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Airpower in U.S. Light Combat Operations

Kenneth H. Watman, Daniel P. Raymer

Project AIR FORCE

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Preface

A U.S. air and ground operation against Iraq during Operation Desert Storm illustrated the striking effect of qualitative improvements on the conduct of heavy conventional operations. However, U.S. operations in Grenada and Panama illustrated the very different character of current light force operations. Much of the damage to the Iraqi force was delivered from "arm's length" using air-delivered and ground-delivered precision munitions linked to powerful reconnaissance, surveillance, and target acquisition capabilities. The Iraqis were virtually powerless to strike back or prevent their destruction. By contrast, usually light force operations still rely heavily on the close, direct-fire battle in which the adversary can inflict casualties on U.S. forces. U.S. light forces do not possess analogous capabilities to conduct reconnaissance, surveillance, and target acquisition or to reliably inflict heavy damage on an adversary without closing with him, especially when collateral damage is a constraint.

This report documents an exploratory project investigating whether qualitative improvements akin to those enjoyed by U.S. heavy forces can be brought to U.S. light forces. As such, it should be of interest to military and civilian planners involved in force structure design, acquisition, and doctrine for all four services.

This research was conducted within the Strategy, Doctrine, and Force Structure program of Project AIR FORCE, RAND's federally funded research and development center for the United States Air Force.

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Introduction and Rationale

Light operations are those undertaken by light or dismounted infantry against similarly armed opponents in close, rough, or urban terrain. On the smaller side, Grenada and Panama would be considered light operations; Bosnia and Vietnam would be on the larger side.

The United States engages in light operations much more frequently than heavy ones like Operation Desert Storm. Yet most of the qualitative improvements in conventional forces developed since World War II, and especially since the mid-1970s, have benefited heavy forces more than light. Examples include precision-guided munitions; advanced command and control; reconnaissance, surveillance, and target acquisition; and stealth. Indeed, in many ways, light operations are conducted today as they were 50 years ago—air mobility and night vision devices are notable exceptions to this generalization. Heavy operations resemble their World War II predecessors less and less.

Specifically, qualitative improvements have enabled heavy forces to strike at their adversaries from "arm's length," a distance at which the adversary can be attacked by long-range precision munitions delivered from air and ground without being able to retaliate. In this sense, heavy forces can be said to conduct part of their battle from a sort of sanctuary.

Unfortunately, light forces are much less able to avail themselves of this sanctuary. For reasons discussed here, the essence of light-combat operations largely continues to be the close, direct-fire battle. In such battles, U.S. technical qualitative advantages cannot be brought to bear easily. Thus, light-combat operations are very dangerous, as illustrated by the fact that a U.S. participant in Operation Just Cause was much more likely to be a casualty than one in Operation Desert Shield/Storm.

Therefore, the objective of this project was to develop concepts for giving U.S. light forces qualitative advantages over their adversaries akin to those enjoyed by U.S. heavy forces. The project's methodology had four parts:

1. Identify those phases of light combat operations that are most problematic
2. Develop ideas for ameliorating these problems

3. Convert those ideas into systems and concepts
4. Conduct rough cost-benefit analysis on those candidate systems and concepts.

Identify Problematic Phase In Light Combat Operations

A survey of the historical literature on light-combat operations, especially concerning Vietnam, Grenada, Panama, and the Falklands, suggests that most problematic are reconnaissance and combat operations by tactical units. The first, reconnaissance, is difficult and dangerous because the United States does not have the capabilities for detecting light infantry targets quickly over broad areas and from long range. Contrast this situation with the spectrum of resources, including Joint Surveillance Target Attack Radar System (JSTARS), available to heavy forces. By contrast, light forces frequently discover the presence, location, and strength of their adversary by making ground contact. Since surprise and confusion are often unavoidable, casualties result.

The second problematic phase, combat operations, is related to reconnaissance. Light infantry would prefer that supporting fire from air and artillery destroy the adversary as much as possible before entering into close combat. Unfortunately, because target acquisition is difficult in rough terrain, supporting fire takes crucial minutes to arrive, collateral damage is often an inhibition, and the role of supporting fire is constrained. The result is that light infantry frequently has to close with the adversary to conduct the decisive battle. Again, casualties result.

Therefore, we focused our efforts on qualitative improvements in reconnaissance and combat operations.

Qualitative Improvements in Reconnaissance

Unfortunately, we were unsuccessful in identifying any concepts, technical or otherwise, that hold much promise in this area for the near term. The problem of detecting human adversaries, rather than vehicles, in rough, close, or urban terrains is very difficult. Therefore, we conclude that the individual infantryman will continue to be the primary reconnaissance system in these operations. Follow-on research will explore ideas for extending his capabilities, including simple remotely piloted vehicles (RPVs) and sensors at the small unit level.

Qualitative Improvements in Fire Support

We sought to identify an approach for delivering supporting fire with greater accuracy and promptness to shift more of the burden of the decisive battle away from close combat. We found that the exploitation of global positioning system (GPS) technology seemed feasible as a basis for a target acquisition system and munition that would meet these requirements at an affordable price.

The target acquisition system is a small laser target locator (consisting of a range- and direction-finder), a digital data link, and a GPS receiver that would be carried by one or more members of light infantry units. When contact is made with an adversary, the laser target locators would be used to *ping* targets. Range would be determined by the laser travel time to and from the target. Directional bearing would be determined by a sophisticated electromagnetic compass slaved to the laser. The location of each infantryman who carries a GPS receiver (perhaps on his webbing) and uses a target locator would be known in GPS coordinates. Therefore, the location of each target *pinged* also would be known in GPS coordinates. These locations would be transmitted by data link to a weapons platform at considerable distance from the battle.

That platform could be an aircraft, a ship, or artillery. In this case, because of their mobility, we focused on using large, long-endurance aircraft like B-52s, C-130s, or C-141s. The platform would be loaded with 100 or more new munitions called the Precision, Standoff, Support Munition (PSSM). Each PSSM would weigh about 350 pounds, of which 200 pounds would be the warhead. The warhead could be high explosive or antipersonnel bomblets. Each PSSM would be equipped with a gliding wing, control surfaces, and a GPS-based guidance receiver. When released from an aircraft at about 25,000 feet and 300 knots, a PSSM can glide as far as 25 n mi in about 3.5 minutes. Shorter flights would be briefer. The PSSM would be targeted at the GPS aimpoint sent from the ground, glide to that point, and dive onto the target. The launching aircraft never needs to see the target through the foliage; also the target does not need to be marked in any way.

Cost-Effectiveness Assessment

We found that each PSSM should cost in the low thousands of dollars. The most expensive component would be the GPS guidance receiver.

Map exercises drawn from battles that occurred in Vietnam, Grenada, and Panama were used to assess the effectiveness of the PSSM system. In each case, we asked the extent to which the availability of the PSSM system would have benefited U.S. forces. We concluded that the system would substantially benefit operations in which the location of the adversary is relatively fixed for the period required to deliver the weapons. Such conditions are frequently met in light combat operations. Ambushes and assaults on prepared defenses are good examples.

Acknowledgments

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Glossary

AAA	Antiaircraft Artillery
AO	Area of operations
CAS	Close Air Support
GPS	Global Positioning System
HE	High Explosive
IMU	Inertial Measuring Unit
IR	Infrared
JSTARS	Joint Surveillance Target Attack Radar System
L/D	Lift/Drag
PRA	People's Revolutionary Army (Grenadan)
PSSM	Precision, Standoff, Support Munition
RPV	Remotely Piloted Vehicle
SAM	Surface-to-Air Missile
SEAL	Sea-Air-Land U.S. Navy special forces
UAV	Unmanned Aerial Vehicle
VC	Viet Cong

1. Introduction and Rationale

This report is the result of an exploratory project supported by the Air Force to investigate ways in which qualitative improvements could be made in U.S. light operations. It is important at the outset to define what we mean by a light operation, for it is not a recognized term in the official U.S. military lexicon. In this context, we mean operations undertaken by either light or dismounted infantry of the Army or Marine Corps against similarly armed opponents in close, rough, or urban terrain. Although this definition is not terribly rigorous, it helps to give examples of what we mean by light operations. On the smaller side, Grenada and Panama would be considered light operations; Bosnia and Vietnam would be on the larger side.

