that are able to buffer, store and route packets of information. Such a system would be capable of non–line-of-sight transmission, a critical requirement for urban warfare. The military community must either develop such systems themselves or fund commercial enterprises, because the

Sophisticated ISR and target-acquisition capabilities will be essential to detecting and tracking enemy ground formations. Swarm units will need to rely on multiple layers of ground, airborne, and space-based sensors and a robust tactical internet. The key to effective fires on all battlefields will be accurate and dependable target location. Precision targeting systems must be able to locate and transmit target information quickly and accurately over reliable communications means in order to deliver indirect fire before it is too late.

Rapidly responsive indirect precision fires delivered by rockets, missiles, naval gunfire, or tactical air must be available. In most cases, a swarming operation will be a joint operation. Ideally, swarm units should possess both organic standoff precision munitions and a capability to call for indirect-fire assets.[24] Indirect munitions will need to be GPS-guided and capable of in-flight corrective maneuvering.[25]

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marketplace is unlikely to produce a mobile wireless system with the necessary anti-jamming, security, and data-rate standards on it own. Commercial communications systems such as digital cellular systems are designed to achieve optimal spectral efficiency (bits per second per hertz), which is usually incompatible with good security characteristics such as low probability of detection. For an excellent study that addresses most of these issues, see Phillip M. Feldman, *Emerging Commercial Mobile Wireless Technology and Standards: Suitable for the Army?* Santa Monica, CA: RAND, MR-960-A, 1998.

[24]Clearly, a mobile light force would need a mix of direct and indirect fires. We should not expect small teams to get along without significant organic firepower, especially if the weather is cloudy or the terrain masks the movement of ground forces. For example, previous RAND work by Randy Steeb, John Matsumura, and colleagues concluded that current and near-future indirect-fire systems are not enough to protect a light airborne brigade against the assault of a division or more of enemy armor. See Steeb et al., 1996.

[25]Space restrictions do not allow a detailed discussion of the possible contributions of long-range indirect-fire assets. Clearly, one problem will be the short exposure time of targets moving between cover, traveling through urban areas, etc. Future systems may be able to detect targets at range, but the exposure time may be too short. For those standoff weapons that have 10, 20, or more minutes over target, the exposure time may be too short to engage the target. One way around this is to use loitering weapons or update-in-flight. For further information, see J. Matsumura, R. Steeb, T. J. Herbert, M. R. Lees, S. Eisenhard, and A. B. Stich, *Analytic Support to the Defense Science Board: Tactics and Technology for 21st Century Military Superiority*, Santa Monica, CA: RAND, DB-198-A, 1997.

Some kind of LSV will be needed to provide superior mobility for certain types of terrain.[26] This vehicle should probably also be light enough to be airlifted around the battlefield if necessary. Striking a balance between speed and survivability is the challenge. Vehicles light enough to be moved by helicopters, such as the 4-ton HMMWV, remain vulnerable because of their minimal armor; medium-weight vehicles, such as the LAV-25 (a 6 × 6 wheeled APC weighing about 14 tons), are top-heavy (although a fixed-wing aircraft, such as a C-130 or a C-17, could transport these to a theater).

It is the synergistic combination of these capabilities that matters. All parts of a "system of systems"[27] approach are mutually reinforcing and dependent. Standoff weapons need targeting data from ISR systems, ISR systems must be controlled with C2 systems, and communication systems provide the backbone for all other systems. No single technological capability will be a "silver bullet."

LIMITATIONS TO SWARMING

Battles are won by the careful meshing of one adversary's advantages with the other's weaknesses. Swarming is no exception. As with any tactic or strategy, swarming will not work against all types of opponents in all situations. It should be used in scenarios or missions for which it is most applicable. Even when swarm units have the advantages of superior situational awareness, elusiveness, and standoff fire, there are foreseeable missions and conditions for which swarming may not be ideal.

