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THE IMPLICATIONS OF THE PGM ERA

Current discussion of the consequences expected to stem from the introduction of "smart" weapons into nonnuclear warfare tend usually to be circumscribed by several tacit assumptions:

- (1) that the available (and future) technology will be applied to the design of weapons that are expected to increase the effectiveness of the major combat arms of existing forces;
- (2) that the major features of present organization, deployment, and operation of forces will not be changed radically; moreover, that traditional appreciations of threats and opportunities, of suitable choices of objectives, and of command doctrine and function will remain valid;
- (3) that the new "high technology" devices are inherently complex and costly; that their employment requires special training and skill; that they will be available in limited numbers, and thus will be designed and used only for certain particular missions.

These assumptions are rarely stated explicitly and their truth even less often questioned; for the present they appear to be self-fulfilling prophecies. It is argued herein that they are not only unnecessary, but also dangerous inasmuch as they risk technological surprise by an enemy who perceives broader opportunities.

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In defense of these assumptions, and of present development programs, it can be said that they are reasonable for the short term. For one thing, they address the immediate problem of improving the effectiveness of forces in being. Further, that they are appropriate during our evolution toward an unforeseeable future: that current development will serve to surmount technical difficulties, and that ongoing programs are yielding weapons with which we will gain needed operational experience. It is not intended here to question the merit of these claims, but to argue that present plans and programs are insufficient.

Some consequences of smart weaponry are foreseeable, and they indicate a coming need for radical changes in force structure and operational concepts. Fundamental changes are likely to require long lead times, even if the evolutionary goal is defined early; undirected evolution, responsive to short-term perceptions of opportunity and need, risks failure. The short term evolutionary steps should be guided by a view of the long-term goal.

Already-available technology would permit the development of a great many varieties of weapons, many of these suited to unusual force structures and operational concepts. Some of these offer attractive novel opportunities, but such recognition is hampered by the absence of corresponding requirements in present forces. The opportunity to invent devices is so great that one's difficulty lies in winnowing out the few that deserve attention. In doing that it is essential that we consider carefully those that a potential enemy might select--devices and concepts that we might find uncongenial and for which we have no stated requirement, but that

would exploit our vulnerability. It would be dangerous to predicate our future military capability on the assumption that an enemy will forego such opportunities.

* * * * *

To clarify the long-term implications of smart weapons it is useful first to consider a simple generalization. These devices, though highly varied in their technical features, share an important common trait: they are fairly likely to hit what they are aimed at. It would be unwise to deny that they can be made to work--if not perfectly, at least very much better than the older-fashion devices. Anecdotes of developmental blunders, technical shortcomings, and operational fiascoes will be misleading if it is thought that they cast a long shadow.

This generalization, that we are talking about things that are likely to hit, deserves more attention than it gets. For several centuries, men have been using weapons that were usually quite unlikely to hit. When, infrequently, the hitting increased, military practice had to accommodate and sometimes a war was lost. We are entering a time when weapons will be very likely to hit, and to hit at unusually long range. We should understand that this is a big change from the experience out of which present forces and concepts evolved. We should be prepared to find that drastic changes will be forced upon us, even if we fail to perceive all this as an opportunity. The new technology presents both the carrot and the stick.

The Yom Kippur War offers a peculiar opportunity to gain more particular insight into what hitting weapons will mean. It was widely remarked that in that war the rate of expenditure of munitions was high, and suggestions have been offered that such rates will be characteristic of PGM warfare. Inasmuch as nearly all the munitions expended in that war were not at all smart, and neither were some of the users, the inference is not well founded. However, a very high consumption rate of smart weapons would imply an equally high rate of exposure of targets and of killing. At those rates one would exhaust the supply of enemies pretty quickly, for which reason it has been suggested that such wars will be brief but deadly. Indeed, such a spasm war might occur; today's weapon developments, based upon the limiting assumptions mentioned above, seem to be headed in that direction. The outcome of such a spasm is probably unpredictable; it would be better to avoid it rather than to hazard that our side would win.

With or without the occurrence of a few spasms, they certainly will not be a long-term characteristic of smart warfare. The targets will learn how to hide because, to put it simply, if you can be found you will be hit. Hiding, per se, is no novelty; people have hidden in forts and in trenches for centuries, and they will hide in the future. But hiding⁴ bespeaks a low rate of target exposure, not a high rate, and a long war not a short one; probably it will be a war of attrition, not a blitzkrieg.

Today's forces will find it hard to hide from smart threats. An armored division certainly can't hide; neither can an infantry division that rides in APC's and Jeeps. It is doubtful that one could hide any

vehicle that carries enough firepower to deserve the enemy's attention. Nevertheless, the combat forces must figure out how to hide yet retain capability. That is a major implication of the advent of high technology devices in the battle area.

