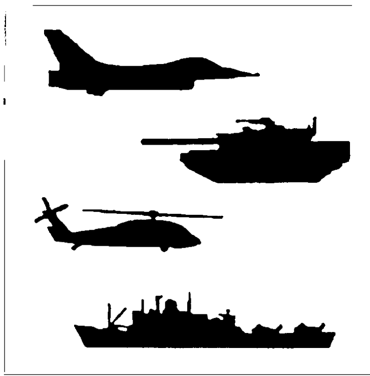
Avoiding Fratricide: General Considerations 3

America's recent combat in the Persian Gulf War brought new attention to an old problem: fratricide. Twenty-four percent of all U.S. combat fatalities in the war were caused by friendly fire.[1] This figure seemed much higher than in previous wars and caused a sudden focus on avoiding fratricide in future wars,

The U.S. military and the American public are becoming increasingly sensitive to the human costs of military involvement, especially for contests of less than national survival. For this reason, the United States has invested much in energy and equipment to keep casualties low. As casualties from hostile action decrease, the relative importance of fratricide increases and fratricide should receive more attention.

The previous chapter found that only in a very few cases are reliable estimates of fratricide available but in each of those cases, the fratricide rate was much higher than the nominal two percent rate that frequently appears in the military literature, Fratricide has been, and probably will continue to be, a significant source of combat casualties.

Moreover, the political and psychological cost of losses due to fratricide will always be greater than those due to losses inflicted by an enemy. In military operations involving allies, fratricide between countries can cause international friction at a time when strong cooperation is of utmost importance.[2]



[1] This value derives from 35 friendly fire fatalities out of a total of 148 combat fatalities. "Military Probes Friendly Fire Incidents, " Office of Assistant Secretary of Defense (Public Afairs), Aug. 13, 1991.

[2] During Operation Desert Storm, 9 British soldiers were killed when Maverick missiles from A-10 ground-attack aircraft destroyed their armored personnel carriers, causing considerable political controversy in the United Kingdom. See Glenn Frankel, ''In Britain, Fallout from Friendly Fire, " *Washington Post*, May 18, 1992, p. D1.

Fear of fratricide has been a constraint on combat tactics and maneuvers. The previous chapter described how lack of effective identification during both World Wars limited the use of air power for close-in support of ground troops. In at least one case, danger of fratricide is the primary constraint on tactics: the joint use of air defense fighters and air defense missiles in the same area. Conversely, development of a good, reliable antifratricide system could open up new tactical options. Better identification could allow more rapid attacks on enemy strong points, more aggressive defense and covering fire by dug-in second-line defenders as first-line defenders withdraw, closer and more agile air-to-ground or artillery support, and so on.

Fratricide becomes increasingly important not just because of its *relative* increase due to the smaller numbers of total casualties, but because of the way that the United States wants to keep those numbers low. The U.S. military believes that the best way to win quickly and decisively with least loss is to apply overwhelming firepower against the enemy. However, if the only people on the battlefield shooting are Americans, then it follows that the only way for Americans to get killed is from fratricide. Indeed, some simple theories suggest that fratricide may blunt the advantage of overwhelming advantage in number (or "force ratio") so that the U.S. approach to decisive combat may require solving the fratricide problem to be viable.[3]

TRENDS IN THE FREQUENCY OF FRATRICIDE

Some incidents in the Persian Gulf show trends that may exacerbate the problem of fratricide as weapons' development continues to advance. First, the tempo of battle has increased, oftentimes allowing combatants only seconds to make life and death decisions. Second, engagement ranges have increased. Mistakes of identification were difficult at the close ranges needed in the age of sword, but many modern weapons' range far exceed the range at which the human eye, or even instruments, can distinguish friends from foes. Also, the destructiveness of weapons has increased. In the past, fratricidal attacks could sometimes be stopped if the mistake was realized quickly, but now the first shot is often fatal, making an initial mistake irreversible. Finally, a potential problem often overlooked during the Cold War is that future enemies may have weapons similar or identical to those of the United States or its allies.

Other technical developments make avoiding fratricide easier. A British investigation early in World War II showed that among strategic bomber crews reporting that they had attacked their assigned targets, only one-fifth had actually dropped their bombs within five miles of them.[4] Absolute rates of fratricide may have peaked in World War II because the destructiveness of ordnance increased faster than the ability to deliver it precisely. Clearly, improvements in navigation, communication, and weapons-delivery accuracy improve the control of fire, making avoidance of fratricide easier (at least in principle). This hypothesis is supported by experience in Operation Desert Storm where, contrary to past wars, there were no artillery fratricides.

Since estimates of past rates of fratricide have been unrealistically low, any telltale that allows unambiguously attributing a casualty to fratricide causes a jump in the number of *visible* incidents. This accounts for part of the picture coming out of the Persian Gulf experience. For example, only U.S. tanks were armed with depleted uranium (DU) antitank shells in the Persian Gulf. The shells leave a small but distinctive and easily detectable trace of uranium on any target they hit. Thus, after Operation Desert Storm, a quick test could reveal clearly any fratricide caused by U.S.

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[3] Leonard A. Wojcik, "The Manchester Equations in Defense Policy Analysis," July 3, 1984, unpublished.

[4] John Terraine, *A Time for Courage: The RAF in the European War, 1939-1945* (New York, NY: Macmillan, 1985), p. 292

tanks. In World War II, the same poor communication and navigation that might cause fratricide would allow it to occur in the midst of the confusion of battle without anyone, shooter or victim, ever realizing it. Today's improved communication could make fratricide less likely while also making it more likely to be discovered when it occurs.

By any *absolute* measure, fratricide was not worse in the Persian Gulf War-or in Panama and Granada-than in previous wars. *The fraction* of deaths due to fratricide was apparently high, but this was due in part to the very low *total* American fatalities from all causes and, in part, to past underestimates of fratricide rates.

MEASURES OF THE SEVERITY OF THE PROBLEM

Part of the challenge of evaluating any antifratricide effort is deciding on an appropriate measure of how bad the problem is. On the one hand, the most common—and most public—measure is the fraction of all U.S. casualties caused by U.S. weapons; that is, a comparison of the number of U.S. casualties caused by U.S. forces to the total number of U.S. casualties.[5]

On the other hand, some argue that U.S. casualties caused by U.S. forces are more appropriately compared to the number of casualties inflicted on the *enemy* by U.S. forces, In the case of the Persian Gulf War then, the dozens of mistaken fratricidal attacks by U.S. forces should properly be compared to the tens of thousands of appropriate attacks on enemy targets.[6]

Comparing friendly fire losses to losses inflicted on the enemy is probably more appropriate in cases of wars against comparable enemies where the outcome is uncertain, such as the Cold War contest between NATO and the Warsaw Pact. In this case, relative rates of attrition will determine, in part, which side wins. In contests of less than national survival, such as the Persian Gulf War, final victory is less uncertain-if the Nation is willing to pay the price. The question is what that price will be in lives lost. In these cases, casualties should be as low as possible and military planners should address the causes of casualties in their order of importance. Thus, in these cases, comparing fratricide to total friendly casualties is the more appropriate measure.

Neither of these simple measures is adequate by itself. Avoiding fratricide is never the sole objective of a military force; it must be balanced with other military goals and efforts to hold down overall human costs. Combat is inherently dangerous and casualties are inevitable, and some of those casualties inevitably will be due to fratricide. Moreover, some measures to reduce fratricide could be so stringent that they would reduce military effectiveness and, in the end, increase the casualties inflicted by enemy forces.[7] (See figure 3-l).