For example, the Massed Swarm maneuver used by the most-conventional armies in the past would present a problem today because the initial mass of troops that approached the battlefield (before they swarmed) would be vulnerable to modern munitions. The Dispersed Swarm maneuver is preferred, because it increases the survivability of future forces by allowing dispersed operations.

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[26]In mountainous and other impassable terrain, dismounted units may be the only option.

[27]Admiral William A. Owens uses the term *system of systems* to represent a concept whereby weapons and systems from three technology areas—sensors, C4I, and precison guided munitions (PGMs)—will interact synergistically on future battlefields. See "The Emerging System of Systems," *Military Review*, May–June 1995, pp. 15–19.

Defensive swarming along a border or any area without maneuvering room could be a problem. If, prior to hostilities, swarm units have to defend border areas adjacent to the enemy, they are probably not well suited to providing a fixed, linear defense. The swarmer must either be allowed to preemptively swarm on the offense (see Figure 5.1) and cross into enemy territory first, or the attacker must be allowed to penetrate the swarmer's home territory in order to allow defensive swarmer attacks from all directions (see Figure 5.2).

Deliberate swarming attacks against fixed, defensive positions may not succeed when the defender has had time to fortify those positions and place extensive minefields.[28] A swarm attack that is channeled will fail. Heavily mined areas pose a problem for a swarming doctrine, which places so much emphasis on dispersion and maneuver.

If the enemy is an elusive guerrilla force in difficult terrain where vehicles cannot operate, only dismounted swarm units may be feasible. Dismounted swarm units will probably not have a direct standoff fire capability over their opponents (except perhaps at night).

SCENARIOS CONDUCIVE TO SWARMING

One small war rarely resembles another, so smaller wars tend to present more-unorthodox challenges to conventional powers. In general, the decentralized nature of swarm organizations offers added tactical flexibility, which may prove more advantageous in small-scale contingencies. Guerrilla campaigns present a special challenge for the conventional army; oftentimes, the dominant force must adjust its strategy and tactics to suit the nature of the enemy and the terrain.

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[28]Extensive minefields might be a problem for swarm units with little logistics support, because they may not have the capability to clear and detect minefields quickly.