Ordinarily, light operations dominate in what are known as lesser regional contingencies, usually in the Third World. Light campaigns, however, need not be small or for less-than-vital national interests. Vietnam could be called a large-scale, light operation, in large part, although heavier weapons certainly were used in various phases and locations. The operations in Vietnam, however, were usually characterized by small units operating against other small units in jungle or rough terrain.

Note that the focus of this project is on combat operations rather than the noncombat activities so often part of light campaigns. For example, often when light forces are involved, considerable nation-building or civic action activity is underway as well. While those activities are of great interest, especially today, they were not considered in this study.

The project has two rationales. The first grows out of the realization that the astonishing performance of U.S. forces in the desert against Iraq was a result of the qualitative advantages that are not also enjoyed by U.S. light forces. However, the United States engages in light operations like Panama and Grenada far more often than in major heavy operations against an opponent like Iraq. At most, an Operation Desert Storm-type operation may occur every decade or two—and probably less often than that. Every president since World War II, however, has overseen at least one or two light operations while in office. There is no reason to believe that this relative prevalence of light operations will change in the foreseeable future.

Yet virtually all the most striking innovations in conventional warfare, especially those of the last 20 years, are intended for large, heavy operations. Indeed, it is not an exaggeration to argue that light operations are conducted today in much the same way as they were 50 years ago—or even at the beginning of this century. At least, today's light operations more closely resemble those of 50 years ago than do today's heavy operations. Exceptions to this generalization are air mobility and effective night vision devices. Unquestionably, these innovations have given U.S. light forces qualitative advantages over less sophisticated adversaries. Yet, even so, these advantages are less pronounced than those the United States enjoys in heavy operations, such as Operation Desert Storm.

This finding should not be surprising because defeating massed armor has been the primary focus for conventional force improvements since World War II. The principal qualitative solution to this problem has been to develop capabilities to destroy heavy forces very efficiently from long range. *Efficiency* in this case means compensating for U.S. numerical inferiority in platforms by linking large quantities of long-range, precision weapons to powerful reconnaissance, surveillance, and target acquisition capabilities. This greatly increases the killing ground an enemy has to cover before he can use his own weapons effectively against U.S. forces. Until he succeeds, U.S. forces can occupy a sort of sanctuary from which to strike powerfully at an adversary while primarily remaining beyond his ability to reply. This advantage can be likened to that sought by surface warship designers as they strove to achieve range advantages for battleships. A ship with that advantage could occupy a similar sanctuary until the enemy closed the range. Now as then, the closer the combatants come to one another, the more purely technical superiority can be offset with numbers. Put another way, the closer a technologically inferior force can come to a technologically superior one, the less the qualitative difference will determine the outcome of combat. Certainly, some types of qualitative advantages can be preserved even at close ranges. As a general proposition, however, the sanctuary the United States can enjoy, when the battle is kept at arm's length, is reduced to the extent the adversary can close the range.

This is precisely the problem with light combat operations. The United States is much less capable of conducting them at arm's length. So, U.S. light forces seldom, if ever, enjoy a similar sanctuary from which to strike while not being struck in return. This situation occurs because the United States does not possess equivalent long-range, precision weapons and reconnaissance, surveillance, and target acquisition capabilities for this type of warfare that would permit light forces to employ concepts of operations analogous to those available to heavy forces. Instead, light combat normally occurs at relatively close ranges, using direct fire weapons. The classic weapons of light infantry are the rifle, the sidearm, the grenade, and the light mortar. Because these operations are conducted at close range and because the opposition frequently can see one another or see evidence of one another's position, many of the most important qualitative advantages of the United States are not applicable in light combat operations.

The result is that in Panama an American participant was about three times as likely to be killed or wounded as was a participant in Operation Desert Storm. Many reasons exist for this, of course, and to a large extent this statistic can be deceiving. It does, however, underline the fundamental truth that the essence of most U.S. light operations is close, direct-fire combat in which both sides can see and shoot at the other, while the essence of U.S. heavy operations is long-range, precision attacks from sanctuary.

In addition to the need to make light operations less dangerous, this project has a second rationale. Although the United States seeks to avoid a repetition of Vietnam, a strong possibility exists that, over the next 10 to 20 years, the United States will have several opportunities to become involved in large, light contingencies. Their similarities to Vietnam are difficult to know, but they will share some common characteristics. They will be large, long in duration, and ambiguous as to enemy and objective.

Light operations, for the reasons discussed above, are labor intensive. The capital-labor trade-offs available in more mechanized kinds of combat are not available; therefore, for large, light operations, usually large amounts of manpower are required. Unfortunately this requirement takes place precisely when our light forces are being reduced. Every reason exists to assume that they will continue to bear the brunt of the reductions, if the Army reduces its force below 10 divisions over the next 10 to 20 years.

If we have to become involved with a large, light contingency like Bosnia, therefore, we will encounter manpower constraints, especially if U.S. forces are committed elsewhere at the same time for peacekeeping/peacemaking. To a certain extent, the manpower squeeze will be offset by the participation of allies. Nevertheless, it is difficult to know the extent to which we can count on them to supply the large amount of forces that probably would be necessary. Indeed, it is precisely this problem that we find to be so daunting in Bosnia and Somalia. The manpower shortage will become even more acute if we have to stay in a theater long enough so that troop rotations become a requirement. Since the U.S. active force rotation base for light forces will be quite small, qualitative improvements in light operations are needed not only to ameliorate the danger of these operations but also to bring force multipliers to bear.

U.S. involvement in large, light contingencies could arise in several ways, and it may be useful to outline these to offset the natural reaction of some readers to reject their plausibility. While it may be true that the United States has learned the "lessons of Vietnam," unfortunately we may not have the alternative about getting involved in future Vietnam-like contingencies. There are several ways in which they might come about:

- As we have discovered to our dismay, peacemaking and peacekeeping in a state like Somalia entail the investment of large forces for a long time.
- Large, light contingencies may develop in places like Cuba, or they might have been present in Nicaragua. It is difficult to predict where others might take place, but many states of only medium size could make for a very difficult light campaign.
- The United States may be required to act in the foreign internal defense of nations that occupy strategically important resources or locations in the world. Obviously, the first step in the case of a nation being endangered by an insurgency movement would be to provide assistance of various kinds but not American combatants. However, in the case of a vital nation (such as Saudi Arabia, Mexico, or Egypt), if the noncombatant type of assistance failed to successfully conclude the conflict, the United States could be presented with a very difficult dilemma as to whether or not it should add its own combat forces to the balance. These or similar places may be so important that the United States simply cannot tolerate a hostile government.
- A large light contingency could occur as a second phase of a successfully concluded large, heavy contingency. The United States was quite lucky that it could conclude the operations against Iraq easily. When Iraqi-organized units in the field were defeated, Operation Desert Storm ended. The Iraqis showed no eagerness to continue resistance in other forms. The next time we undertake a large heavy contingency against an Iraqi-type opponent, however, that adversary may decide that after its forces in the field are defeated, it will continue to resist by undertaking a preplanned, insurgent type campaign utilizing hit-and-run tactics. In that case, the United States will be faced with another dilemma: to leave the resistance unquelled and depart for home or to engage in counter-insurgency operations against that resistance as a second phase of the major regional contingency.

2. Project Objectives and Methodology

For the reasons given in the first section, the objectives of this project were to develop ideas for substantial qualitative improvements to U.S. light forces and to assess those ideas for cost and effectiveness.

A four-step methodology was used for this study. The first was to identify the most problematic phases of light combat operations. *Problematic* connotes the types or elements of light operations that are most apt to result in casualties. The source of our information for this stage was the analysis of the extensive historical literature on light operations that permits some statistical breakdown of the locations of most casualties.