There is a second implication, a corollary of the first but deserving of further discussion. This stems from the fact that the ability to achieve hitting accuracy is not limited to short range or line of sight. There are at least two ways known now (possibly three) to hit at long range a target whose location is known (they are: optical or radar area correlation, remotely-linked television, and, perhaps, any of several electronic coordinate systems). It would be risky to bet that one's fixed targets can be protected from such standoff attack; neither active nor passive defense does more than raise the attacker's admission price, often at excessive cost to the defender.

An enemy who perceives the opportunity could deliver hitting attacks upon the entire rear structure that supports a modern force. He could attack not only every structure on every operating base, even hundreds of miles in the rear, but also every wharf, bridge, warehouse, ammo dump, POL depot, and maintenance facility in the logistic system. He could undertake to destroy the ability to deliver consumables to the combat forces and to prevent the movement of reserves. He might succeed, and thereby win the war without much engagement on the battlefield.

For reasons discussed below it should not be supposed that the attacker will run out of weapons; he could have a great many. Neither should it be supposed that dispersal of the rear structure would save it.

Dispersal is not concealment, and the materiel supply upon which present forces feed can't be hidden. The implication is simply that we should not count on standoff range to provide shelter from attack, and we should not rely on our ability to deliver copious amounts of materiel to the combat elements; to do those things would invite our enemy to exploit our vulnerability.

No doubt still other implications of the nature of the PGM era could be foreseen, but these two will do for a start:

- combat forces must be concealed yet remain capable
- the delivery of consumables to the combat elements must be circumspect, the amount must be scanty, and the capability of the force must not depend upon bases in the theater.

Our present force, indeed our entire "style", involves large numbers of vehicles at all echelons and an immense flow of consumables--none of which can be protected. We don't know how to do otherwise, but we had better learn because we will be vulnerable. Accommodation certainly will involve changes so radical as to seem outlandish by present standards. Reluctance to adopt radical goals toward which to direct our evolution will extend the lead time and increase our danger; it should not be thought that this future is remote.

Even if one writes off existing forces, institutions, and concepts. It is not easy to devise ways to meet the two major needs above. To commence, it is worthwhile to consider how a concealed force, lacking in-

theater bases, could cope with a heavy attack by current forces. The next logical step, consideration of how an enemy might try to accommodate to this novel force, and the response in turn, will not be addressed here. The discussion below offers a rationale for the design of such a novel force together with some considerations that suggest its technical and budgetary feasibility. Some of the serious social and political problems are mentioned; these latter present greater impediments in the way of any novel force concepts than would the technical uncertainties.

* * * * *

In designing a new concept, an obvious first option to consider is: might it be feasible to do without ground-based combat elements--to employ only aircraft? There is undoubtedly a role for aircraft in carrying and delivering strikes and other payloads, and that topic is discussed in some detail below. However, to do without ground-based elements would put the entire target-finding burden on the aircraft. Aircraft, even when operating over terrain containing enemies, do not offer adequate target-finding ability--for example, against men on foot. Moreover, the SAM threat will make the airspace over hostile forces virtually untenable (except perhaps at altitudes so high that the aircraft's combat effectiveness is at least as questionable as that of the SAM launched against it). Both reconnaissance and strike aircraft will have to stand off. Standoff reconnaissance is certainly incapable of providing sufficient target-finding today, and the prospect of ever developing such a capability is

poor. Moreover, an emitting aircraft will invite standoff SAM attack. We should await a demonstrated ability of standoff reconnaissance aircraft to survive and do the job before committing our force evolution to the elimination of ground forces.

Whether or not RPVs might play a role will depend upon whether survivable basing and logistic support for them can be provided, and upon whether a workable scheme can be devised to make effective use of their reconnaissance information. Both these needs must be met; either one alone will not do. If these things can be done, then RPVs might play a welcome, but probably minor, role. The force discussed below could do without them.

For the present, until we know we can do without them, the ground force must contain men. They are needed for their target-finding ability and for very little else. Fortunately, modern technology makes it possible to put a man in control of immense standoff firepower--as much as we are accustomed to attributing to a whole division. Thus, it is not necessary for the men to carry the munitions. That is just as well, because a man can't carry enough on his shoulders, and we wouldn't be able to resupply him. The proper role for the man is to carry electro-optical equipment, to find and identify targets, to call for standoff fire, and perhaps to participate in terminal guidance. Having no heavy burden to carry, he can walk; in the concept presented here there is no need for him to move very far or very fast. Afoot, he can hide behind a bush. That ability is important because it diminishes the enemy's ability to diagnose his location from a map study.

For numerous reasons the man should not be alone, but there is no need for many men at one location. Thus, we are led to the idea of a small team of men. There doesn't appear to be need for as many as five, but two seems too few; a team probably should contain three or four men.

There is no need for a second team close to the first, and proximity is undesirable for several reasons. For one thing, the probability that any one potential hiding place in a region is occupied should be low; otherwise the enemy will find it advantageous to lay artillery fire on every bush. For another, teams in close proximity must coordinate their movement and their fire; that would risk exposure. Finally, such dense deployment is unnecessary; the job can be done with sparse deployment.

