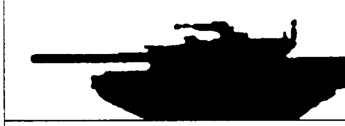
Avoiding Fratricide of Land Surface Targets

5

All of the U.S. fratricidal casualties in the Persian Gulf War were among land forces. Near-absolute dominance of the air and Iraq's inability to project power to sea allowed conservative rules of engagement in those media, which avoided accidental attacks on friendly forces except in a couple of cases that did not result in casualties.

The fratricide of the Persian Gulf War was unusual compared to that of past wars. As pointed out in chapter 2, the most striking aspect at first was the apparently unprecedented high fraction of total casualties resulting from fratricide. In addition, however, the importance of each type of fratricide was different from other large mechanized land battles. In World War II, for example, the most deadly fratricide were the result of aircraft bombing friendly troops. Surface-to-surface fratricide resulted most often from indirect fire in which artillerymen fire at a target that they could not see, The Persian Gulf War, in contrast, had an unusually high fraction of fratricides from direct-fire weapons, such as tanks, shooting mistakenly at other land targets.



Most of the U.S. personnel were mounted in vehicles; thus, not surprisingly, most of the fratricide occurred when vehicles were hit, so that current emphasis is on protection of vehicles, not on that of individual infantry. Helicopters are included in this chapter; although helicopters are aircraft, their operation and employment gives them more in common with surface vehicles than fixed-wing airplanes, at least as far as fratricide technology and equipment are concerned.

The next sections discuss general approaches to avoiding fratricide of ground targets, a number of specific technologies available to implement these approaches, and some of the advantages and disadvantages of each approach and technology, U.S. ARMY

US. armored vehicles destroyed by friendly fire during the Persian Gulf War were recovered and collected,

INCREASING KNOWLEDGE OF THE TACTICAL ENVIRONMENT

Reviews of past cases of fratricide, including those from the Persian Gulf, show that a prime culprit is the shooter's poor understanding of where friends are, and even where he is himself. A unit spreads further confusion among neighbors when—instead of being flatly lost—it believes it knows exactly where it is and reports an incorrect location to other units. Thus, navigation and communication are two vital keys to avoiding fratricide.

Navigation

Current multimillion dollar U.S. tanks do not have compasses. This may seem astonishing until considering that magnetic compasses are useless inside 60-ton metal boxes. Alternatives-like gyrocompasses—have been prohibitively expensive in the past and were often unreliable in the rough environment of a tank. Nevertheless, the first step for improving tactical knowledge of mobile units requires improving their navigational tools. Fortunately, new technical developments make this easier.

During the Persian Gulf War, tanks used equipment—including some off-the-shelf commercial equipment—that calculated latitude and longitude from data received via radio pulses from a network of satellites, the so-called Global Positioning System or GPS. If desired, the same principle could be applied on a local tactical scale using airborne transmitters.[1] Gyroscope compasses provide direction, and some, in particular ring-laser gyroscopes, are improving in accuracy and coming down in cost. Current plans call for broad use of GPS and compasses, or azimuth indicators, as the Army calls them.

Chapter 2 showed location uncertainty to be a prime cause of fratricide from artillery. Global or local positioning systems could provide artillery batteries and their forward observers with accurate, consistent coordinates. Some proposals call

[1] Briefing "Very Low Frequency Identification Friend or Foe, " Willie Johnson, U.S. Army Communications and Electronics Command, Mar. 10, 1992.

for use of positioning systems to increase fire accuracy and perform last-instant IFF.

Communication

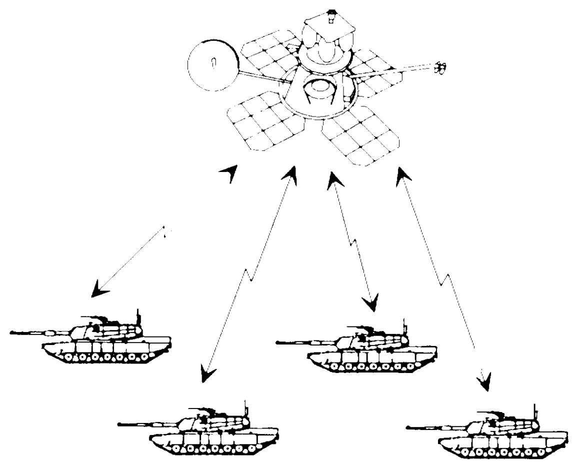
Knowing location is just part of the job of avoiding fratricide; each individual and unit must inform nearby units of its location. One approach is for each unit or vehicle to send its location to some central distribution point. This might be a ground-based or airborne communications node, or it could be a satellite, perhaps the same one that provides the location broadcasts as illustrated in figure 5-1.