The second step was to develop ideas for ameliorating these problematic phases of combat. This focus was intended to prevent us from frittering away our concentration on parts of light operations that are less in need of help. Our sources for material in this phase were brainstorming among the project participants, a thorough canvassing of the literature, and traveling to various bases and locations in the country to collect other people's ideas.

The third step was to convert these ideas into systems and employment concepts sufficiently specified to permit rough cost-benefit analysis. Note that this research is exploratory, and our cost-benefit analysis was much more superficial than could be the case in more detailed, rigorous follow-on research.

The last step was to conduct this cost-benefit analysis. Costs were estimated qualitatively based on those of current systems. Benefits were assessed by using map exercises of light operations drawn from previous campaigns, notably Grenada, Panama, and Vietnam. We extracted several representative scenarios from those campaigns and then performed a series of "what if" exercises with them. The remainder of this report is organized along these four steps in our methodology.

3. Problematic Aspects of Light Operations

A *generic light combat operation* is shown in Figure 1. The units moving from left to right are sweeping or patrolling a contested area. The area is assumed to contain the terrain usual to light operations: rough, forested, urban, etc. This operational concept is designed to postpone closing with the enemy for as long as possible. Rather, the aim is to rely as much as possible on the U.S. strengths in supporting fire to minimize the need for the infantry to engage in close combat.

Usually, movement to locate the enemy is the first phase of a light combat operation. In most cases, the location, disposition, and strength of the enemy are not known with precision, because of the character of the terrain and the difficulty of locating people. The United States is far more capable of sensing the location of vehicles than it is the location of personnel. Therefore, in light operations, most of the reconnaissance activity is performed by the infantrymen on the ground using their eyes and ears, as they move carefully through the terrain in search of the enemy.

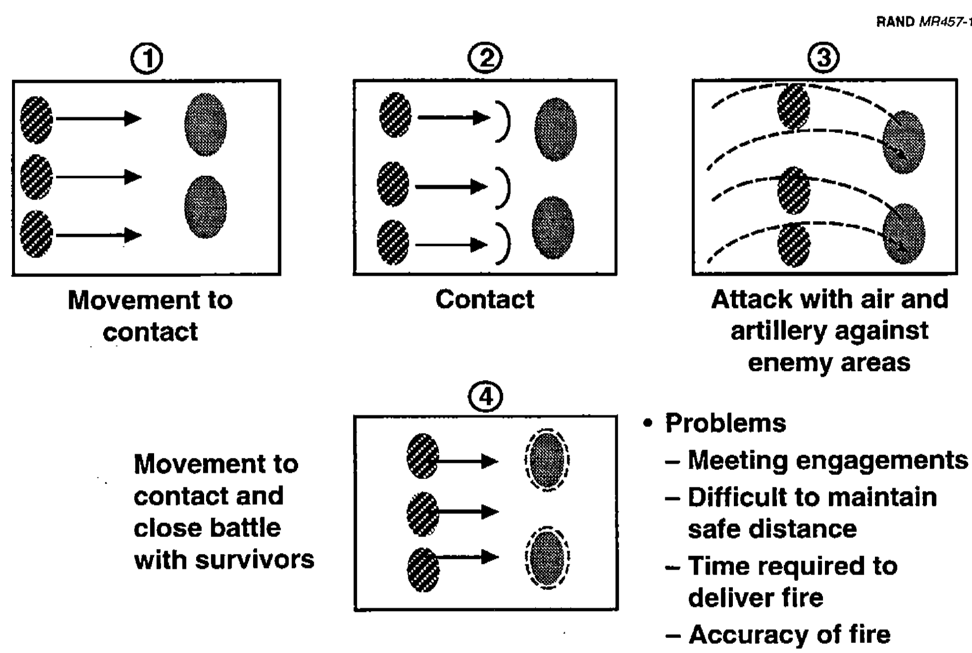

Figure 1—Generic Light Combat Operation

The second phase is contact with the enemy, usually by actually running into him or seeing evidence of his presence at close range. For obvious reasons, this encounter is very dangerous, especially if the enemy is prepared. In that case, the offensive force may be ambushed or confronted with a prepared defense. When contact is made, the light force's immediate objective is to shift from reconnaissance to target acquisition. The precise location, strength, and disposition of the enemy must be determined as quickly as possible, usually by seeing or hearing the enemy personnel or the signatures of their weapons.

The third phase of the operation is to engage the adversary with direct and supporting fire from the air (rotary or fixed wing) or artillery. The objective of this phase is to inflict as much damage on the enemy as possible before closing with him to minimize friendly casualties. The most preferred result of this phase is that the adversary is defeated substantially by supporting fire.

In the last phase, after artillery bombardment and close air support, the infantry will move forward to assault the enemy in the hope that little or no evidence of him is left. Most of the time, however, some amount of close combat is required, and friendly casualties are sustained—sometimes many.

Unfortunately, this operational concept often is not suitable in many of the situations in which U.S. light forces find themselves. Several problems make it difficult to use supporting fire as the primary method of destroying the enemy in light operations. First, often a nontrivial time lag occurs between when supporting fire is needed and when it can arrive. Our research suggests that, in Vietnam, when supporting fire was not preplanned, an average of 10 to 15 minutes was necessary before indirect fire from artillery or close air support could arrive. In many firefights, most casualties were inflicted during this waiting period, even if brief. Second, in many types of operations such as Panama and Grenada, concerns about collateral damage may limit the application of supporting fires. Third, in close terrain it can be very difficult to identify targets, especially for close air support; therefore, the effect of the fire is likely to be less significant than would be desired. Fourth, at the point of contact, the enemy often succeeds in closely engaging the American forces, thereby making it difficult to target the supporting fires in which the United States is so strong.

Most often as a result of these four problems, the light infantry, rather than the supporting fire, must bear the brunt of the decisive phase of battle. Here the enemy is closely engaged in a firefight until he is destroyed or resistance ceases. Unfortunately, U.S. qualitative advantages are least applicable in this close combat.

This discussion highlights the two phases of light operations that are most problematic: reconnaissance and combat. Indeed, these two are linked. The reconnaissance phase is difficult and dangerous because the United States has few capabilities for remotely detecting enemy light forces—at least, in the context of light, offensive operations. For this reason, light forces are compelled to sweep physically through an area. Thus, they can become closely engaged by the enemy very quickly and suddenly. Contrast this scenario with heavy operations in which the United States can detect enemy forces from the air at great distances and over large areas. Once engaged, effective supporting fire may not be available for a substantial time or not at all. Our research suggests that most light infantry casualties are sustained in the initial minutes after contact has been made and during offensive operations.

Therefore, two approaches for improving U.S. qualitative advantages are suggested. First, we would like to provide our light infantry with the ability to sense the enemy at greater distances now and with more time between sensing the enemy and engaging him. This capability would reduce the need for the light infantry to close with the enemy, and it would certainly reduce the likelihood of our own forces being taken under surprise attack from ambush.

Second, we seek to delay the direct assault for as long as possible while supporting fire does the work for the infantry. Indeed, ultimately we would like to simply eliminate the need for the infantry ever to assault its opposition. A form of supporting fire is needed that can arrive quickly, precisely, and from relatively long range.

We will deal with each of these two problem areas, effective long-range reconnaissance and supporting fires, in turn.

4. Ideas for Ameliorating These Problems

Qualitative Improvements in Reconnaissance in Light Operations

We reviewed the literature concerning reconnaissance systems with potential in this area. These include radars that can penetrate foliage to detect human targets, laser 3-D imaging systems, multispectral systems for detecting light at various wavelengths, passive infrared systems with special processing, and synthetic aperture radars of various kinds. Unfortunately, in our view no systems presently could be in the force within five or ten years, which would substantially improve our current ability to detect infantry targets in close, rough, or urban terrain. Part of this problem arises because of the difficulties of penetrating cover—especially structures—and the inherent difficulties of detecting human targets when they choose to conceal themselves. Various types of existing radars can penetrate both foliage and soil. These have been used in civilian applications, notably for archeological expeditions to discover the sites of ancient cities that have been buried underground. Unfortunately, these radars require special conditions of soil and climate and, therefore, would present severe problems in their application in most military theaters. In our assessment, they cannot be made militarily useful for about a decade and are not included among the systems considered here.