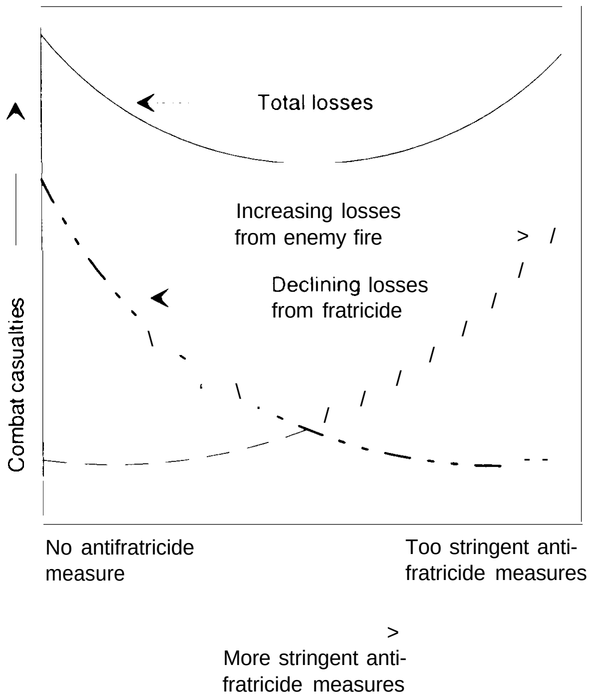
Yet a death due to fratricide will never have the same psychological effect as just another casu-

[5] When possible, this report uses fatalities as a measure of comparison rather than total casualties because of ambiguities of defining ''wounded.

[6] For example, if the 35 Americans killed arc compared to the 20,000 or more enemy killed in Desert Storm, then the fratricide rate is well under one percent. See Center for Army Lessons Learned (CALL), "Fratricide: Reducing Self-Inflicted Losses, " CALL Newsletter No. 92-4, April 1992, p. 5.

[7] This is precisely what some alleged happened during the opening phases of the air war against Iraq, that over-stringent IFF requirements allowed to go free an Iraqi fighter that later downed a U.S. jet. See Mark Crispin Miller, "Death of a Fighter Pilot, " New York *Times,* Sept. 15, 1992, p. 27 and New *York Times, ''Officer* Says Iraqi Jet Downed Navy Plane During Gulf War, Sept. 15, 1992, p. 5. The Department of Defense is uncertain but believes that the airplane was downed by a surface-to-air missile. See the rebuttal letter from Pete Williams, Assistant Secretary of Defense for Public Affairs, New York *Times,* Sept. *26, 1992,* p. *20.*

Figure 3-I—Casualties and Antifratricide Measures



SOURCE: Office of Technology Assessment, 1993.

alty. The destruction of morale, esprit, and military cohesion from a fratricide is far greater than that from a similar loss inflicted by an enemy. If fratricide's importance is measured simply by its effect on the outcomes of battles or wars, it seems of little significance: the historical review found no cases in which a fratricidal error clearly reversed the outcome of a battle. But incidents of fratricide can cause soldiers to become too cautious, too timid, and too conservative. These psychological effects may be intangible but every experience of combat shows how very real they are. In the end, military effectiveness is reduced. Thus, some military analysts believe that the secondary, hidden effects of fratricide on the psychology of the surviving troops may be greater than the direct effects of losses of forces.

THE ATTACK SEQUENCE

The review of fratricide incidents shows that very few result exclusively from mechanical malfunction; in almost all cases, fratricide results from deliberate-but mistaken-human decisions and actions that cause casualties among friendly forces.

The final decision to attack a target is the last step in a multistep process. If, at any stage of this process, the shooter could get information showing that his weapon is directed at friendly forces, then fratricide might be reduced.[8]

Attacking a target begins with the detection of something. That ''something' might be an intuition, a slight movement among the trees, a blip on a radar scope or other sensor, or even incoming free.

The next step is classification. The process of classification can itself contain several steps. At the moment of first detection, the observer is typically uncertain whether the small blob seen through the thermal sight is an enemy tank or a large warm rock. Is the object a rock or a vehicle? If a vehicle, is it wheeled or tracked? If tracked, is it a tank or armored personnel carrier? If a tank, is it foreign- or U.S.-built? And if U.S. forces are fighting alongside allies, can the foreign-built tank be identified as an allied or enemy foreign-built tank?[9]

[8] This discussion is based largely on the Defense Advanced Research Projects Agency briefing by Lt. Col. Joseph H. Beno, "Battlefield IFF'' (undated).

[9] Readers familiar with the intelligence and photointerpretation process should note that this sequence of identification is different from that used by photointerpreters of reconnaisaince images. They assume that all the vehicles parked in the interior of an enemy country are enemy vehicles. First, they want to know whether the spot on the photograph is a vehicle, if so is it a tracked vehicle, if so is it an armored personnel carrier or a tank, and finally, what type of tank and what are its capabilities. IFF can be in some ways a much harder problem. Combat identification is less concerned with the problem of whether a vehicle is a truck or a tank but in the potentially very hard problem of whether the truck is U.S. or enemy.

Once a target is identified as enemy, a decision to attack must be made. This decision is not automatic. For example, an air-defense missile unit may clearly identify an aircraft as hostile, but the aircraft may also be beyond the range of the units missiles. An infantryman may see a enemy tank but be armed with a shoulder-launched rocket that is effective against armored personnel carriers but not against tanks; a tank gunner may see several enemy targets and decide to ignore distant ones because those closer are more threatening.

Finally, after a decision to attack has been made, the attack must be carried out. Weapons must be aimed properly and ordnance delivered where it is intended and not elsewhere, With modern weapons, ordnance almost always goes whither the weapon is aimed; in the overwhelming majority of cases, fratricide occurs when the weapon is aimed at the wrong place.

Separating the attack sequence—which may only take a few seconds—into these individual steps may seem a more complex description than needed. But most fratricide are errors that could have been avoided if proper information had been available at *any one* of these steps. Thus, when fratricide is the result of a chain of errors, it could be avoided if the chain is broken at any link. Breaking a link in the chain requires that the shooter be given correct information about a falsely identified target.

THE COMBATANT'S SOURCES OF IDENTIFICATION INFORMATION

Three overlapping types of information affect each step of the decision to fire or not to fire on a potential target. The first and highest level of information is an overall, general knowledge of the tactical environment during the battle: where friendly units are-or at least supposed to be—and where enemy units are thought to be, plus the plan of action for the battle. The Army calls this knowledge ‘‘situational awareness," an awkward but useful term; other Services include it under “battle management.”

High-level, general knowledge is not adequate alone; people involved in the battle must also have specific information about whether any particular weapon or vehicle is friendly or enemy. This information is usually called the Identification of Friend and Foe, or IFF. The military calls the synthesis of these two types of information “Combat Identification, ” or CID.

Connecting these first two sets of information is another type of a priori information brought along to the battle: doctrine and rules of engagement. These rules tell those engaged in the battle how to treat information from other sources. In particular, rules of engagement contain assumptions about how to make decisions with imperfect knowledge; specifically, is an ambiguous target assumed friendly until proven hostile, or assumed hostile until proven friendly? Different forces under different circumstances will use different assumptions.

Because destroying a target is a multistep process and fratricide can be avoided by properly intervening at any step, more than one approach can be used to prevent fratricide. This must be kept in mind when comparing claims about the efficacy of various approaches. Those proposing solutions that improve knowledge of the tactical environment might claim that, say, 75 percent of fratricide could be avoided by improving situational awareness. While those proposing IFF solutions might also claim that 75 percent of fratricide could be avoided by improving IFF. Clearly, both systems will not eliminate 150 percent of a problem, but both claims might be true because *either* approach could reduce fratricide. One study using computer simulation of land combat illustrates this point in an interesting way: fratricide was eliminated entirely if forces were assumed to have either perfect tactical knowledge-provided by hypothetical perfect communications and navigation equipment--or if they were assumed to have perfect IFF—

provided by hypothetical perfect sensors or IFF transponders.[10]

Knowledge of the Tactical Environment

A sense of the tactical situation on the battlefield is so important to avoiding fratricide that it is sometimes taken for granted. A tank commander in a rear assembly area is surrounded by other potentially lethal tanks but does not even think of firing on them because of the firm knowledge that they are all friendly. This is a case of almost subconscious tactical awareness.