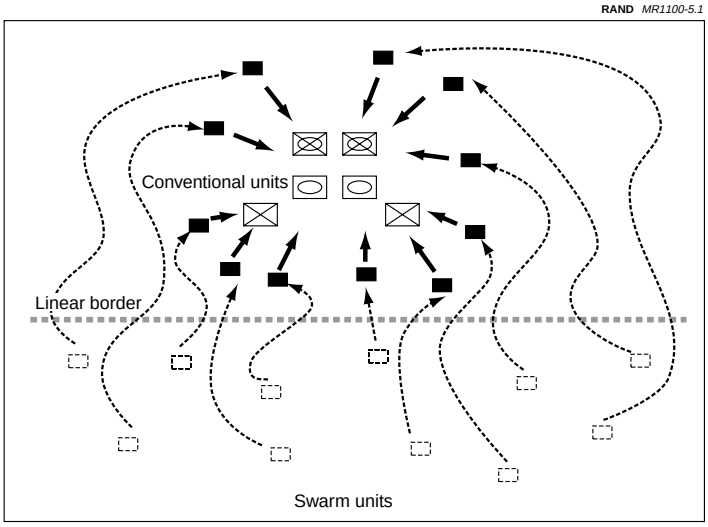

Figure 5.1—Offensive Swarming at a Border

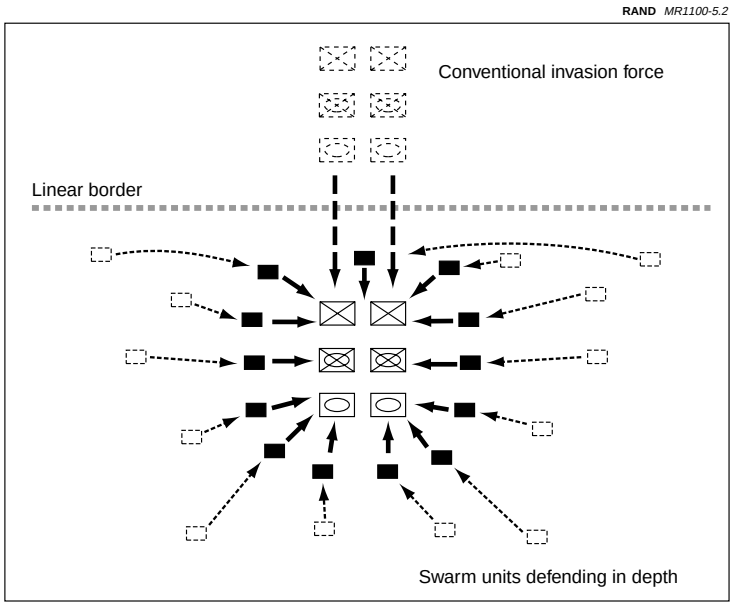

Figure 5.2—Defensive Swarming at a Border

In the changing post–Cold War environment, a network-based army that swarms may be better suited for certain missions. In fact, some of the very missions that U.S. military leaders foresee as being more likely in the future are conducive to swarming, including small-scale contingencies such as expeditionary (rapid force projection) operations, dispersed operations, counterinsurgencies, and peace operations.[29]

Rapid Force Projection

The problem of how to airlift heavy vehicles long distances will not be solved soon. As long as the United States must rely on relatively slow, oceangoing transport for its strategic lift, power-projection forces will not be able to rely on heavy weapons such as the 60-ton Abrams tanks at the beginning of a crisis. The most rapidly deployable units, such as the 75th Ranger regiment, are basically light infantry units without heavy, organic firepower.

Currently, the mission of rapid force projection is handled by light units such as the Marine Corps Expeditionary Units and Army airborne and air assault units, which lack tactical mobility and the capability to lay down heavy ordnance and so are vulnerable to enemy armor. Airborne units are capable of rapidly deploying (within a few days) and slowing down enemy armor, but not halting armor. What is needed is some sort of intermediate unit, in terms of mobility and mass, that can deploy between the arrival of the lightest forces and the arrival of heavy armored units some weeks later. The light nature of the hypothetical swarm unit seems ideally suited for this role.[30]

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[29]AAN studies suggest that future land warfare will include contingencies that cover the spectrum of warfare, from operations other than war (which include peace operations and low-intensity operations) to high-intensity warfare, expeditionary operations, operations involving greater geographic scale, and operations with a greater probability of WMD use. See Lt. Gen. Edward G. Anderson III, "The New High Ground," *Armed Forces Journal International*, October 1997.

[30]The role in this case is rapid projection to defeat heavy ground forces. This monograph does not mean to imply that swarm units could supplant the United States' lightest forces for missions such as airfield seizures, raids, ambushes, and operations in the most difficult terrain such as mountains.

WMD Environments and Dispersed Operations

Given the increasing dominance of U.S. conventional power, future adversaries may conclude that the only effective way to fight the United States is to employ asymmetric strategies. One such asymmetric response is the use of chemical, biological, or even nuclear weapons against U.S. forces deployed in a regional crisis. Breaking a force into many smaller pieces and increasing the distance between maneuver units is one way to lower the vulnerability of U.S. forces.[31] Tactical dispersion provides force protection: The more dispersed a deployed ground force is, the less vulnerable it is to WMD and other destructive weapons.[32] Swarm units deployed in a network are ideally suited for this type of environment, assuming they would be trained to operate as an extremely dispersed force.

As Table 5.1 indicates, increasing battlefield dispersion is a natural historical trend, caused by the increasing lethality of weapons.