Thus, we arrive at a ground force consisting of a number of teams of men dispersed throughout the region and concealed. It is quite appropriate to think of them as guerrillas--albeit perhaps trained uniformed professionals--in command of heavy firepower delivered to them, on call, by standoff missiles. Like Mao's guerrillas, they should "swim in a friendly sea"; it would be well, when possible, that they be natives, in place in peacetime, and thoroughly familiar with their region.

In war they must remain in place except for local movement to enhance their concealment or their effectiveness. They should seek to attack targets as opportunity affords, except on occasions when attack would put them in undue jeopardy. After the leading edge of an enemy force passes they should continue killing targets in his rear. They should be capable of operating indefinitely, waging an ongoing attrition war. Such a force should be deployed throughout the entire theater so

as to attrit the invader, wherever he goes or stops, for as long as the enemy remains.

It is commonly thought, on intuitive grounds, that such a dispersed force would need unreasonably dense deployment, or unobtainable radius of effect about each site, and unattainable deadly weapons at their disposal, to be effective. To a considerable extent these are technical questions amenable to estimation by analysis. A preliminary analysis is summarized in the Appendix. It is shown there that a force fewer than one division, dispersed throughout West Germany, with modest terrain visibility, and calling in low kill probability fire, could nevertheless impose quite substantial and continuing attrition. The Appendix also shows that a similar force, numbering about 16,000 men, deployed at higher density along the West German frontier, and calling in antitank mines as well as other munitions, could slow and then chew up a heavy invasion even across a wide front. The attrition force dispersed throughout the country would await the invaders who broke through the frontier force. The particular numbers cited in the Appendix should not be regarded as recommended values or as the best attainable; they were chosen as plausible but illustrative. Their purpose is to show that the usual intuitive estimates are seriously erroneous and that the whole problem warrants careful study.

Lest it be thought that a team deep behind the enemy front would soon be put out of business, their self-defense capability deserves mention. First there is the matter of just how the enemy might go about finding the team. Preliminary analysis indicates that it would be possible

for the team to communicate over several hundred miles to the standoff missile launch platforms, to defeat enemy jamming, and to defeat enemy direction-finding. (The methods used would include spread-spectrum transmission, copious use of decoys against DF, and standoff emitter-killing missiles against high-power jammers.) During the enemy search for them, the team would continue to kill searchers. Heavy CBU delivery would defeat even a large infantry force searching afoot. It would be quite impractical and fruitless for the enemy to lay fire on every bush, tree stump, hillock, and shell hole in the country.

Clearly, the self-defense needs of the team require that the delivery time of the standoff missile be short. So too does the problem of attacking moving targets. It is suggested here that the delivery time should be about three minutes. (That number is about the least that seems feasible; perhaps four minutes would do; five minutes seems too long. The matter needs study.) This brings up the matter of launch platforms.

Those missiles that must arrive promptly cannot be based far away. Preliminary analysis indicates that an air-launched missile could arrive from 200 miles in three minutes and yet not involve an unreasonable missile design. Such a missile, capable of delivering about 1000 pounds (payload, guidance, control, etc.) is thought to weigh not more than 5000 pounds. The foregoing numbers will be used here as a basis for tentative estimation. Some missiles used by this force (including long-range PGMs for attacks on fixed elements in the enemy rear, resupply canisters for the ground forces, communication decoy dispensers, and emitter-killers) need not arrive so quickly. These latter could be based further away and

could travel somewhat more slowly.

It does not appear possible to base these standoff missiles on the ground. For one thing, there are too many of them (discussed below) and not enough real estate. Further, such basing would be in danger of being overrun as well as subjected to standoff PGM attack. Mobile surface basing would use too much highway and too much fuel. Any surface basing would raise the gross weight of the missile quite significantly if prompt delivery is to be achieved. Finally, it is highly desirable that this force be capable of rapid global deployment.

No alternative to the use of air platforms to transport and launch the missiles is evident. However, foreclosure of theater basing of the aircraft dictates that these must be long-endurance large-capacity aircraft. It is suggested here that the aircraft be based in the United States and be capable of flight to NATO and return without landing. Such an aircraft must be capable of carrying a useful number of standoff missiles, some models of which might weigh 5000 pounds, together with handling and launching machinery. The aircraft must be capable of loitering in the launch area for many hours, available for prompt launch in response to a call. Moreover, it must be capable of returning with the entire load aboard lest jettisoning deplete the missile stockpile in responses to feints. One is led to seek an aircraft that can fly out, say, 5000 miles, loiter 12 to 24 hours, and return while carrying 100,000 to 300,000 pounds of load.