As the likelihood of encountering hostile forces increases, tactical information provides clues to make the search for targets more productive and helps in the classification of targets as friendly or enemy. Rarely does a ground force expect an attack from any direction; typically, their knowledge of the battlefield suggests to them the likely direction from which an enemy might approach. The tactical environment thus helps to classify potential targets as most probably friendly or enemy. For example, a unit approaching from the rear is first assumed friendly but a unit approaching from enemy-held territory is frost assumed hostile. Or, if a commander knows that his and all other friendly units have orders to advance in a certain direction, then a unit seen moving at right angles to that axis will be assumed to be most likely hostile.[11]

Before these types of presumptions can be usefully reliable, however, each unit must have confidence that it, and its neighboring units, are unlikely to be heading in a wrong direction and that wherever each unit is and whichever direction it is headed, nearby units can inform each other. This requires, in turn, reliable navigation and communication procedures and equipment.

Communication may be through some centralized clearinghouse. Tactical air forces typically use this approach. It allows the optimal allocation of resources across the entire theater of operations. Since airplanes travel so far and so fast, centralized control is almost required to respond to enemy attacks and to avoid unintended encounters among friendly forces. The disadvantage of a centralized system is that large quantities of information must be transmitted up and down the chain from the controllers to the units in the field.

Communication may also be through local networks that link nearby forces. Ground units are more likely to use this approach. It has the advantage of minimizing the required flow of information up and down the chain, Problems can occur, however, since ground units report up through a chain to some central commander but also need to communicate across the chain of command to units that might be remote in the command network but happen to be geographically close. Armies have long recognized this problem and have developed special procedures to ameliorate it. The simplest approach is to make major command divisions correspond to real geographic barriers-for example, rivers or mountain ridges—thus minimizing the *need* for communication across command lines. Failing that, command lines must be clear and special attention must be given to liaison between adjacent forward units that report up through different chains of command.

Navigation, like communication, can be global or local. The pilot of a long-range aircraft clearly needs to know where it is in absolute terms, that is, its latitude and longitude. World War II experience shows that when artillery fire was misplaced, the cause often was a forward observer

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10 See MIT/Lincoln Laboratories briefing by A.B. Gschwendtner, "DARPA Combat Identification Program at MIT/Lincoln Laboratory" (Aug. 28, 1992). In the extreme, perfect tactical awareness, that is, precise and complete information about the location of all nearby friendly forces, would provide as one benefit the equivalent of perfect identification of friends and, by the process of elimination, foes. Thus, perfect tactical awareness is equivalent to perfect IF'F.

11 Recall the case described inch. 2 from Operation Desert Storm in which lost U.S. armored personnel carriers were assumed to be Iraqi because they were cutting across the general direction of advance.

correctly calling in fire relative to his position but erroneously reporting his *absolute* position. In many if not most cases, however, position relative to nearby friendly forces is good enough or even better, Perhaps only the leader of a tank platoon needs to know his absolute position, while the rest of the tank commanders are primarily interested in local terrain features and the tanks' positions relative to each other.

Rules of Engagement

The criteria for deciding on the nature of a target and the response to it are called "rules of engagement. Military commanders, theorists, historians, and tacticians have long recognized the chaotic confusion of combat. No battlefield participant has perfect knowledge, and critical decisions must be made, sometimes quickly, with incomplete and occasionally flatly contradictory information. Of necessity, every combatant enters a battle with some a priori knowledge in the form of a set of decision-making rules to use under these difficult conditions. This a priori knowledge is learned through training, exercise, and indoctrination. At the tactical level, military doctrine provides rules or criteria that are used to decide when to attack, when to defend, and so on. Fratricide is affected more by some of the rules used by each individual combatant to determine whether an unidentified target is hostile or friendly, Targets are rarely classified by appearance alone but also by location, behavior, and recent experience. Thus, the combatants' tactical environment affects strongly their decisions about the danger posed by ambiguous targets.

Two kinds of identification errors are possible: friendly forces or neutrals can be mistakenly identified as hostile, and hostile forces can be mistakenly identified as friendly or neutral. Rules of engagement will also depend on a comparison of the consequences of each of these mistakes. For example, interceptor aircraft pilots typically use different rules of engagement in different tactical situations because of the differences in the consequence of each type of mistake. The differences are clearest when comparing point defense of an extremely valuable target and defense of a large area.

For example, Navy fighters fly from an aircraft carrier, which is a single asset of enormous value. The loss of the carrier implies the potential loss of all the aircraft and crew on the carrier. Carriers are heavily defended, but even a single attacker getting through can do substantial damage, perhaps disabling the carrier for an extended period. Moreover, the carrier is a' 'point" target, making the geometry of an attack unusually clear, Thus, the Navy's rule of engagement during hostilities is that an aircraft approaching the carrier must be able to prove that it is friendly, or at least nonthreatening, or else it is *assumed* to be hostile.

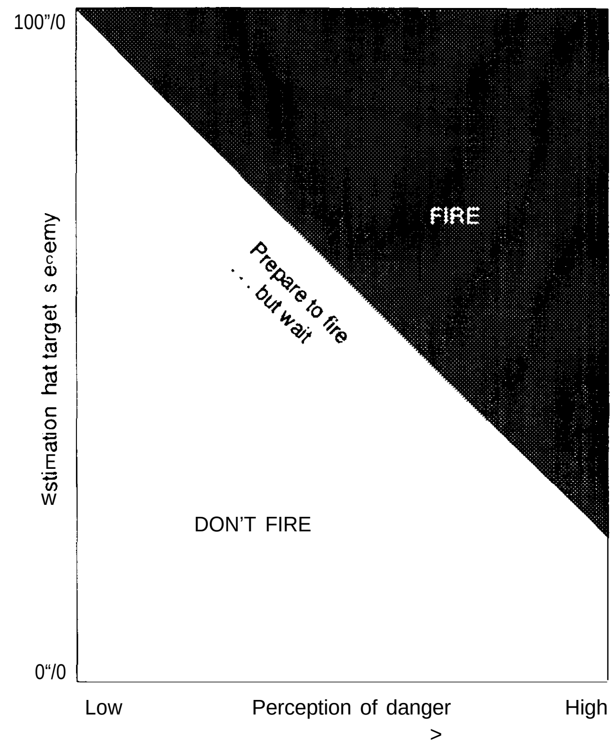
Tactical interceptors trying to defend a large area face a very different situation and respond with different rules of engagement. For example, the classic defense of NATO would have involved a large and confusing array of fighters over the battlefield. Air defenses of NATO were multilayered. The first ' 'defense" was attack against enemy air fields. Enemy intruders would then have to pass through a screening force of defending interceptor fighters. These aircraft might be backed up by a band of defenses composed of surface-to-air missiles (SAMs). Any intruders that survived could be attacked by defending fighters specifically left prowling in rear areas to catch these ''leakers. ' Finally, particularly valuable targets would be defended by their own local air defenses of short-range missiles or guns, Thus, the battle would include a confused and dense air traffic, with fighters coming from many places and heading toward many targets. Most of the defended combat assets—for example, Army assembly areas—would be more dispersed than an aircraft carrier, so that a successful attack on any one asset would be far less critical than a similar attack against a carrier.