Future enemies may themselves also use dispersed operations to counter U.S. air superiority and artillery-delivered cluster munitions. As U.S. precision-fire assets continue to improve, adversaries may adopt dispersion as a tactical countermeasure for increasing their survivability.[33] The footprint of a typical U.S. deep-strike weapon such as the ATACMS Block IIA (a missile-delivered package of several brilliant anti-armor submunitions) is a fixed area; the fewer armored vehicles located in that footprint, the fewer kills are made. On the

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[31]In the future, the emphasis will be even more concerned with dispersed operations as both sides improve their "see-it/kill-it" capabilities. In a "pop-up-warfare" environment, concealment is crucial to survivability. Dispersed forces can hide more easily.

[32]During the 1950s, the Army reorganized its divisions to fight on the atomic battlefield. It wanted to disperse American forces to minimize the damage from any single bomb. The "Pentomic" division consisted of units of five throughout its structure: 5 platoons per company, 5 battalions per brigade, etc. The Army viewed tactical nuclear weapons as a conventional warfighting option, and dispersion became the first imperative for its new Pentomic division. Tactics called for a rapid concentration, or massing, to defeat the enemy at the critical time and place, then a rapid and immediate dispersion. See A. J. Bacevich, *The Pentomic Era: The US Army Between Korea and Vietnam*, Washington, DC: National Defense University Press, 1986, p. 68.

[33]The recent lessons learned in Operation Allied Force in Kosovo in 1999 make it clear that concentrated masses of troops on the battlefield are highly vulnerable to weapons such as the satellite-guided Joint Direct Attack Munition.

future battlefield, concentrations of mass will be vulnerable to such deep-strike weapons. When the enemy does disperse into small groups of troops or vehicles to counter U.S. precision fires, a dispersed network of U.S. swarm units would be well positioned to swarm around clusters of enemy vehicles.

Table 5.1

Battlefield Dispersion from Antiquity to the Present

Area Occupied by Deployed Force, 100,000 Strong	Antiquity	Napoleonic Wars	U.S. Civil War	World War I	World War II	1973 Israeli-Arab War	Gulf War
Square kilometers	1	20.12	25.75	248	2,750	4,000	213,000
Front (km)	6.67	8.05	8.58	14	48	57	400
Depth (km)	0.15	2.50	3	17	57	70	533
Men per square km	100,000	4.79	3,883	404	36	25	2.34
Square meters per man	10	200	257.5	2,475	27,500	40,000	426,400

SOURCE: All figures except Gulf War column are from T. N. Dupuy, *The Evolution of Weapons and Warfare*, Indianapolis, IN: Bobbs-Merrill, 1980, p. 312. The area data for the Gulf War came from William G. Pagonis, *Moving Mountains: Lessons in Leadership and Logistics from the Gulf War*, Boston, MA: Harvard Business School Press, 1992; the rough number of 500,000 soldiers was used for the number deployed within this area.

Counterinsurgency Operations

We have already noted the similarities between guerrilla units and swarm units. The question is, Will swarm units be more effective than hierarchical division-based units in counterinsurgency (COIN) operations?[34] In the past, conventional armies have discarded their

[34]This does not imply that a network-based swarm force can replace Special Operations Force (SOF) personnel who are trained to raise guerrilla armies. In addition,

heavy equipment and attempted to meet the enemy on equal terms, light infantry versus light infantry. But regular forces forfeit much of their technological superiority when they do so, sometimes absorbing higher casualties as a result. In contrast, swarm units deployed as a network will be more capable of finding and finishing elusive guerrillas. It takes elusiveness to counter elusiveness.

Intelligence-gathering is the heart of COIN operations.[35] The insurgent's knowledge of the local terrain and population is his greatest asset. He gains the support of the local population either by force or by popularity—can blend easily with the indigenous population, staying in safe houses and other hiding places.

For some time to come, U.S. space and air assets such as unmanned aerial vehicles, satellites, high-altitude aircraft and battle management aircraft like the Joint Surveillance and Target Attack Radar System (JSTARS) will be limited in their ability to detect small ground forces in difficult terrain such as mountains, heavy forests, cities, and jungles. Because of the limitations of surveillance technology and other uncontrollable factors such as inclement weather, the combination of light forces and rough terrain will probably remain impenetrable to our airborne sensors.