Airplanes offering this class of range/payload performance are outside present engineering experience, and estimates of possible future

designs are controversial. There have been recent design studies of aircraft that might be developed in perhaps 8 to 10 years at a cost of several billion dollars prior to initiation of production. They assume some 60 percent improvement of cruise efficiency over the C-5; such a development program is believed to involve acceptable technical risk, and is in line with historical airplane development.

One representative conceptual design recently produced by Boeing as part of an Air Force-sponsored study can be used to illustrate the performance that can be expected. This airplane would have an empty weight of 630,000 pounds, a maximum payload weight of 400,000 pounds, and maximum gross weight of 1.5 million pounds. For missile payloads, the cargo compartment will undoubtedly be weight limited. To consider possible trade-offs, it will be assumed arbitrarily that, for any payload between 100,000 and 300,000 pounds, three-quarters of the load are missiles at 5000 pounds each. It will also be assumed that the ready fleet can sustain operations indefinitely with ground time equal to air time.

Flying the entire mission without refueling, this aircraft could carry 100,000 pounds of payload (15 missiles) and loiter on station 12 hours. The total mission duration would be 37 hours for 5000-mile radius. To maintain 500 aircraft on station continuously would require a ready fleet of 3084 aircraft. There would be a continuous on-station supply of 7500 missiles at an average launch rate of 625 per hour. This unrefueled mode avoids the operational complications of aerial refueling.

Alternatively, the same basic aircraft could be used in a mixed fleet of missile carriers and tankers. To achieve the same 7500 missiles

on station at an average launch rate of 625 per hour, refueling arrangements suitable for 300,000-pound payloads (45 missiles) and 12-hour loiter time would sustain the operation with a fleet of 1516 ready aircraft. Using the same 300,000-pound payload, 24-hour loiter, and different refueling arrangements, the 7500 missiles could be sustained on station by a ready fleet of 1334 aircraft. However, in this case the limiting average launch rate would be only half as great; whether the reduced average rate might suffice would depend upon the nature of the war at the time.

To put the contrast between the two modes differently: If one purchased the fleet of 3084 needed to sustain the unrefueled mode, but used them in a 300,000-pound/12-hour loiter refueled mode, he could sustain about 15,250 missiles on station with an average launch rate of 1270 launches per hour. Acceptance of the operational drawbacks of refueling would more than double the missile delivery capability of a fleet; whether or not refueling is operationally acceptable in this instance requires careful study. The comparative gross fuel consumption between these modes has not been estimated, but it too would bear on the decision.

It would be inappropriate to undertake here an adequate discussion of the air defense of these aircraft, but it should not be thought that they would be easy prey. They should carry emitter-killer standoff missiles with which to kill surface-based and airborne radars that seek them (as well as to kill hostile jammers and radars the enemy uses for his own defense against PGMs). These aircraft should radiate little signal themselves, and what emissions they do make should be protected by

decoy emissions. They should carry self-defense AAM, and, in some theaters, the dispersed ground forces between them and the enemy should carry man-transportable SAMs. Finally, they should lay very heavy stand-off fire on the enemy airbases, communication and navigation facilities, and logistic support structure.

When sizing the missile stockpile for this force, it must be borne in mind that, except for AAM and man-transported SAMs, all the munitions used in a major nonnuclear war would be delivered by standoff missiles. These would include not only the munitions expended for attack directly upon hostile combat elements, but also missiles used to emplace mines, to attack hostile emitters, and to attack a large number of individual aim points in the enemy rear. In addition, missiles will be needed to emplace and replenish communication decoys needed to protect the ground forces against direction-finding, and missiles will be needed for canister delivery of consumables (e.g., food, batteries, spares) to the ground elements. A large number of missiles must be on call at all times, to sustain the ground forces' confidence in their self-defense as well as to avoid easy saturation of the missile supply; it is essential that the force not run out or be rationed. For this discussion it will be assumed that the stockpile should number one million missiles; careful study might show that this is too few.

In the context of current procurement budgets and unit prices, it seems pointless to discuss a stockpile of a million missiles and a fleet of several thousand large aircraft. Nevertheless, the United States probably could purchase these quantities during a decade at an annual

cost of perhaps one-quarter of the present DoD budget.

To gain perspective on hardware costs it is worthwhile to note that most 1976 production-line American automobiles cost (sticker price) about \$2/pound; some cost as little as \$1.60/pound; none cost over \$3/pound. (Imported German and Japanese cars do not cost less per pound.) These prices are one to two magnitudes lower than those to which we have become inured for some modern military hardware. The disparity arises in part from costly and wasteful procurement practices, and in part from our habit of buying too many kinds of things and too few of any. Much of this results from a system that fosters the development of numerous models that differ marginally, and from sub-optimization in the name of cost effectiveness. Very little of the cost disparity between automobiles and missile hardware stems from intrinsic difficulty or cost of construction. There is no reason to believe that one of these standoff missiles is much harder to build than a modern automobile, nor reason to believe that the missile should cost much more per pound--if missiles were built, as cars are, on an assembly line, and if their design did not crowd the limits of available technology.