Therefore, we find that for the near term, the human senses of the individuals on the ground will continue to be the dominant reconnaissance system for light operations. Improvements in this area have to be focused on ways in which the senses of those individuals on the ground can be extended. Night-vision devices are perfect examples. We should point out that a variety of scatterable or projectable types of sensors can be used to detect the passage of enemy forces, but these are not easily used by units as they move through terrain. They are useful, however, for seeding on enemy territory to detect the enemy at long distances, and they can also be useful in helping protect a defensive perimeter. Because of the need for friendly forces to sweep through an area, static devices such as the acoustic sensors that are currently in the force are much less usable.

Therefore, we intend to focus in follow-on research on ways in which inexpensive unmanned aerial vehicles (UAVs) can be utilized employing various simple sensors, which might add a few minutes of warning to infantry operations. For example, we have superficially explored the possibilities of small, inexpensive, rotary-wing drones that could carry small and simple sensors of various kinds, particularly metal detectors, to detect enemy forces in areas where there could only be one reason for the presence of metal objects. Frequently in ambush situations, this kind of advantage can prove very helpful if it buys the infantry unit five or ten minutes of warning. We have not taken this line of research very far at this point.

In sum, with the possible exception of this application of UAVs, we have not been able to develop concepts for reconnaissance in light operations that represent a great qualitative improvement over current practice.

Qualitative Improvements in Fire Support for Light Operations

The solution to the problem of how to give light infantry more precision, standoff firepower begins with consideration of the relative strengths and weaknesses of light infantry versus air and artillery. The infantry's strengths are its ability to move over rough terrain without a great deal of logistical tail and its ability to find with precision and destroy similar enemy forces with a minimum of collateral damage. The weakness of light infantry is their dependence on supporting fire that may not be effective or prompt enough. Without it, they have to run the risks of engaging the enemy with light weapons at close ranges where U.S. advantages are minimized and risks of casualties are highest.

The strengths of air and artillery are the mobility and weight of fire they can deliver. Their weaknesses are that they cannot destroy their targets on the ground with precision, especially in rough, close, or urban terrain, in part because of the problem of target acquisition. Also, frequently they require several minutes to deliver, and passage of several minutes in a firefight can be decisive.

The most logical division of labor between infantry, on the one hand, and air and artillery, on the other, is for the infantry to find the enemy (that air and artillery frequently cannot do) and for air and artillery to kill him (that the infantry often cannot do without suffering casualties). The problem with this concept of operations is that air and artillery have been incapable of delivering fire as promptly and precisely as needed. Therefore, is it possible to develop a way of overcoming this difficulty?

The concept we have developed is entitled, "Precision Standoff Support Munition," or PSSM (pronounced POSSUM). It consists of giving light infantry the capability to locate with precision the Global Positioning System (GPS) coordinates of targets to be struck. These coordinates then can be communicated digitally via data link to a ground-or-air-delivered fire system. One example is described in the next section. Any of the developing family of GPS-guided munitions could be used in this capacity. Thus far, however, they are all too large and expensive to be used routinely in support of light operations, especially when the combatants of the two sides are close together. Therefore, the RAND-proposed, GPS munition is meant to be both inexpensive and small.

5. Specification of the PSSM Concept

Target Acquisition

The GPS coordinates of any ground target can be secured by equipping some number of ground troops with GPS receivers; small, handheld, laser target locators (containing a range and direction finder) and digital data links. We have found that, in most light infantry engagements, the U.S. forces know the locations of some or all of the enemy force either because the enemy personnel themselves or their signatures (muzzle blasts, prepared positions, etc.) are visible. The difficulty, however, is in bringing fire to bear on these locations during a firefight. The laser range finder would be used by simply *pinging* the enemy's locations with the laser. *Pinging* should be distinguished from the kind of *lasing* that is necessary to designate a target for a laser-guided munition. To *ping* the target, the infantryman only has to shine the laser on the target or its location for a brief moment; therefore, his exposure to enemy fire can be similarly brief.

Although range information is necessary, it is not sufficient for target location without the capability to determine the directional bearing of the target relative to the location of the target locator. Technically, this task is not difficult. For example, two laser range finders, a known distance apart, could locate a target by triangulation. The constraint is operational rather than technical. Any approach requiring complex coordination between individuals or precise prearrangements will certainly fail in combat, especially direct fire, small unit engagements. Azimuth determination must be performed by one individual with one target locator in the same, brief time needed to determine range. Thus some type of compass must be incorporated into the same unit as the laser range finder. A gyrocompass would be one choice but would suffer unacceptably from drift. Therefore, a magnetic compass would be the most practical source of azimuth information. A magnetic compass would suffer from at least two sources of error, but both seem manageable.

The mass of the compass needle, the first source, would cause the needle to lag behind the correct bearing as the target locator is swung quickly into line with the target and to swing beyond the correct bearing because of the needle's momentum. Thus the infantryman with the target locator either will obtain seriously flawed information, or he will have to wait until the compass needle steadies on the correct bearing.

The smaller the mass of the needle, the more this problem is ameliorated. One approach might be to use a tiny ferrous needle wrapped in an electric coil. When energized, the needle would very quickly snap into alignment with the earth's magnetic field.[1]

The second source of error is common to all magnetic compasses: the need for declination compensation and the impact of local magnetic anomalies. The adjustment for declination could be performed automatically on the basis of the information supplied by the GPS receivers linked to each target locator. Alternatively, the declination adjustments could be made manually whenever the unit leader adjusted his land navigation compass.

Magnetic anomalies could arise from nearby sources of ferrous metal, either natural or man-made. At this stage of the research, we cannot evaluate how difficult a problem magnetic anomalies are likely to pose. Presumably, it would be difficult to obtain accurate azimuth information near vehicles or iron ore deposits.

What amount of error can be expected using the Wilkening compass? If magnetic anomalies are excluded, topographical maps in the hands of a capable land navigator produce errors of 0.5 to 1 degree, which correspond to an error of 20 to 40 meters at a 1500-meter range. Automatic declination adjustments using GPS would probably produce better results. Since infantry engagements most often occur at ranges of 500 meters or less, the error would be on the order of 7 to 13 meters or less. This combined with a GPS position location error of approximately 10 meters produces a total PSSM error of approximately 20 meters, well within the lethal radius of the weight of munition contemplated for PSSM.

As mentioned, each infantryman equipped with the laser target locator also will be equipped with a small, light GPS receiver, attached to his belt or back. Thus his location is known at any given moment. The laser target locator will give the range and azimuth of the target relative to its own position, which is known continuously by using the GPS receiver. Therefore, the location of the target in relative GPS coordinates can be derived easily, and the digital data containing that information can be transmitted to any appropriate source of fire support (see Figure 2).

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[1]This device is called a Wilkening compass, in honor of my RAND colleague, Dean Wilkening, who suggested the idea.

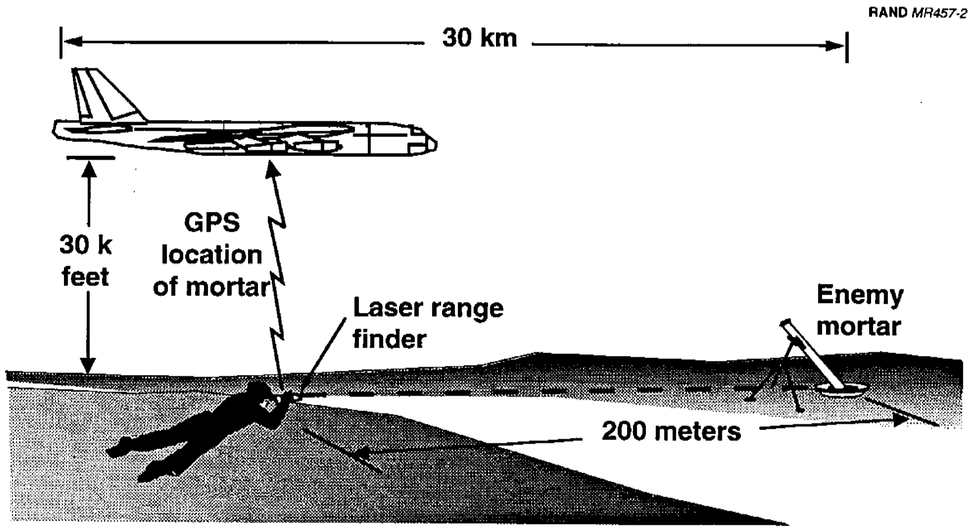

Figure 2—Location of Targets in Relative GPS Coordinates

Note that this method of target acquisition is superior to existing techniques used in close or rough terrain. Specifically, the infantryman no longer is required to estimate the target's location by "eyeballing" military map grids and adjusting the fire. Similarly, pilots in aircraft providing close air support (CAS) do not have to see the target or a target designator (such as smoke) that may or may not be near enough to the target to permit accurate fire. Indeed, the problem of target acquisition in forests or jungle can be obviated in this way.