The consequences of firing on a friend are as severe in the case of area defenses as in the case of defense of a valuable point target-a friendly aircraft gets shot down-but the consequences of passing up an opportunity to shoot at an enemy are much less severe—if the first layer of defenses does not get an intruder then the next will, and so on, until he approaches the target when he finally must make his intentions clear. Therefore, the rule of engagement for unknown aircraft during area defense is different from that used by the Navy when defending a carrier: area defenders assume that an unknown aircraft *might* be friendly unless some positive evidence is available to show that it is hostile.

Ground combatants have a slightly different perspective on the consequences of the two types of misidentifications. They tend to think of the problem as a comparison of the consequences of either shooting or not shooting. The situation facing a tank commander can provide a specific example. Historical evidence from World War II, training exercises, and testing show a substantial advantage to the tank that shoots frost in tank-on-tank engagements. To hesitate is to risk destruction. And the loss is not a vague, difficult-to-quantify overall loss of combat capability, but a loss that spurs the very compelling motivations of self-preservation: the tank that fails to aim and fire first will itself be receiving the fire that might cause the crew's death. Thus, ground combatants' rules of engagement frequently are closer to those appropriate for defense of a valuable point target; indeed, the shooter is his own ''high-value" target. A potentially threatening unknown target is generally assumed hostile unless there is some evidence that it is friendly.

The danger that a shooter perceives also affects his incentives to wait or shoot; the greater the perceived threat, the greater the urgency to shoot frost and the more likely a shooter is to assume an ambiguous target is hostile. This dynamic is represented in figure 3-2. The vertical axis represents the shooter's estimate that the target he sees is an enemy. His estimate can range from zero at the bottom of the axis, that is, absolute confidence that the target is a friend, to 100 percent at the top of the axis, that is, absolute confidence that the target is an enemy. (Note that these estimates of classification confidence refer to the shooter's perception; these perceptions, in turn, may or may not be correct.) The horizontal axis represents the shooter's motivation to fire based on his perception of danger and urgency. It can range from a minimum motivation, represented on the left-hand side, to maximum motivation, on the right-hand side.

F gu e 3 2—The Dec s on o F e

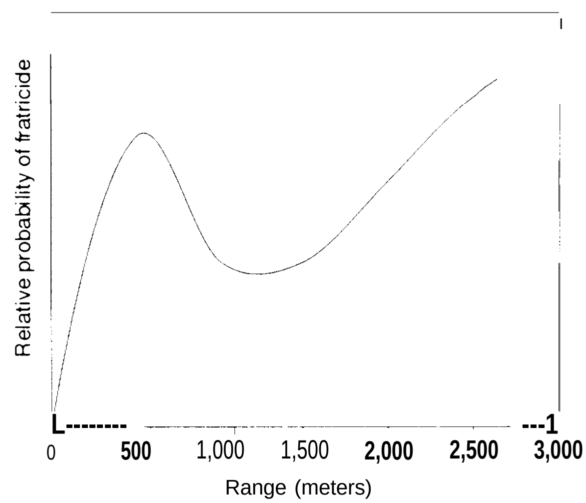


SOURCE: Office of the Assistant Secretary of Defense (C3I).

The motivation to fire will change due to several factors, but the most important variable is the shooter's estimate of his own danger. The graph lays out the different regions that result in decisions to fire or not fire. If the shooter feels reasonably secure, then he is willing to wait to make absolutely certain that the target he has detected is, in fact, an enemy. Thus, the "free" area of the graph occupies only the upper comer of the left-hand side, where confidence is high. Toward the right-hand side of the graph, the shooter's perception of danger increases and he becomes increasingly "trigger happy" until finally, at the extreme right-hand side, where he feels in immediate grave danger, the shooter may need high confidence that a target is not an enemy to keep from shooting. That is, ambiguous targets will be assumed hostile until proven friendly.

The effect of a shooter's sense of danger on his identification accuracy has, in turn, an indirect but interesting effect on the relationship of target range and identification accuracy. That increased weapon range makes IFF more difficult is a commonplace. The development of long-range weapons, especially guided weapons not requiring any form of forward spotting, has increased the range of engagement beyond that at which targets can be identified, thereby inviting mistaken attacks on friendly targets. Some military analysts have suggested that reliable IFF range be made a design *constraint* on weapon range.[12] Some data, for example, from tank combat training exercises at the National Training Center, show a clear relationship between range and likelihood of fratricide. Accidents are less likely at shorter engagement ranges, with an important exception: at very short ranges when the rate of fratricide engagements is again very high.[13] This phenomenon occurs because, all else being equal, identification becomes easier at shorter ranges—reducing fratricide-but all else is not equal. Engagements occur at very short ranges only under the desperate and chaotic conditions of a close-in melee. The effect of greater ease of identification is overwhelmed by the greater

Figure 3-3—Fratricide and Engagement Range



SOURCE: U.S. Army Training and Doctrine Command.

stress and confusion characteristic of close combat. See figure 3-3.

Similarly, air defense training shows that the highest frequency of identification errors occurs among those manning the shortest range weapons. A Vulcan gun crew cannot engage an approaching jet aircraft until it is virtually on top of them, thus forcing an ''us-or-them' approach to target engagement decisions. Increased weapon range certainly is not the solution to fratricide, but neither is its effect entirely negative: it might make quick identification more difficult, but it also can allow more time for decision and evaluation.

The rules of engagement include other tactical information. Some is explicit. For example, if a fighter plane determines from, say, detection of an enemy radar frequency that an approaching

12 Some arguments in the debate about the usefulness of increasing weapon range have gone so far as to suggest that air-to-air missile range ought to be tied to accurate target identification range such that targets at greater ranges are impossible to engage. For example, from a congressional report on IFF: "Correcting this imbalance between missile and ID capabilities now requires an accelerated, closely coordinated, interservice and NATO-wide effort to concentrate resources on achieving the needed identification capability. A concomitant slow-down in tactical missile acquisition could support that effort. ' U.S. House of Representatives, Committee on Government Operations, "Identification of Friend or Foe in Air Warfare-A Capability Long Neglected and Urgently Needed' (Washington DC: U.S. Government Printing Office, Nov. 1, 1985), p. 3. However, an artificially imposed constraint on range persists even when identification presents no problem due to, for example, the clarity of the tactical situation.

13 See ''CALL Fratricide Study'' (undated), Center for Army Lessons Learned (CALL), pp. 8-9.

aircraft is hostile, other aircraft flying in the same formation are also assumed hostile. (This is informally called "guilt by association.") This assessment is usually accurate, but scenarios in which a friendly fighter is in hot pursuit of an enemy are also easy to imagine. Some other "rules" are implicit and seem to result from human nature, or can be understood in terms of the effects of an increased perception of threat—whether real or not-discussed above. Analysis of training exercises shows clearly that a gunner's recent experience strongly influences his judgments about friend and foe. If, for example, an air defense unit has just been attacked by "hostile" aircraft in a training exercise, then the next airplane that flies over is much more likely to be judged hostile than it would have been if the previous overflight had been by friendly aircraft. Gunners are not, of course, taught to make these prejudicial assumptions, and this is not an explicit ''rule,' but few will be surprised by the observation.

IDENTIFICATION: FRIEND OR FOE

"The first requirement in warfare is the ability to distinguish friend from foe."[14] This statement from a World War II field manual makes clear the importance-but not the difficulty--of IFF. Even the most straightforward technique, looking at a potential target with human eyes, is neither simple nor reliable; combatants need training to identify forces quickly. Even with training, mistakes that appear egregious in the calm of peaceful retrospection are all too common in the confusion of combat. The great increase in weapon range-made possible primarily by developments in weapon guidance systems since World War II-has in many cases far outstripped the ability of human observers relying just on their eyes. IFF today requires additional information from longer range sensors.