The key to buying this missile hardware at "civilian" prices is to buy very large numbers of very few models for a long time and to avoid performance demands that lead to expensive designs. For that reason the various standoff payloads needed for this force concept should ride in only about three missile vehicles; at present only about seven kinds of payloads seem to be needed. Let it be supposed for the moment that all of the missile/payload combinations will weigh 5000 pounds (perhaps none

will turn out to be this heavy, and quite a few will be much lighter). Despite the suggestion above that perhaps these could come off an assembly line at "civilian" cost, let it be assumed that the cost will be \$20/pound. Even then a procurement of 100,000 per year would cost \$10 billion annually--less than 9 percent of the present DoD budget. Such a procurement, sustained for 10 years or more, would justify the needed production engineering, tooling, and assembly line; the budget would get the attention of people who know how to build on an assembly line.

The prospect for buying the needed aircraft cheaply is not so good. The airplane discussed above crowds the available technology; it will need large engines that are appreciably more efficient than current engines, large titanium billets, and the many other things that raise cost. In spite of possible savings that may come about from increased use of new composite materials and adhesives instead of rivets, that airplane is likely to cost \$100/pound in production--\$63 million each. Nevertheless, to buy in 10 years the fleet of 3084 for unrefueled operation would cost a little less than \$20 billion per year; the fleet of 1516 for the refueled mode would cost a little less than \$10 billion per year. In both cases, additional numbers per year or procurement years would be needed for out-of-commission aircraft and operational losses. Continued procurement at about half these rates would be needed to replace losses caused by over-age.

Annual procurement budgets of \$20 billion to \$30 billion for a decade, although high by current standards, are clearly not beyond U.S. economic capacity (nor that of the U.S.S.R.). Moreover, the choice of

a decade was arbitrary; stretchout to 15 years would reduce the annual budget without much impact on total cost (excluding allowance for inflation). However, when preceded by a decade of development, that stretchout would move the readiness date beyond the year 2000; it is not clear that the problem will wait that long.

The basic difficulty here arises out of a threat that might make obsolete a large portion of our current military establishment. Replacement by entirely new and different forces, of whatever kind, is sure to cost a whole lot of money. In these terms, the concept sketched here may be relatively cheap. In any case, although there are many technical problems to be worked out, the serious impediments are undoubtedly political and social. Fortunately, the milestones for truly difficult decisions are spaced out in time, and lie far enough ahead so that we may by then have stronger incentives for action. The decisions needed now, to initiate the early work and minimize the ultimate lead time, are comparatively painless.

* * * * *

The foregoing suggests several summary conclusions:

- technology offers the opportunity to invent and to use a wide variety of weapons that are likely to hit;
- this will compel combat elements to rely upon concealment and will prevent the delivery of large quantities of materiel to the battlefield;

- such a drastic revision of our military customs will demand the adoption of highly novel force structures and operational concepts;
- one such concept is sketched herein; it calls for the control of heavy fire of air-launched standoff missiles by a dispersed guerrilla-like ground force, and the waging of a drawn-out war of attrition;
- such a force, globally useable, would be suited to many "third area" problems;
- in special circumstances, notably NATO, a similar ground force deployed at much greater density along a frontier, and using extensive air-installed minefields, could probably repel a heavy invasion by present forces;
- the new force requires very large amounts of new hardware; these could be obtained, with feasible annual budgets, by adopting unusual (and politically difficult) procurement policies;
- the annual operating budget of such a force would be large; thus it should not be anticipated that big reductions in the DoD budget would ensue. There would, however, be significant changes in military manpower. These manpower aspects involve substantial political and social problems;

- the acceptance by allies of these concepts for their defense--notably in NATO--is questionable; here too there are serious political impediments;
- from the standpoint of arms control, the kind of force discussed here, with minimal manning and little or no hardware in place, would simply obviate the present MBFR negotiations. However, a large fleet of long-endurance missile-carrying aircraft would complicate strategic arms control problems quite seriously. If we do not wish now to foreclose a force of this kind, we should avoid barring these aircraft under the SALT agreements;
- the 10-year procurement cycle mentioned above would follow after a protracted period of development, test, and production engineering. Thus the time to full readiness of such a force would probably exceed 20 years if we began now. It is not evident that we will have that much lead time;
- the thoughts presented here are hardly more than a skeleton description of gross concepts. Considerable study effort is needed to examine the concepts and to substantiate all their aspects. Such study effort should commence now; we should not risk an unguided evolution toward an unforeseen future.