As mentioned above, the GPS coordinates of the target can be used to direct artillery or any air-delivered, GPS-guided munition. However, in principle, it would be particularly desirable to be capable of delivering large quantities of infantry-supporting munition from the air. Air's mobility and capacity for carrying large weights give an air-delivered munition a reach and promptness that artillery does not have. Such capabilities are particularly important in quick-arising regional contingencies when there is a premium on being able to move large amounts of combat power in a short time, especially in the early days. Currently, because the United States has difficulty in this area, early arriving ground forces tend to be both light and vulnerable until sufficient supporting firepower arrives. A capability to provide greater coverage during this window of vulnerability would require air as the only source of sufficient mobility. This approach could be called *Light-on-the-Ground, Heavy-in-the-Air*. This division of labor corresponds to the strengths of each type of force.

Unfortunately, as mentioned earlier, the air-delivered, GPS-guided munitions under development are not well suited for light infantry operations. They are large and expensive, which constrain how many can be carried and how they will be used. The ideal weapon would be small and inexpensive, perhaps a modification of an existing weapon.

Precision, Standoff, Support Munition

An idea for such a weapon was developed during this project. The system consists of a large, long-endurance, fixed-wing aircraft such as a B-52, C-141, C-130 or similar aircraft; communications links to the troops at the FLOT; a weapon carriage and release mechanism installed in the back of the aircraft; and a number of the glide weapons, hereafter referred to as PSSMs (possibly 100 or more per aircraft). The weapons could be preloaded in the carriage and release mechanism that would be slid into the aircraft before a mission, or a high-speed loader device could be used.

For launch, the PSSMs would be moved mechanically from a storage position in the aircraft to the launch position (probably on a beam telescoped through the open aircraft cargo door to a location roughly under the aircraft tail), armed, provided with *to-to* GPS coordinates, and released (all automatically). On release, the PSSM would free fall clear of the aircraft, open its wing, turn if required, dive to pick up speed, and glide to a position above its intended target. At the appropriate location, the weapon would shed its wing and perform a ballistic fall onto the target.

While many elements of this system concept require investigation, this study has focused strictly on the PSSM itself, to determine if this key element of the system is even feasible, and what performance in terms of speed and glide distance could be obtained. To be useful and survivable, the PSSM system will have to operate beyond the range of antiaircraft artillery (AAA) and infrared (IR) surface-to-air missiles (SAMs) and have sufficient range and speed to cover a large area quickly.

PSSM Conceptual Design

To evaluate the feasibility of the PSSM concept, a notional design was prepared and evaluated. No claim is made that this design is the best possible or even that all problems have been worked out, but overall the concept seems feasible.

Figure 3 shows this notional design of a PSSM. The warhead is 34 inches long, 8 inches in diameter, and weighs approximately 200 pounds.

The entire PSSM is 6 feet long, with an extended wing span of 5 feet. The body is 8 inches in diameter, and the folded wing adds approximately 2 inches in height. The tails fold within a box 8 inches on a side and are positioned so that, when folded, they align with the folded wing. The total weight is 350 pounds.

The aerodynamic configuration of the PSSM is quite conventional, with a straight wing and an aft tail unit with tail surfaces at 45 degrees to horizontal. The wing is one-piece for ease of manufacture. Its ring-bearing pivot mount allows it to be stored flat along the fuselage and rotated out 90 degrees when released. Actuation would be provided by a stored energy device (spring or bungee) or by an explosive gas strut. Explosive bolts would separate the wing for the final, ballistic dive to the target. If required, a lever arm extending behind the wing and attached to a pivot on the aft fuselage could be used to guide the wing away from the tails during separation (see Figure 4).

The tails are stored folded and pop out on launch using either stored energy, gas struts, or possibly just aerodynamic forces. Tails are all-moving for maximum control, with (probably) electromechanical servo motors for actuation.

The forward half of the PSSM body is the shell itself. Within the aft body are the GPS/inertial measurement unit (IMU), batteries, tail actuators, and connections to the launch aircraft. GPS antennas could be in the aft body or possibly on the wing.

The PSSM probably would be carried and released upside down (wing-down) to simplify attachment, and would perform a half roll before wing extension. It

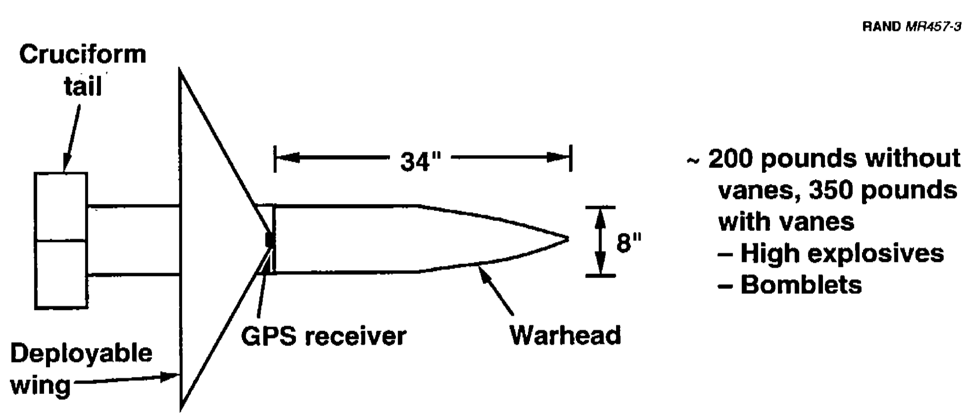

Figure 3—Notional PSSM

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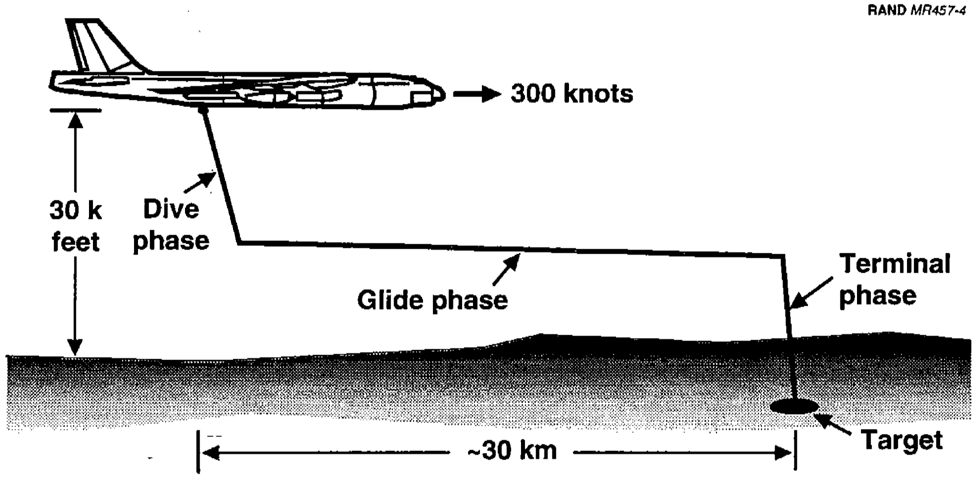

Figure 4—PSSM Flight Profile

would glide wing-up as shown to provide better aerodynamics and to take advantage of the natural dihedral effect of a high-wing position.