Different weapon systems have different requirements for IFF systems. The IFF needed for short-range and long-range weapons, for example, may have very different reactions times, abilities to track multiple targets, likelihood of revealing position, and so on, as well as the obviously different requirements for range.

IFF and the Rules of Engagement

Differences in the rules of engagement will shift emphasis among technical approaches to IFF. There is no technical solution that is optimal for providing positive identification of friend *and* foe, where "positive identification" means identification based on positive presence of some evidence. For example, response to a reliable IFF interrogation system is positive evidence that the target is a friend, but lack of response is not positive evidence that it is an enemy.

In defense of critical point targets, aircraft carriers being the premier example, defenders must assume that ambiguous targets are potentially hostile until proven friendly. Thus, the emphasis is on systems that can prove a target friendly, such as cooperative question-and-answer systems. The rules of engagement for area defense will give relatively greater emphasis to positive identification of foes, hence, noncooperative foe identifiers will be relatively more important with question-and-answer systems providing frost-order sorting of targets into friends and unknowns.

Ground forces, when under extreme pressure to fire quickly, also find themselves in a situation where ambiguous targets must be assumed hostile until proven friendly. Thus, ground forces will concentrate on developing question-and-answer friend identifiers. (In addition, active IFF by ground forces is in a primitive state compared to that of air forces and question-and-answer systems, being easier to implement than noncooperative systems, are a good place to start.)

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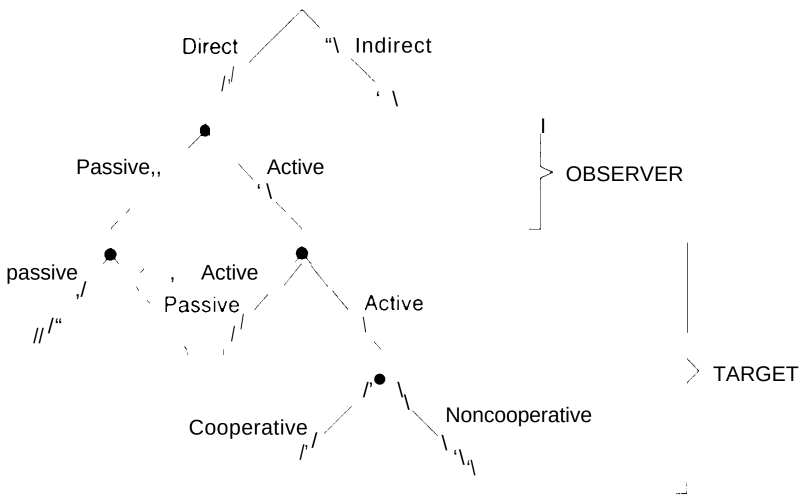
14 Recognition *Pictorial Manual,* War Department Field Manual 30-30 (June 1943), p. 1.

Figure 3-4--Sources of Information for Identification



SOURCE: Office of the Assistant Secretary of Defense (C3I).

Sources of IFF Information

Successful IFF requires that the shooter have information--carried by some form of energy—from the putative target. The sources of this energy and how it is collected can provide a general, overall classification of the various technical approaches to IFF. Figure 3-4 shows the possible combinations of energy and information sources. The first branch is between direct and indirect collection. A ''direct' system is one in which the shooter collects the information about a target, while in an 'indirect' system some other observer collects the information and passes it on to the shooter. An artillery forward observer is a good example of indirect IFF. The forward observer, or spotter, uses whatever technique he has to determine whether a target is friend or foe and then radios that information back to the artillery, which accepts it as accurate without any ability to confirm the information. The rest of the direct and indirect branches are identical to each other, so only the direct branch is shown in the figure.

The observers may be passive or active. Passive observers do not transmit any energy themselves but only collect energy normally transmitted or reflected from the target. An active observer transmits energy at the target to somehow affect the target in a way that can be observed.

The target as well may be either passive or active. A passive target only reflects energy from its environment. This energy may be natural, like sunlight, which a passive observer can detect or, in the case of an active observer, the energy might be artificially produced specifically to be directed to and reflected back from the target, as is the case, for example, with a radar beam. An active target transmits its own energy, for example, radio signals or sound.

Thus four possible observer/target energy transmission routes are available: passive/passive, passive/active, active/passive, and active/active shown in figure 3-5. An example of the first case is the simplest IFF system imaginable: a passive observer identifying a passive target by sensing reflected sunlight. Or, a passive observer might also sense energy that is actively transmitted by the target. This could be radio transmissions in a foreign language, or radio or radar transmissions

Box 3-A-The Electromagnetic Spectrum

Chapter 3 discusses in general terms-and the next two chapters discuss in much more specific detail--some oft he identification and communication techniques important for avoiding friendly fire. Many of these techniques depend on detecting some form of electromagnetic radiation. The figure 3-A represents the electromagnetic spectrum. Visible light is the most familiar part of the spectrum but radiation at higher and lower wavelengths is exactly the same physical phenomenon, just not detectable by the human eye.

Radiation of different wavelengths interacts with matter in different ways, which has two important consequences: first, the wavelength determines how easily the radiation passes through the atmosphere, including obscurants, such as fog, smoke, rain, or dust; second, the wavelength affects how the radiation is generated and detected. In general, radiation is little disturbed by particles smaller than the radiation's wavelength, thus longer wavelengths tend to pass more easily through airborne particulate like smoke or fog. Infrared radiation--with a longer wavelength than visible radiation--can be used to see through clouds of obscurants that appear impenetrable to the human eye and even longer wavelength radar waves can pass through rain that would stop infrared radiation.

at a characteristic frequency not used by friendly forces, or the sound of a tank that is different from that of friendly tanks.

The observer could be active and transmit energy to the target. Most commonly this is in the form of radio signals of some sort. Even if the target is passive, the shooter can still bounce radar signals off it—this is standard radar. Thus an active shooter can detect the radar return of a passive target and get some information about the target that might allow it to be classified as friend or foe.

Alternately, the target might actively transmit energy in response to the shooter's transmission. In such a system, the shooter sends a special signal to the target. If the target wishes to be identified, and is equipped with the proper transponders, then it sends back a signal signifying that it is a friend. This is the principle of ''cooperative' IFF systems, such as the MARK XII. These are often called ''question-and-answer" systems.

Finally, each branch of the tree shown in the figure can be cooperative or noncooperative. Painting special insignia on a vehicle for others to see is an example of a passive/passive cooperative system. Normal radar is an active/passive noncooperative system, but if the target adds special radar reflectors to enhance radar echoes, it becomes an active/passive cooperative system. Just because a target gives an active response to an active observer does not imply necessarily that the target is cooperative; it might be tricked into responding. Military electronics experts are always trying to find ways to cause an enemy to transmit energy revealing his position, intentions, or capability.