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Appendix

THE EFFECTIVENESS OF A CONCEALED DISPERSED FORCE

The potential effectiveness of a concealed dispersed force is sometimes questioned on the grounds of subjective estimates that an excessive number of concealed sites would be needed, or that each site would need an unattainable radius of effect, or that the weapons employed by the force would have to be unrealistically deadly. Inasmuch as subjective opinions of these matters tend to be seriously erroneous, a simple numerical analysis may serve a useful purpose by indicating the potential effectiveness of a force wherein these parameters exhibit rather modest values. Needless to say, the example below is not intended as a thorough or definitive study. The particular numerical values are not to be regarded as the best that might be achievable, but rather as representative of an achievement that might suffice.

For the purpose of this analysis it will be assumed that a ground-based force consists of a number of teams of men distributed randomly throughout a region. Each such team carries electro-optical equipment, sidearms, and (perhaps) a man-transportable SAM. All other weapon systems available to them are on call as standoff missiles, several of which types can arrive within about 3 minutes. The payloads on call should include hard-target munitions, area munitions against soft targets, anti-vehicle mines, and a few others not discussed here.

Their technical feasibility will not be discussed here; it is suggested that all are developable, and that it appears to be possible to deal with such obvious problems as hostile jamming and direction-finding, air attack on the missile launch platforms, and numerous anti-PGM countermeasures. These all require separate extensive treatment.

It is essential that a team be concealed, for which reason the members walk. There is scant reason for them to move about except to enhance their concealment and to improve their effectiveness by moving to advantageous positions. They must be capable of finding concealment in a great many places within their region, lest the enemy diagnose their position from a map study. A team is assumed below to contain four men; there is no need for more, but three might suffice. Such a team will be regarded here as being located at a "site," although they might agree among themselves to take up slightly separated positions.

Figure 1 shows the detection capability attributed here to a typical site. This curve is at best a "guesstimate" intended to reflect the limitations imposed by terrain relief, vegetation, and atmospheric transparency, but also that a team can avoid some of the local masking, and that a team need not observe a target over its whole track in order to achieve useful detection. For present purposes the shape of the curve is less important than the numerical value of the parameter P_d --taken here to be 2570 feet.

For several reasons, including concealment, a team may prefer to avoid attacks on targets whose tracks approach too closely (excluding, of course, targets that present an immediate threat), but that the team

might choose to attack some such targets when they are approaching or receding. Figure 2 shows the assumed probability that a site will detect and attack a target. Here too, the shape of the curve is less important than the numerical value of the parameter ρ_a --taken here to be 2050 feet.

If N sites are distributed randomly over a large area A , and a target undertakes to move distance L through the area, the probability of any one site detecting the movement is

$$p_d = \frac{2\rho_d L}{A}$$

The probability that any one site will attack the target (provided the target has not been killed by an earlier attack) is

$$p_e = \frac{2\rho_a L}{A}$$

The expected rate of detections, as the target moves along the path, is

$$2\rho_d \frac{N}{A} \text{ detections per unit distance}$$

and the corresponding rate of attacks is

$$2\rho_a \frac{N}{A} \text{ attacks per unit distance}$$

When a target undertakes to travel distance L , the probability that it will not survive the trip.

$$P = 1 - [1 - p_a p_k]^N$$

where p_k is the probability that the attack from any one site will kill the target. The average number of attacks expected to occur during such a trip is P/p_k . This latter number is somewhat less than the number of detections that would be expected, Np_d , because of the chance that the target is killed prior to some otherwise-expected detections.

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The foregoing simple analysis is applied first to the problem of distributing defense teams throughout a large region, such as a whole country, for the purpose of imposing serious and continuing attrition on an invader. It must be supposed that the defender does not surrender if his capital city is occupied, and that sustained losses (at least outside the city, and perhaps also within) deny that enemy beneficial occupancy of the country. Numerous nonanalytic questions, such as public morale, political continuity, taking hostages, and others, deserve more extensive treatment than is possible here.

Such a defensive force would be appropriate in numerous "third area" situations, for each of which the suitable deployment densities and attrition rates might be quite different. The particular case of such a defense throughout West Germany--about $250,000 \text{ km}^2$ --is discussed here. Similar deployment densities and rates would be appropriate for most of NATO--a region of such high value that extreme demands are placed upon the defense.

Table 1 shows the expected attrition of enemy movements versus the deployment density of the defensive teams. It should be emphasized that this table assumes rather low kill probability for an attack--at least it is low for the PGM era wherein "hitting" weapons are widely supposed to be available. This relatively low lethality might be attributed to detailed difficulties of terrain, smoke and haze obscuration worse than assumed in Fig. 1, enemy countermeasures, technical shortcomings, or operational difficulties. Nevertheless, it is seen that attrition might be imposed by a dispersed force numbering fewer than one army division. Indeed, an attrition rate as low as that imposed by only a few thousand men might suffice. It deserves emphasis that this analysis treats only attacks on moving targets, whereas the defenders will also be capable of attacking the enemy where he stops--perhaps more effectively.