PSSM Weight Analysis

A first-order weight analysis of this notional glide-shell configuration was conducted. Tail fins, wing, and aft-body weights were estimated using historical data for guided bombs, plus comparative data for fighter aircraft. Actual weights were used for a munition resembling a 203mm shell and GPS/IMU package. Weights for actuators, batteries, and other items were estimated by comparison with similar guided weapons. The total PSSM weight including a reserve for unknowns is estimated to be 350 pounds, as detailed in Table 1.

PSSM Performance[2]

Overall, we learned that glide ratios of between 8 and 14 were readily obtainable, depending on lift coefficients and Mach numbers; also that with reasonable allowances for pullout, turn, and terminal dive, a total range of about 25 n mi could be obtained. At 450 kts, the glide time is 3.3 minutes.

In sum, a notional design was prepared and evaluated for a GPS-guided glide-weapon called PSSM that is capable of airborne launch from large tactical

[2]See the Appendix for details on the calculations supporting these results.

Table 1

PSSM Weight Analysis

Warhead/Shell	200	pounds
GPS/IMU	5	
Batteries	20	
AFT Fuselage Structure	35	(5 pounds/square foot)
Tail Surfaces (4)	8	(4 pounds/square foot)
Tail Actuators	12	
Wing	30	(10 pounds/square foot)
Wing Bearing and Actuator	5	
Attachment, Connectors, Misc.	10	
Reserve	25	
Total Weight:	350	pounds

aircraft. Based on this study, it appears feasible to develop such a glide-weapon using current technologies and to obtain a range of about 25 n mi with a glide speed of 450 kts. In particular, note that this nominal range would have been sufficient to have covered the entire areas of operations for Operations Just Cause or Urgent Fury (see Figures 5 and 6).

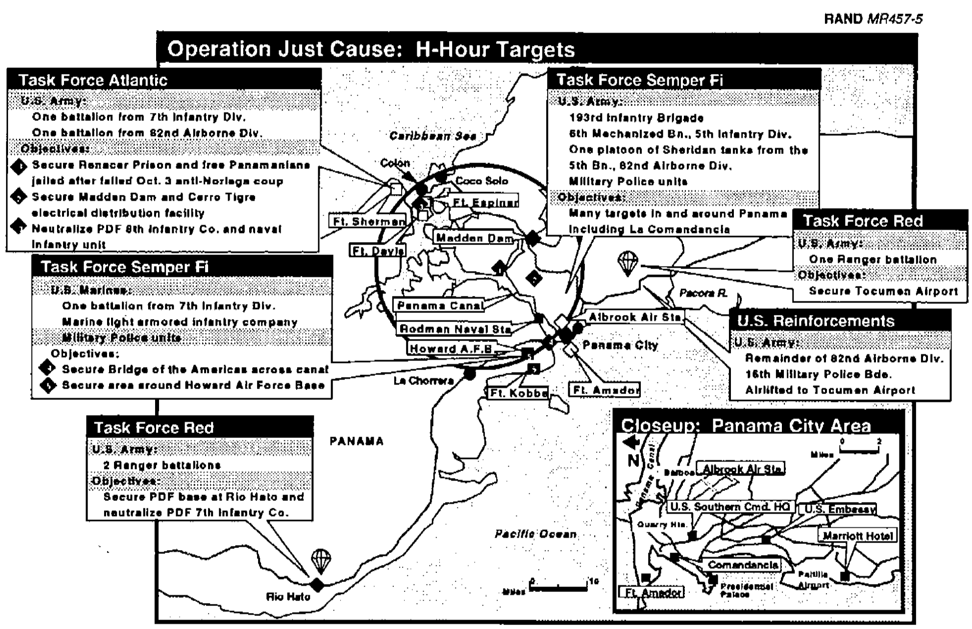

Figure 5—Operation Just Cause

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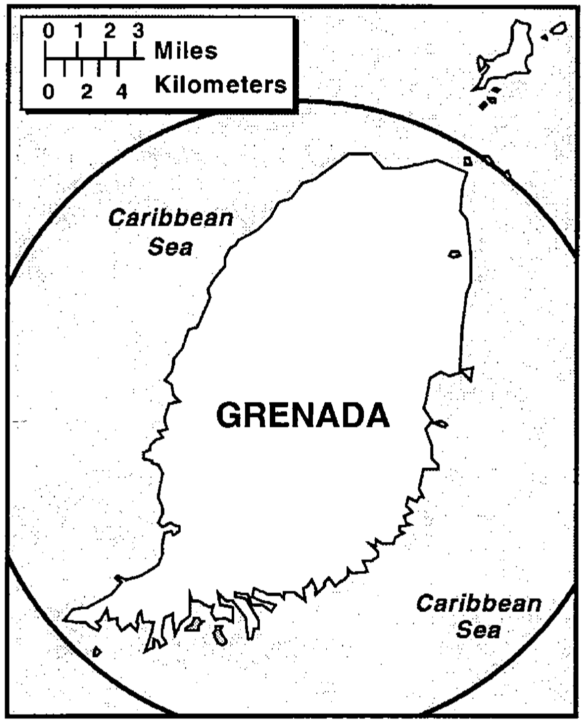

Figure 6—Operation Urgent Fury

While cost was not evaluated in detail in this preliminary study, the only substantial cost item should be the actual GPS/IMU guidance system. All other new components are simple, conventional, and inexpensive.

6. Effectiveness Assessment

Map exercises were performed to examine the effectiveness of this concept and system. Light operations from previous campaigns were replayed with and without PSSM. These operations were taken largely from Vietnam, Panama, and Grenada, although the Falklands campaign also provided some material. Three of the operations used are included here as examples.

The first example is drawn from the campaign in Grenada. Navy special forces (SEALs) were inserted by BLACK HAWKS near the Grenadan Government House to protect and remove the British Governor-General (see Figure 7).

They were armed only with light, personal weapons. As in the Panama case, these SEALs encountered unexpectedly heavy resistance from a Grenadan battalion, which attacked the Government House along two axes. The SEALs and the Governor-General were pinned down inside the Government House for several hours without any means to obtain supporting fire. Fortunately, the Grenadan forces did not press their attack as vigorously as they might have. Nevertheless, the SEALs' position steadily worsened and became critical when a Grenadan BTR-60 approached. The SEALs were saved by the happy coincidence

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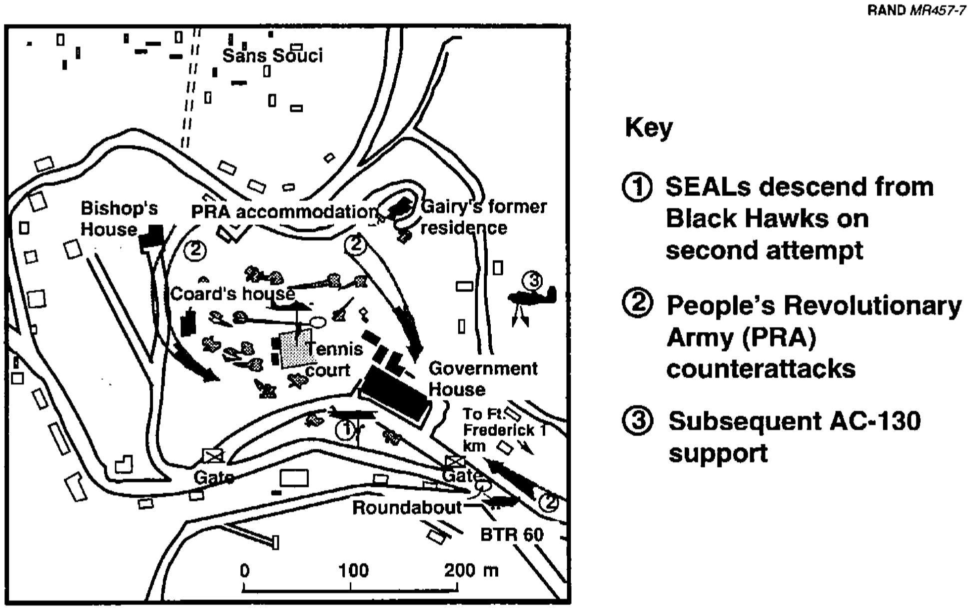

Figure 7—Example 1: Grenada Campaign

that an AC-130, returning to base to rearm from another mission, was able to intervene, kill the BTR-60, and suppress the attacking Grenadan infantry.