Figure 3-5—Examples of Approaches to IFF

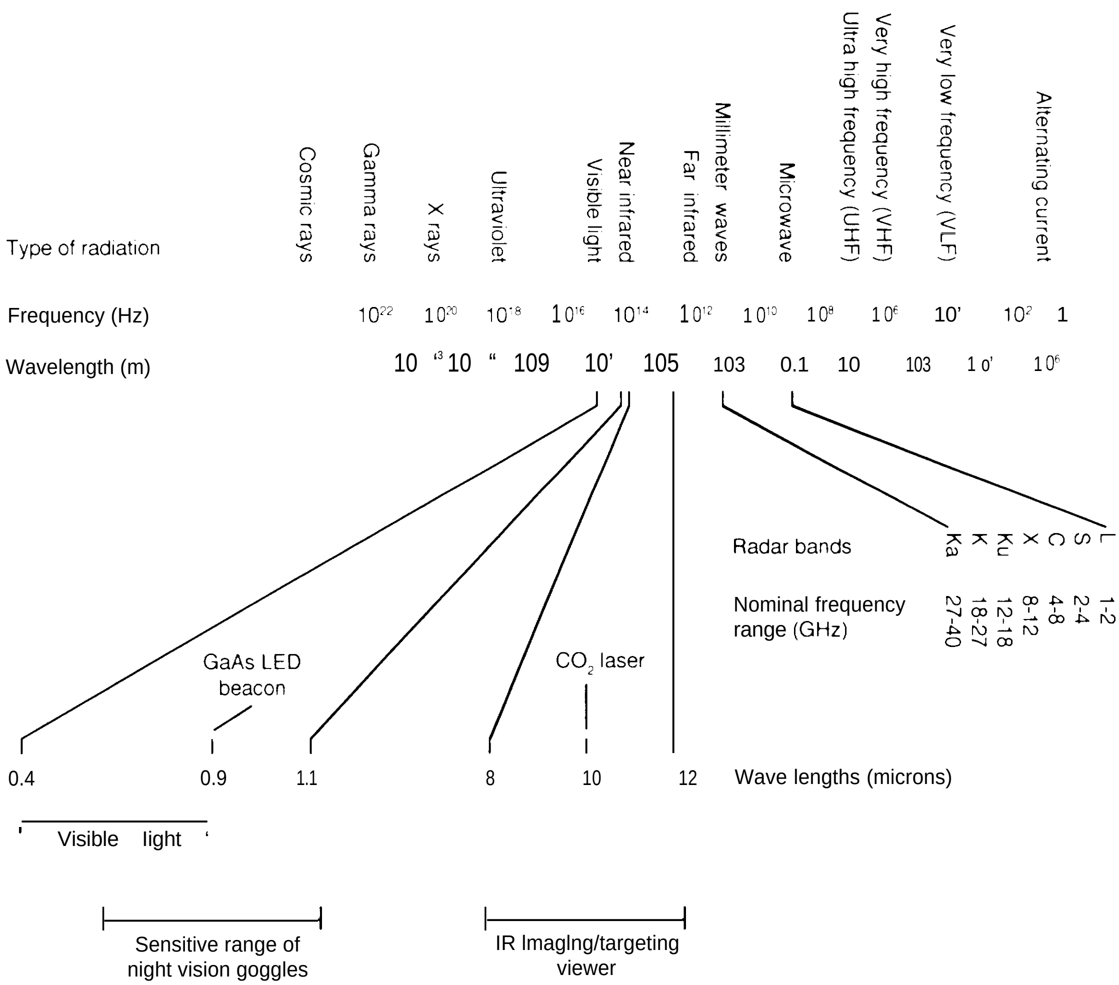
OBSERVER \ TARGET	Passive	Active
Passive	Visual ID of weapons type, painted insignia	Beacons: e.g., Budd-lights, DA RPA-lights
Active	Radar	Question-and-answer systems

SOURCE: DoD and OTA.

Longer wavelength radiation may be able easily to penetrate the atmosphere but another problem arises as longer wavelength radiation is used: the ultimate resolution of any imagining device is limited by the ratio of the wavelength and the size of the imaging optics. Radars using radiation with waves several centimeters or meters long may easily penetrate long distances, but to achieve any resolution requires proportionally large antennas. Thus, long wavelength radiation may be useful for communication and detection but is not much use for deriving an image.

Several parts of the spectrum are of importance to the problem of avoiding fratricide. Communication usually uses UHF and VHF radio bands. The radar bands shown are used to detect objects and perhaps identify them, The infrared bands are important because ground forces use them for seeing at night and under conditions of limited visibility. With increasing wavelength, infrared blends into the millimeter wave bands that will be used by the proposed question-and-answer identification system for ground combat vehicles.

The Electromagnetic Spectrum



Advantages and Disadvantages of Each Approach

Each approach to IFF has comparative strengths and weaknesses. The military prefers, at least as an ideal, systems that allow the shooter to remain completely passive because these pose least risk of revealing information about the shooter. But passive systems must exploit subtle difference in emissions, that is, the "signature," of a vehicle. Keep in mind that the objective is not to detect a tank but to distinguish one type of tank from another against a very complex battlefield background, and in spite of possible efforts by the enemy to hide or alter their weapons' appearance. Thus, purely passive systems may require sensitive hence expensive—sensors. Most IFF experts interviewed by OTA felt that no single passive sensor would be adequate but that the fused information from several may have future application.

Active IFF systems—the most obvious examples are radars and question-and-answer systems—can have longer range but they, of course, might be detected, providing the enemy information about friendly forces. This risk can be minimized by transmitting the least power necessary, transmitting intermittently, using and looking for special transmission patterns (or "waveforms' known only to other friendly forces, and so on.

In general, cooperative systems are cheaper per platform and have longer range; it is always easier to get information out of a target if it wants that information to get out. Cooperative systems have the cost disadvantage, however, of becoming useful only when virtually all of the platforms within a theater of action are equipped, making partial deployments unattractive.

Clearly, cooperative systems are really just friend identifiers, they do not positively identify enemy. If no reply is received, the shooter might *assume* that the target is enemy but perhaps it is a neutral or a friend without an operating transponder. The final classification in these cases will depend on the rules of engagement.

Noncooperative systems can, under some circumstances, positively identify enemy. For example, classification could be based on type of weapon. This approach was easy and reliable during the long NATO-Warsaw Pact confrontation; NATO forces had NATO weapons and Warsaw Pact forces had Warsaw Pact weapons. Thus, the *type* of weapon identified it as friend or foe. This approach can, with luck, still work but in general the world is much more complex today. For example, in the Persian Gulf War, Syrian allies were armed with the same Soviet tanks as the Iraqi enemy while the Iraqis also had the same French-made aircraft as the French allies. This profusion of weapon types does not make noncooperative IFF impossible, only more subtle and difficult. A weapon is much more than the shape of an outside shell; for example, the same type of aircraft in two different air forces may use different engines, have different weapons mounted, and have different radio or radar frequencies. Noncooperative IFF may even try to exploit the habitual tactical behavior of the enemy.

Under some circumstances noncooperative systems may have a cost advantage even when costs per platforms are higher since the anti-fratricide benefit is roughly proportioned to the extent of deployment in contrast to cooperative systems, which have little benefit until deployment is virtually complete within a combat group.

Differences in rules of engagement push toward different technical solutions to IFF. As was discussed before, area defense rules of engagement really require an enemy identifier since, without some positive evidence that a target is enemy, it will not be engaged. Thus, in the extreme, with no way to identify enemy, they would not shoot at anything. A cooperative question-and-answer IFF system identifies friends, but that provides little additional help to the interceptor pilot: he starts off *assuming* that the unknown target is potentially a friend. The pilot needs some system that can identify an enemy as an enemy; thus, the need for noncooperative IFF system.

In contrast, a Navy pilot returning to a carrier has to convince the carrier's defenders that he is a friend. Anything that identifies enemies does not give much additional useful information because the defenders start off *assuming* that unknowns are enemy. Thus, the Navy needs a fail-safe friend identifier and concentrates its attention on cooperative question-and-answer IFF systems.

Information Security

A potential danger with any question-and-answer system is that the enemy might exploit it. Of course, the occasional transmission of a query might reveal the shooter's position, but two even graver failures are possible. First, if an enemy could receive the query and then respond with the proper answer to make himself appear to be a friend, he could then penetrate defenses easily and cause great damage. Second, if an enemy could produce the proper query, he could fool friendly forces into responding, revealing both their positions and their identity.