The kind of defense sketched above might suffice in many situations. For example, a quite sparse force would probably have sufficed to defeat the Cuban force in Angola and thereby to return the conflict to the guerrilla-like affair that pro-United States elements seemed to be winning. However, for overriding political reasons, this kind of attrition defense is probably not sufficient for the central front of NATO. That is: such an attrition force throughout the country would have to be bolstered by a much more destructive defense at the frontier--a "crust" capable of inflicting heavy loss in a fairly shallow zone.

It must be supposed that the threat from enemy smart weapons demands that even the defensive crust consist of dispersed concealed

sites, and that they be sufficiently sparse that barrage fire will not be effective against them. Moreover, that they can't possibly be concealed while possessing the requisite firepower; they must employ standoff missiles. For these reasons, consideration is given here to a crust that differs from the dispersed force discussed above primarily in deployment density. To be specific: a crust 800 km long, covering the West German frontier, and 80 km deep--an area of $64,000 \text{ km}^2$. This is about one quarter of the area of the whole country, so one may regard one quarter of the sites listed in Table 1 as being components of the crust.

For various reasons, including mutual interference and exposure to barrage fire, the site density in the crust should not be excessive. It is suggested that about one site per 16 km^2 is the maximum reasonable value to consider. That would entail 4000 teams, about 16,000 men; the teams would be roughly 4 km apart along the entire frontier.

Consider now a heavy attack by many thousands of vehicles along a total front of, say, 100 km (perhaps in several prongs). The defensive deployment would place about 5 crust teams before each kilometer of front. As few as 500 teams might have to deal with more than ten thousand targets in a short time. Obviously, they would be saturated. The analysis sketched above ignores defense saturation arising, in this force concept, not from weapon availability or from weapon delivery rate, but from human limitations in handling multiple attacks while remaining concealed. It is simply unrealistic to suppose that a team could kill, say, a dozen targets per hour, hour after hour.

However, the team might indeed be capable of killing a very great many targets at a slower rate. What is needed in this situation is a means to slow the attack down so as to obtain improved killing capacity--~~not~~ to marshal conventional reserves in the rear.

The easiest way to slow the enemy advance would be to use fields of anti-vehicle mines. The mines should not be emplaced along the whole frontier in peacetime (for obvious reasons), but should be installed promptly, where needed, by standoff delivery. It would not be necessary that this extensive minefield be installed very quickly. However, when a defense site seeks to attack a few fast-moving vehicles, it would be advantageous to place a small minefield around the target vehicles as to slow them and thereby facilitate a prompt follow-on PGM attack. The latter use would require prompt delivery of the mines (so too would the use of mines for self-defense of a team). To avoid the need for two kinds of mine delivery missiles in the stockpile, it would be advantageous also to use the prompt delivery system to install the extensive "crustal" minefield.

The analysis method used above can also be used to estimate the density and extent of the minefield needed to slow a heavy frontal attack. It is assumed here that a vehicle must run over a mine to be endangered, and the frontal width of a typical vehicle will be taken to be 4 feet. Table 2 shows the kill probability versus distance traveled through three different minefield densities.

The enemy's determination to push onward is unknown, but all three densities would decimate a force that ran on for a great distance; a

more pertinent consideration might be the defender's desire to stop the advance at a particular place. Perhaps the most compelling consideration is that a suitable standoff delivery vehicle could probably carry 100 or more mines, but it might be technically difficult to spread them out as sparsely as 200 per km². The installed density might, for technical convenience, have to be higher. Nevertheless, inasmuch as this detail is open to possible future development, let it be assumed here that a density of 200/km² is decided upon.

The minefield should be installed throughout the entire 80 km depth of the crust--not because there is appreciable risk that an isolated vehicle might otherwise leak through, but to minimize the consequences of saturation. That is: the minefield must be capable of killing a great many vehicles. At the chosen density the field would present 16,000 mines per kilometer of front--a very respectable kill potential. There is, of course, no danger that the attacker might try to run his whole force up one narrow corridor. If he tried, the attack would develop very slowly and the individual vehicles could be picked off as they appeared. Moreover the defenders could lay an immense number of mines in that narrow corridor.

If the delivery vehicles could disperse mines at a density of 200/km², and if one such vehicle could carry 100 mines (the latter number is probably more plausible than the former), then this minefield would require 160 standoff deliveries per kilometer of front--16,000 for the 100 km attack front. The problem of achieving such sparse density, together with a possible need to augment or replenish

the field, might escalate the needed number of vehicles to 50,000. Such matters require further analysis and development.

This minefield should suffice to stall an attack for a very long time. If the attacker sought to move men afoot through the field, either to sustain the attack or to clear mines, those men would be quite vulnerable to attack by area weapons. The defense teams could probably cope with those men as fast as the enemy could insert them.