A swarm force can physically cover down over a geographic area,[36] and it is more likely to pick up battlefield intelligence. A network of swarm units dispersed over an area can perform such COIN missions as conducting frequent and random cordon search operations; establishing checkpoints that vary from location to location at random times; quickly reacting to suspected areas of insurgent activity when needed; and constantly gathering human intelligence.

Guerrilla armies usually operate as very small, light, and highly mobile units, are dispersed over a large area, and have no traditional flanks, rear, or line of communication. They must remain elusive to

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Rangers, Civil Affairs, and PSYOPS units all provide unique functions that a regular Army swarm unit is unlikely to replicate.

[35]O. Kent Strader, Captain, "Counterinsurgency in an Urban Environment," *Infantry*, January–February 1997.

[36]To *cover down* is to blanket or cover an area with numerous personnel. Units physically deploy in enough local areas that no area is left uninvestigated.

heavy conventional forces in order to survive. As Chairman Mao once said,

> When guerrillas engage a stronger enemy, they withdraw when he advances; harass him when he stops; strike him when he is weary; pursue him when he withdraws. In guerrilla strategy, the enemy's rear, flanks, and other vulnerable spots are his vital points and there he must be harassed, attacked, dispersed, exhausted and annihilated.[37]

Swarm units on the ground are natural sensors for detecting low-signature guerrilla units. Once a guerrilla unit is detected, all adjacent swarm units can seal off the area in which the guerrilla unit was last seen and converge toward that location. This is similar to what a traditional, hierarchical ground unit does today: It seals off the area and sweeps it in a linear, systematic fashion. But contracting a circle is much faster than sweeping a line across an area. Swarm units dispersed with their "ears to the ground" can ambush the ambushers.

Peacekeeping and Peacemaking Operations

Traditional combat divisions are not organized well for peace operations. Swarm units may be more effective at performing peace operations than hierarchical divisions because of their organization, ability to shape the environment, and decentralized command during operations in urban terrain.

Peace operations demand flexibility. Hypothetical swarm units make up a flatter, more flexible organization than the division-based army of today. Swarm units are more modular, and they can be reconfigured more easily than conventional units into task forces to support peace operations. The structure of the typical Army division-based task force today is not as well suited for peace operations, which emphasize policing, building, transporting, and facilitating rather than combat-arms functions. The current combat division

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[37]Asprey, 1994, p. 257.

does not contain all the unique personnel necessary to conduct these duties.[38]

A primary role of U.S. peacekeeping and peace enforcing units is to shape the environment with their actual physical presence. Whenever a peace mission calls for a patrolling presence of many small units dispersed over a large area, swarm units are ideally organized to adopt temporary duty of this sort. They can be trained to respond quickly to isolated incidents within their overall zone of control. Police forces around the world essentially use swarm tactics every day—for example, they swarm patrol cars to bank robberies in progress.[39]

Many peace operations are increasingly conducted in urban areas. The very nature of urban warfare requires decentralized control of assets, because communications capabilities are degraded, fields of fire and observation are limited, and mobility is reduced. The command system proposed in this monograph is designed specifically for decentralized command.

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[38]These missions demand a greater number of CS, CSS, and SOF forces. Because of this demand, task forces are sometimes drawn from the deployment of partial units and individual augmentees, rather than whole units. One might assume that because a hierarchical division-based force contains more CS and CSS personnel, it is more capable of forming peace operation task forces. However, most of the Military Occupational Specialty (MOS) augmentees in special demand for peace operations are in the Reserves. Activating these Reserve MOS augmentees requires a Presidential Selective Reserve Callup (PSRC), a mobilization step rarely taken for peace operations. In the absence of a PSRC, the demands of a major peace operation can strip critical MOS personnel such as military police from the rest of the active force that is not deployed.

[39]The bank robbery analogy is not perfect. Whereas police forces can afford to empty other areas of the city of police while responding to a crisis, military forces will not have that luxury because many “bank robberies” will be in progress.