Securely encrypting the query and the answer eliminates both dangers.[15] An enemy trying to exploit a question and answer IFF system could transmit queries to try to have U.S. weapons identify themselves, but if an encrypted message, which only U.S. or allied forces knew, were used as the query then friendly forces would simply not respond to any queries that were not properly encrypted. But what if the enemy could not create a valid query of his own but at least could recognize that it was a query? The enemy could respond with an answering signal to make himself appear to be a friend. This is called ''spoofing, Again, if replies were encrypted and only friendly forces knew the encryption technique, then the enemy might try to reply with some signal but it clearly would be counterfeit.

To be genuinely secure, an encrypted message must be sufficiently complex to foil enemy efforts to figure out a way to create a valid query and reply. Additionally, even without understanding the encryption method, an enemy could simply record valid queries and then retransmit them. Therefore, the encrypted form of the query must be changed frequently. The combination of these two requirements creates a burden of generating—and distributing to forces in the field-encryption keys and other materials. Transport and dissemination of these materials is further complicated because they must be protected during distribution; if the encryption keys fell into enemy hands, then the IFF system would be compromised until new keys could be created and distributed.[16] Some front-line forces in Europe, such as Army air defense units, claim that handling of the classified IFF encryption keys is so onerous that proper training with IFF systems is stifled.[17]

New technical developments allow easier handling and dissemination of secure information like cipher keys. Systems are under development, called electronic key management systems, that would allow the electronic dissemination of partial keys to regional distribution centers, and thither to a "Local Management Device" containing a "Key Processer. ' At the local level a "Data Transfer Device" is used to carry the key to the individual weapon. The partial keys alone would not allow any enemy to decrypt messages or IFF queries and answers. Instead they would

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15 The words ' 'code" and "cipher" and, similarly ''encode'' and ' 'encrypt'' are often used interchangeably in the nontechnical literature. Experts, however, make a very clear distinction. Code is any set of symbols that represents something else and mayor may not be secret. Thus, "20500" is the ZIP code for the White House, but anyone that calls can get the code. If a message is encrypted, then anyone who knows the cypher can read the code but no one else. See Nationat Security Agency briefing, ''Cryptography and Security for Combat ID Systems, " May 6, 1992, p. 5.

16 See National Security Agency briefing, ''The Electronic Key Management System (EKMS)" (undated), pp. 3-4.

17 Monti Callero, "Combat Identification and Fratricide Analysis, " a briefing presented at the *Modeling and Simulation Workshop on Combat Identification* sponsored by the Defense Advanced Research Projects Agency (DARPA), Nov. 4, 1992. In fact the keys are only classified ''cotildential; part of the problem may be more the users' perception and lack of motivation,

provide an input to a computer that would generate the actual keys. Thus, the partial keys could be transmitted over the open airwaves for all to hear. The local computers could load the actual keys directly into the IFF question-and-answer transmitters so there would be no need to have the keys written on easy-to-steal paper and no person-or potential spy—would even need to know what the key was.

Advocates of noncooperative IFF systems are ready to point out the burden of handling encryption keys, but noncooperative systems have their own data-handling challenges. Noncooperative systems, especially ones that rely on a passive target, must have available stores of information on each weapon that might be encountered. Identifying aircraft from their radar return, for example, would require detailed information about the radar returns from dozens of aircraft, each with several different configurations or weapon loads, from all possible perspectives. This information might take the form of databases in which the characteristics of enemy aircraft would either be looked up or calculated quickly from models, but whatever approach is used the data required could be substantial.

Moreover, these data need to be protected just as much as encryption keys. Not every detail of a weapon's signature will be used for identification and loss of the data would help an enemy discover which particular attributes were being used. Updating data or adjusting for compromised information during combat could pose severe data distribution problems. Thus, using a noncooperative approach to IFF will alter but not remove the requirements for data security and handling.

Compiling the databases required for noncooperative IFF raises delicate diplomatic and intelligence questions. Would allies be willing to provide sufficient data on their weapons? (Would the United States be willing to provide comparable data to allies?) If not, would surreptitious attempts to collect data cause international friction? Would the very existence of data collected surreptitiously need to be kept secret from allies? How would information on enemy weapons be collected? If weapons data are available, could they be shared with allies during joint operations without revealing intelligence methods?

Whether using cooperative or noncooperative IFF systems, operations with allies pose special problems. In the new global strategic and political environment, the United States will almost always be engaged militarily with allies at its side, for political if not military reasons. Moreover, unlike the relatively stable allied relations in NATO, future alliances are more likely to be ad hoc, with even former-and perhaps future--unfriendly nations acting as temporary allied partners. The Persian Gulf War, which included the participation of Syrian forces, provides a perfect example.

Clearly, it is in the interest of the United States to help allies not to commit fratricidal attacks on themselves or on U.S. forces. But the need for both protection of identification techniques and allied cooperation creates dilemmas.

For example, encryption keys needed for question-and-answer IFF systems would have to be shared with allies. But today's allies might be hostile tomorrow. At the very least, the United States must be able to make any system secure again by changing the encryption keys. Thus, a temporary ally would not have irrevocable ability to trigger IFF systems on U.S. weapons.

Encryption keys that fell into the hands of other nations can be changed quickly-and thus rendered useless—but the same is not true for hardware and technology. Cooperative question-and-answer systems require that allies have compatible equipment. Presumably the United States would have to provide the equipment or at least explain the encryption systems in enough detail that other nations could produce their own comparable systems. Yet the United States has invested significant resources to develop reliable and secure encryption systems because expert opinion holds that the resulting capabilities offer profound tactical and strategic advantages. Even though keys are changed, if the equipment is left behind, other nations can generate their own keys and use the equipment for their own IFF with all of the tactical advantages that accrue.[18]

The United States must decide whether the benefits of having a unique technical advantage in IFF outweigh the benefits of allied interoperability. Without exchange of IFF technology, geographic areas of responsibility would have to be clearly divided among allies, with each responsible for fratricide avoidance within its area and special procedures used to reduce accidents at the boundaries between areas. This problem becomes particularly important in ad hoc coalitions; the United States may be willing to share technology with NATO allies that it is unwilling to share with temporary allies. The ideal solution might be a technically less sophisticated, or 'stripped down,' IFF system that could be shared with some allies and was compatible with, but not have all the advantages of, the complete system.

MAKING CHOICES ABOUT HOW TO AVOID FRATRICIDE

Criteria for Judging Antifratricide Technology

Any successful antifratricide system must meet several criteria. First, and probably of greatest importance to the combatants in the field, is that using the system must not significantly increase the users' danger. For example, transmitting an IFF query in a question-and-answer system must not give the enemy a chance to intercept the radio signal, thereby giving away the shooter's location. A second, and related criterion, is the difficulty of using the system. If it is too complex or time-consuming, then it will not be used at all. The whole process of using the IFF system must not take so long that the enemy can shoot first while friendly forces are still fiddling with knobs.

A third criterion is how widely applicable the system is. Can it tell the shooter something about everything on the battlefield from infantrymen to jet fighters? Or is the system limited to those platforms that can carry a large and expensive transponder? A fourth criterion, related to the third, is the system's reliability. This is more than simply a question of how long a piece of equipment will work without maintenance, but of how well it will work under a complex—and ultimately unpredictable--array of battlefield conditions that might include active measures by the enemy to undermine or exploit the system. For example, how reliably can a noncooperative IFF system identify an enemy if the enemy knows what characteristics are being observed and used for classification and then tries to alter those very characteristics? Required reliability also depends on how an IFF system is used. Human eyes and common sense avoid most potential fratricide; if another system is used *in addition to* current procedures as one last check, then 90 percent reliability is adequate, but if used *instead of* current procedures, 90 percent reliability would be disastrous.