The nub of the problem the SEALs faced was the unavailability of supporting fire. The reasons of its unavailability are unclear from the accounts of the battle, but this situation is common in the engagements we examined. Sometimes supporting fire does arrive but only after a critical passage of time. Sometimes it simply cannot be delivered for whatever reason.

A large aircraft (B-52, C-130, or C-141) armed with 100 to 200 PSSMs could be placed on-station over the center of the theater to cover the entire area of operations in campaigns like Grenada. This tactic may be especially important in the early phase of a campaign before the landing of heavy equipment.

In the case of the Grenadan battle around Government House, PSSMs carrying antipersonnel bomblets could have been delivered rapidly and accurately into the nearby wooded areas. The foliage would not have posed much difficulty, since the munitions plunge vertically onto their targets. The lethal radius of the munition was sufficient to break up or suppress the Grenadan attack indefinitely.

The second case is also taken from Grenada. It involves the attack on the Richmond Hill Hospital by a heliborne force of Army Rangers (see Figure 8).

As the aircraft approached their target, they were taken under ZSU-23 fire from the nearby Grenadan base, Fort Frederick. After receiving numerous hits, the helicopters retreated, reassembled, and attacked again through heavy fire. This time one helicopter was destroyed, and the others broke off the attack.

Here again, the problem was the absence of supporting fire. It would have been straightforward to have *pinged* the location of the ZSU-23s from one of the BLACK HAWKS carrying the Rangers. Even if the target's location had been determined with considerable error, a cluster of six to twelve PSSMs should have been sufficient to have swept the roof of the Richmond Barracks.

The third example is drawn from the Vietnam War. In this case, a U.S. convoy of about 60 trucks was sent along Highway 1 from Xuan Loc to Hoi Nai. Several M-113 APCs were included to provide protection from ambush. Indeed, the Viet Cong, having received notice of the convoy, did establish a large ambush close to the road. Their plan was to use two 75mm recoilless rifles to destroy the first and last vehicles to stop the convoy and then to attack the vehicles with automatic weapons fire (see Figure 9).

As it happened, the ambush was executed poorly, and about one-third of the vehicles could run the gauntlet before the recoilless rifles halted the convoy. At

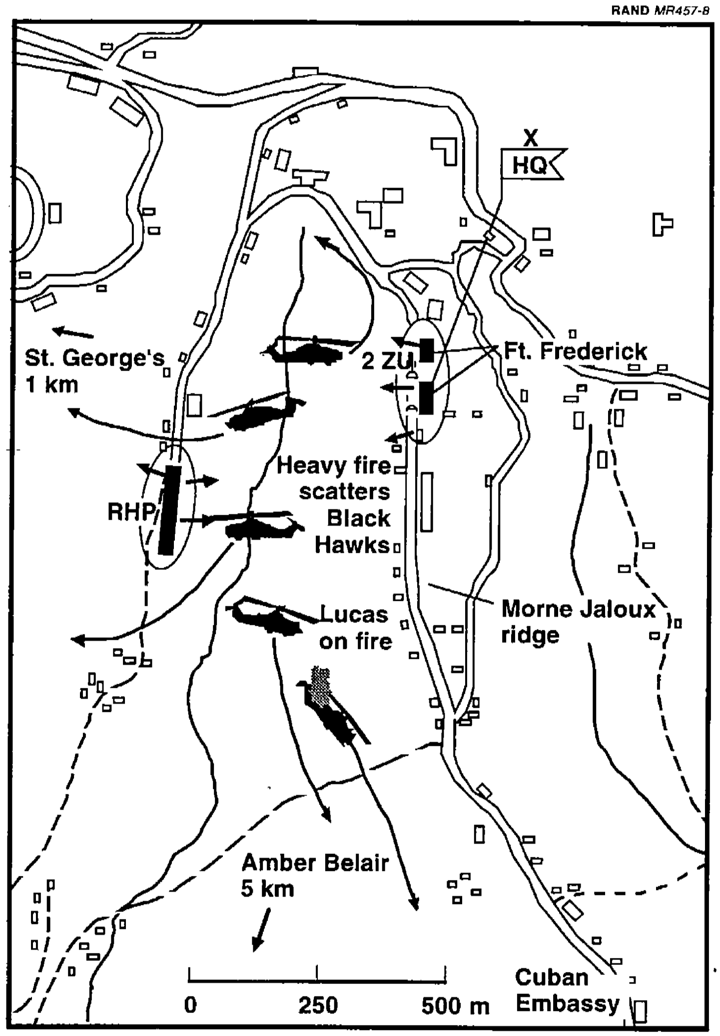

Figure 8—Example 2: Attack on Richmond Hill Hospital, Grenada

that point, about two battalions of Viet Cong took the trucks under heavy fire. This phase of the battle lasted about five to ten minutes before on-call Cobra gunships were able to intervene. The Viet Cong broke contact and retreated to the south.

PSSMs should be quite valuable for ambushes. In this case, the enemy is firing from more-or-less fixed positions, and quick, accurate delivery of counterfire is of the highest importance. Indeed, an ambush may be triggered and concluded in the time it takes to call for and receive support from artillery or aircraft.

PSSMs could have been used here to suppress the fire of the recoilless rifles and heavy machine guns, whose locations were visible to the U.S. forces.

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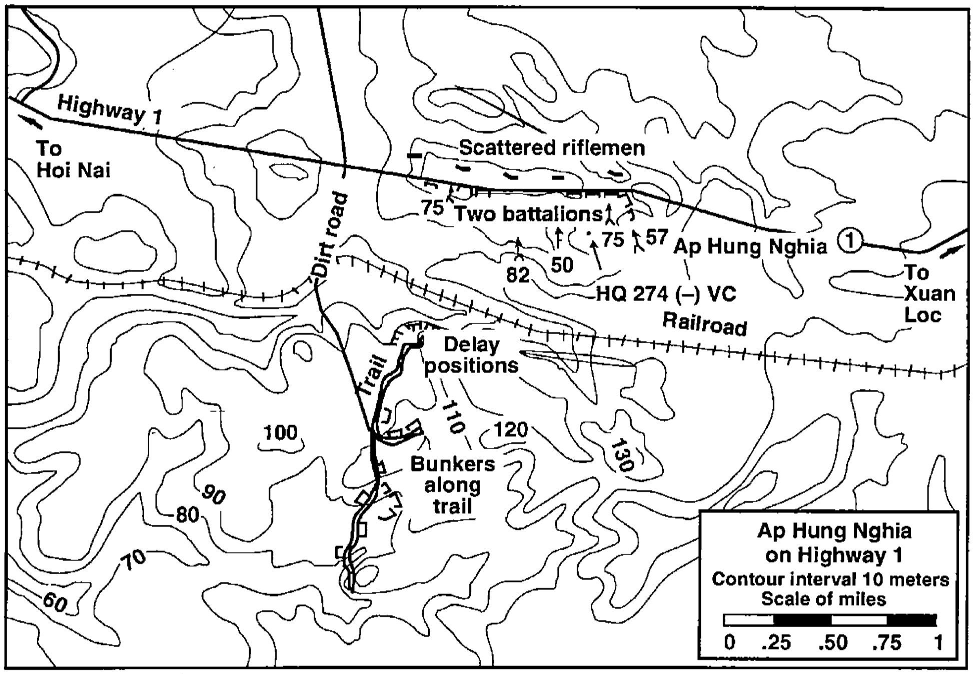

Figure 9—Example 3: Ambush on Highway 1, Vietnam War

Alternatively, PSSMs could have been delivered along a line to saturate the area between the two recoilless rifles located at the front and rear of the Viet Cong (VC) position.