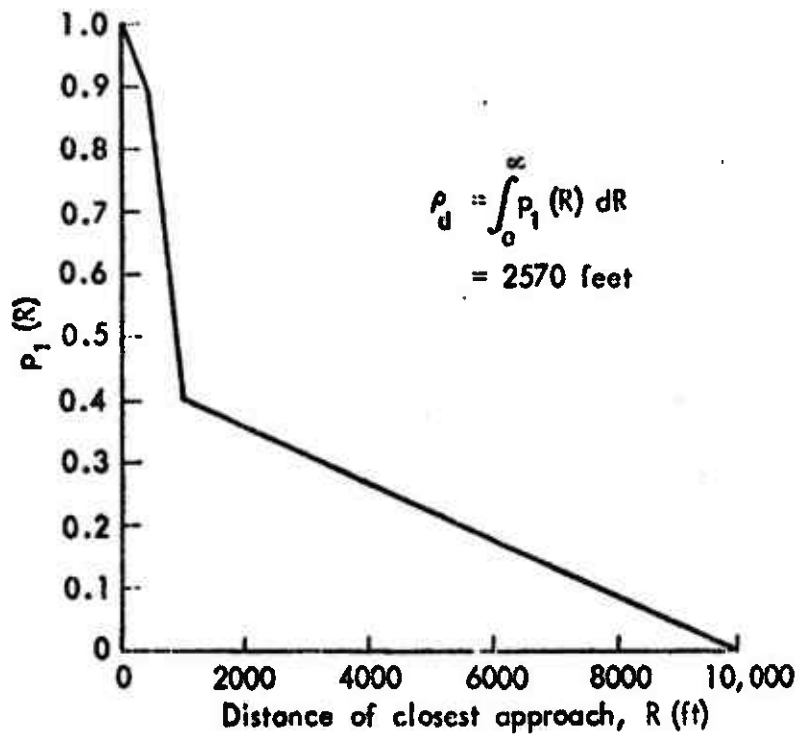


Fig. 1—Probability $p_1(R)$ that a site will detect a target

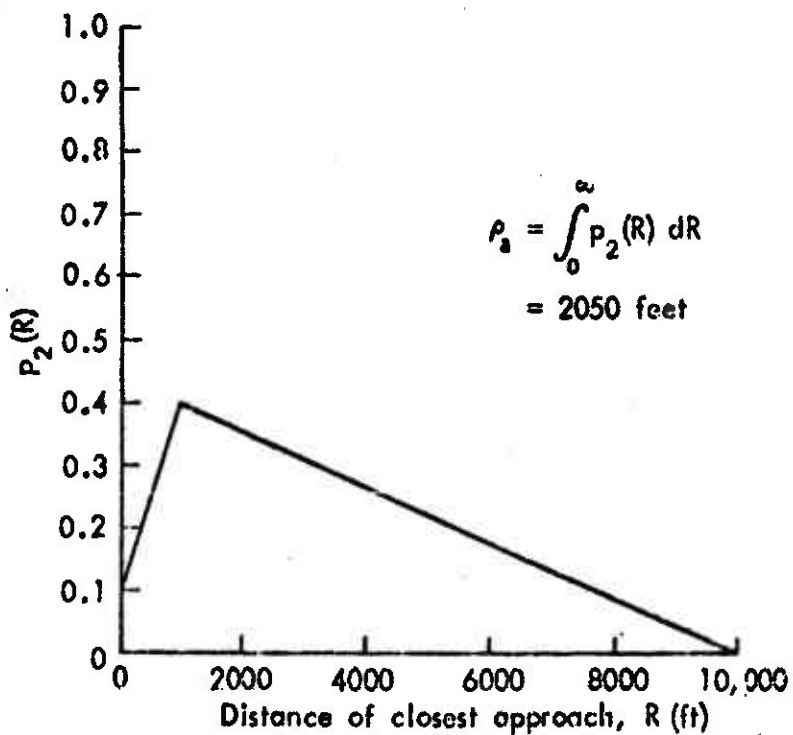


Fig. 2—Probability $p_2(R)$ that a site will detect and attack a target

Table 1

Number of Sites, N	Number of Men (teams of 4)	Area per Site: km^2	P	n
500	2000	500	.0247	.123
1000	4000	250	.0488	.244
1500	6000	167	.0722	.361
2000	8000	125	.0951	.476
2500	10000	100	.1175	.587

The attrition defense of West Germany ($250,000 \text{ km}^2$). Probability, P , that an enemy target will be killed during an attempted trip of 50 km, and the expected number, n , of attacks on such a trip. Kill probability, P_k , of one attack is assumed to be 0.2.

Table 2

Vehicle Movement; Kilometers	50 $\frac{\text{mines}}{\text{km}^2}$	100 $\frac{\text{mines}}{\text{km}^2}$	200 $\frac{\text{mines}}{\text{km}^2}$
0.1	.0061	.0121	.0241
0.5	.0300	.0592	.1148
1	.0592	.1148	.217
5	.263	.457	.706
10	.458	.707	.914
50	.953	.998	1.

Kill probability versus distance traveled through three minefield densities. Effective sweep width of vehicle is 4 feet.