The fifth criterion is cost, both total costs and costs compared to alternative requirements. In absolute terms, total cost is important because resources are finite and combat can never be made safe so decisions must be made about when a system is "good enough." Consideration of comparative costs is potentially less judgmental and more analytical. If the objective is to save lives while maintaining combat effectiveness and a better IFF system is just one way of doing that, then within a finite budget every dollar spent on IFF is a dollar not spent on other things that might also save lives, Perhaps casualties-including those from fratricide--could be lowered more effectively by using the same resources to buy reactive armor for tanks, or for more training, and so on. The relative importance of a fratricide casualty and a hostile casualty-which will determine the allocation of marginal resources—

18 National Security Agency briefing, "Survey of Target Identification," Sept. 9, 1992

is a difficult policy question that will not just be hard to decide but hard to discuss dispassionately.

Comparison of Different Approaches To Avoiding Fratricide

Awareness of the Tactical Environment v. IFF

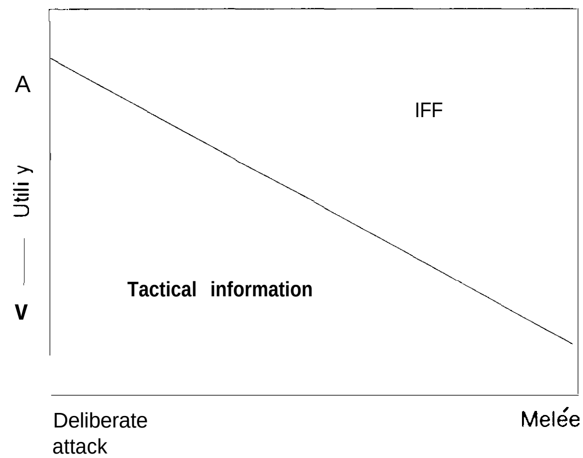
The main two broad approaches to preventing fratricide are increasing tactical awareness and improving target identification. Either approach offers benefits, each has areas of particular importance, and both will need to be pursued in parallel.

The differences are clearest for ground combat. In general, as ground units approach the enemy, knowledge of their tactical environment is most important to avoiding fratricide. This means that units have the navigational information needed to know where they are, know where they are supposed to go, and not stray across avenues of advance. Nearby units need to communicate to avoid confusion along their boundaries.

As the battle is entered, one-on-one identification becomes increasingly important. In the extreme of a melee, the tactical situation could become so confused and fluid that no person could keep up with the changes even if the technology were available to report them. In this situation, IFF would be of greater importance, (See figure 3-6)

When comparing costs of the two approaches, the multiple benefits of each must be weighed in the balance. A reliable point-to-point IFF system would be valuable for IFF but since identification range can set the limit of effective engagement range, it might also allow engagements at longer range. Any system that improved the knowledge of the tactical environment would reduce fratricide but also allow better control of maneuver groups, better coordination of fire and combat units, faster attacks, more efficient movement across country, and so on, thereby increasing the overall combat capability of the force. Thus, when comparing costs of reducing fratricide, only the appropriate portion of the cost of each system

Figure 3-6-Changing Relative Importance of Tactical Information and Identification



SOURCE: Combat ID System Program Office.

should be allocated to the antifratricide requirement.

Training and Simulation

The solution to the problem of fratricide is not just black boxes; training and combat skill are at least as important. Of course, the skills needed to avoid fratricide-alertness, unit coordination, and discipline-are exactly those needed for any unit to be effective in combat. However, the Services realize that the danger of fratricide needs special attention. The Army recently has begun to carry out separate after-action analysis of simulated "fratricides" at the National Training Centers. This includes a standardized format for an evaluation, called the Fratricide Incident Report, which allows comparison of cases and analysis of most common causes. Avoiding potential fratricide dangers are now an explicit part of battle planning. The Army promulgates this new emphasis through the Training and Doctrine Command (TRADOC).

Realistic training can reduce casualties in combat—including fratricide-but the inherent danger of training creates a connundrum. One military analyst has suggested that some of the problems encountered in the Persian Gulf occurred because the military did not train enough and not realistically enough.[19] Intense and realistic training results in better combat performance, no doubt, but it costs lives itself. For example, 1991 was the Air Force's safest year on record, with only ten noncombat deaths due to flying accidents, In one particularly unfortunate 24-hour period late in 1992, the Air Force lost four aircraft and 17 crew in three separate accidents.[20] Training for war will never be both perfectly effective and perfectly safe. Those that suggest more realistic live-fire training must weigh the possible reduction in losses in some future war against the higher annual peacetime losses incurred from the training.

Simulators are an important component of modem training. These need to be improved to better represent real combat identification problems. For example, most ground combat fratricide in the Persian Gulf War occurred at night, but tank training simulators do a much better job of reproducing daytime than nighttime conditions—that is, the world seen though infrared imaging devices.

On a large scale, simulation becomes combat modeling and, until recently, almost all computerized combat models simply ignored the possibility of fratricide. In fact, most computer models proceed as though both sides have perfect tactical information and fratricide never occurs. Indeed, no provision is allowed in most computer programs to investigate the effects or causes of fratricide. This past neglect of the problem is now being addressed.

Doctrine

Doctrine affects the causes and cures of fratricide. Avoiding fratricide has never been the sole, or even primary, determinant in doctrinal development and rightly so. As fratricide is becoming relatively more important as a source of casualties, however, it is receiving increasing emphasis, especially within the Army. Yet fundamental tenets are not being examined as closely as they might. For example, the Army emphasizes a very aggressive approach to ground combat, arguing that speed and ''momentum" are key to success and holding overall casualties low. Yet many fratricide in the Persian Gulf occurred at night at ranges where the enemy—because of inadequate sensors—was unable to shoot back. At least one civilian analyst has suggested that-with the shooters in less immediate danger-slower, more deliberate, attacks could have been carried out to reduce the risk of fratricide. The Army argues that doctrine and training are not something that one can turn on and off like a switch. ''Today, troops, we will use Doctrine B' will not work. Perhaps further development of the "weapons tight/ weapons free' approach would suffice.

Clearly, the Services must coordinate their approaches to avoiding fratricide. The interaction of the ground forces with the air, is one clear example. Close air support has never been the Air Force's primary interest and identification of ground targets has suffered. This is the time, with new interest in developing antifratricide technology, for careful coordination.

With the end of the Cold War, some military analysts are discussing quite radical suggestions for the reassignment of roles and missions of the Services. Avoiding fratricide will not be the primary determinant in these decisions, but it should be important in several cases, for example, whether to assign close air support to the Army or whether to assign ground-based air defense missiles to the Air Force.

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19 ''Training needs to change, too. Although our soldiers are of the highest quality, they still do not train realistically enough for war. There is too much emphasis on *safety*. [emphasis added] As a result, units do not train for integrated combat in a live-fire environment, where artillery, armed helicopters, close air-support jets, armored vehicles and soldiers replicate the violent and confusing conditions found on the battlefield. Col. David H. Hackworth, "Lessons of a Lucky War," *Newsweek*, vol. 117, No. 10, March 11, 1991, p. 49.

20 *Aviation Week* and *Space Technology*, "USAF Loses Four Aircraft, Including B-1B, in 24 Hr., " Dec. 7, 1992, pp. 24-25.

CONCLUSION

Fratricide is becoming more visible and may frequently be a *relatively* more serious source of casualties in modem U.S. combat because major military operations are now sometimes possible with remarkably few losses, as the Persian Gulf War demonstrated. Cures for the fratricide problem deserve serious, continuing attention, but fratricide is not a cause for panic and will not lose the next war.

Avoiding fratricide takes more than just identifying targets properly. And target identification is a complex problem that will not be solved by a "black box." Much of the information needed to avoid fratricide is exactly the information needed to be a coherent combat force.

Future wars will include joint operations among each of the Services and among the United States and its allies. Today, the military R&D community is pursuing several antifratricide developments. Existing efforts to coordinate with sister Services and allies should be vigorously maintained.