These cases share several common themes. First, in two of three, the resistance encountered was much more dangerous than anticipated. Given light infantry's vulnerabilities, it does not require much miscalculation for that situation to arise. Second, supporting fires were either unavailable or long in arriving. Third, the combatants could see one another or could detect one another's positions by various signatures. Fourth, the enemy's positions were fairly fixed. Fifth, concern for collateral damage was low.

The map exercises we performed suggested that the PSSM would have been effective in each of the three battles. The SEALs in Government House could have been supported, the Grenadan ZSU-23s destroyed, and the Viet Cong ambush suppressed much more quickly than actually occurred.

The features of these battles are representative of many light infantry battles. These types of battles are the most appropriate application of the PSSM. The enemy's positions can be *pinged* with the laser target locator because they are detectable from their visual and acoustic cues. Since those positions are fairly fixed, a good chance exists that the enemy will still be at or near the GPS coordinates assigned as aim points when the PSSMs arrive.

This point needs amplification. The volume of fire deliverable using PSSM and its flight times (at long ranges) make the PSSM much less effective against moving targets than fixed ones, at least ones more-or-less fixed in the lethal radius of the PSSM for the seconds or minutes needed to reach the target. Therefore, such targets as bunkers, crew-served weapons, or ambush positions are appropriate for PSSM; vehicles (such as the BTR-60 that threatened the SEALs in Grenada) are much less so. In principle, as it flies down range, a PSSM munition could receive target updates. The munition could maneuver within some envelope against moving targets if it were equipped with additional flight surfaces. Again, in principle, multiple PSSMs could receive updates in flight for multiple targets, although some coding system would be necessary to assure that each target's updates were received by the munition assigned to that target. Since this research has not progressed to the stage of investigating these possibilities, no more can be said at this stage.

Some readers have responded to the examples used here by noting that supporting fire should have been available, if the operations had been planned correctly. Maybe this point is valid; maybe it is not. What is germane is that every light infantry campaign we have examined contains numerous examples of these kinds of operations. If they occur so often, we can have no confidence that the problem is simply a matter of planning errors. Rather, they bespeak the difficulties inherent in the great uncertainty of infantry operations. It is virtually unavoidable that units will continue to find themselves in trouble as a result of the combination of problems illustrated in these three examples.

The PSSM can ameliorate some of these problems by being on station in a central location. Unlike a CAS aircraft, which has to fly to the unit in need of support, a PSSM-equipped aircraft need only orient the munition in the proper direction (by pointing the aircraft correctly) to provide support from a considerable distance. A time of flight of 1 to 3 minutes is much quicker than the average response times for other supporting fires in the cases we examined. Also, even units not expecting to need or receive support can receive it in an emergency. Certainly PSSM could never replace artillery as a source of support because the volume and weight of fire of artillery make it *sui generis*. But PSSM could fill the important gap between the time a unit needs artillery support and the time it receives it.

By contrast, PSSM may be able to replace close air support on some occasions, thereby freeing higher performance aircraft for other, more appropriate assignments. Indeed, PSSM should be considered a form of standoff CAS.

Command and control for PSSM are particularly important if its capabilities are to be fully exploited—in particular, PSSM's large radius of action. Since many operations can be underway within that radius, PSSM aircraft could receive large numbers of near-simultaneous calls for support. This, in turn, implies the requirement for an artillery-like target priority and queuing system that will diminish PSSM's responsiveness. This issue is being researched, but some qualitative points can be made now.

One key to keeping PSSM responsive is a high rate of fire. The higher the rate, the less need for target queuing, since the time between hitting the first target and the last one is short. Obviously the supply of PSSMs cannot be unlimited, so target priority considerations must still be addressed, even if the PSSM aircraft can launch many munitions in a short period.

An interesting approach may be to leave much of the target priority question in the hands of the users on the ground. Specifically, the number of PSSM laser target locators within a given area of operations would be limited to one per platoon. Each platoon would be allotted a given number of PSSM calls depending on the character of its mission, the terrain, the threat, the number of other platoons in the area of operations (AO) also with PSSM privileges, and the total number of PSSM munitions available for the time period in question. Each platoon would receive some share of the available PSSMs. When that share is used, normally no more will be allotted for the mission or time period. Therefore, each platoon leader will have an incentive to be strict in his target priorities, since he will know that only a limited number of PSSMs are available to him. If he uses them wastefully, he will not have them when a real need arises.

This approach should reduce the number of calls for PSSM support received at any given moment, and, when combined with a high rate of fire, may be sufficient to eliminate the target priority and queue problems. Of course, this approach does not permit assignment of target priorities between simultaneous calls from different platoons. If, in spite of these incentives to be thrifty, such calls are still numerous enough to swamp the rate of fire, centralized assignment of target priorities may be necessary. The number of calls necessary to produce this condition is a function of the PSSM rate of fire, which will be addressed in further research.

7. Conclusions

We have found that, for U.S. qualitative advantages in light operations to approximate those enjoyed by U.S. heavy forces, two problems have to be ameliorated. First, U.S. light forces must be able to locate their adversaries reliably, quickly, and accurately without coming within range of hostile fire. Second, once located, U.S. light forces need the capability to engage their adversaries with precision from sanctuary. Unfortunately, this project was unable to discover significant, near-term, qualitative improvements in reconnaissance capabilities for light forces.

However, we have found that GPS-technology can be applied to develop a weapon, PSSM, with the long range and precision needed by light forces. If the weapon could be linked to a light force Joint Surveillance Target Attack Radar System (JSTARS), PSSM or similar weapons could reach their full potential. Even without such a reconnaissance breakthrough, PSSM is a substantial qualitative improvement, because it can reduce the requirement for light infantry to close with its adversaries.

PSSM is not appropriate for all situations. It is most useful when the enemy is relatively fixed and concerns about collateral damage are low.

Appendix

Standard first-order aerodynamic analysis methods were employed to calculate parasitic drag, drag-due-to-lift, and glide ratios. Conservative assumptions were used. A trade study was performed to determine whether the wing should be fully extended to the no-sweep position or whether better glide performance at high speeds would be obtained with a swept wing.

Overall, it was learned that glide ratios of between 8 and 14 were readily obtainable, depending on lift coefficients and Mach numbers. Also with reasonable allowances for pullout, turn, and terminal dive, a total range of about 25 n mi could be obtained. The benefits obtained with the wing swept were determined to be slight at the expected glide speed of 450 kts and not worth the increase in control system complexity (see Table 2).

Based on these data, range analysis was performed assuming the unswept wing with an averaged L/D of 9. The aircraft is assumed to release the PSSM at 30,000-feet altitude at a speed of 250 kts. To accelerate to 450 kts at that altitude requires a theoretical energy exchange equal to 6205 feet of altitude loss, which was increased to 8000 feet to allow for drag, turning, and the pullout. Also the PSSM is assumed to separate its wing for the terminal dive at 5000 feet.

The resulting total gliding altitude change is 17,000 feet (30,000–8000 to 5000). Using the averaged L/D of 9 gives a total range of 153,000 feet, which equals 25 n mi or 46.6 km. At 450 kts, the glide time is then 3.3 minutes.

In the terminal dive, the 5000 feet of energy exchange begun at 450 kts gives a theoretical terminal speed of 948 fps (Mach 0.85), which would probably equate to about 900 fps when drag is accounted for.

Table 2

Glide Analysis, V-450 kts

Altitude	Mach No.	q	C1	Lift/Drag (L/D)	Lift/Drag swept
0	0.68	687	0.17	7	6.5
10,000	0.71	508	0.23	8	8.5
20,000	0.73	367	0.32	10	10.5
30,000	0.76	257	0.46	12	12.5

In sum, a notional design was prepared and evaluated for a GPS-guided glide-weapon called PSSM capable of airborne launch from large tactical aircraft. Based on this study, it appears feasible that a glide-weapon using current technologies can be developed with a range of about 25 n mi with a glide speed of 450 kts.

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