Communication of location could also take place through shorter range networks, as illustrated in figure 5-2. Each vehicle could be a node in a interwoven network of communicating vehicles. Each vehicle would transmit information about itself as well as its neighbors. Thus, not every pair of vehicles would need to be in constant *direct* communication, In the figure, for example, tanks numbered 3 and 5 might not be able to communicate directly because of intervening terrain, but they can communicate by messages relayed via numbers 1 and 4. When tanks 3 and 5 then come into sight of one another around the ridge, neither should be surprised. Systems using these principles are now in development.

As one analyst has pointed out, this is a reversal of how sensor networks have operated in the past: sensor systems have been developed to find information about the enemy, they collect information about the enemy *and all the* friendly forces within range, and then-with only slight exaggeration—the information about friends is thrown away.[2]

Networks would allow the propagation of information about foes as well as friends. Thus, information about a hostile or ambiguous vehicle sighted by any member of the network would be available to each member of the network. In

Figure 5-1—A Satellite Navigation and Communication Schematic



SOURCE: Office of Technology Assessment, 1993.

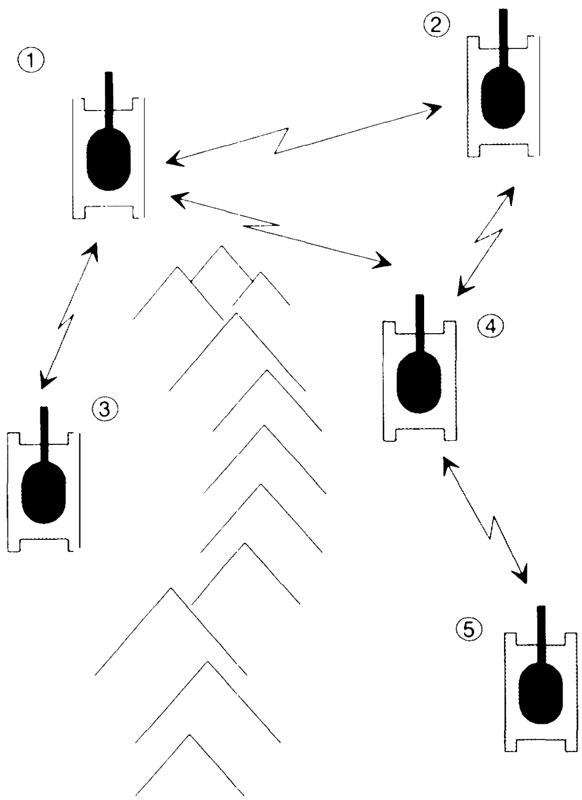
principle, this type of communication allows observers to ‘‘compare notes, ’ develop a composite picture, and thus get a better overall identification. For example, one observer might see an ambiguous vehicle, then try, and fail, to get a reply to a IFF query. Another might have limited information on its appearance, another detected some suspicious radio signals, and so on. No piece of information by itself is definitive, but all of it together might be. The range of the communication links is not a problem; indeed, considered strictly from the point of view of avoiding fratricide, the range does not need to be much more than, say, double the range of the vehicles' weapons.

A simple navigation-communication system could be based on the current standard Army tactical radio, the Single Channel Ground and Airborne Radio System (SINCGARS).[3] More elaborate data exchanges will require radios with higher data rates. Almost any system would be most useful with some way to display the location information inside the vehicle graphically.

[2] Briefing entitled, "Fratricide Prevention, " Mark Fine, U.S. Army Communications and Electronics Command, Mar. 10, 1992.

[3] See ‘‘Combat Identification, Data Pose Battlefield Awareness, " *Signal*, November 1992, pp. 37-39 and Mark Tapscott, ‘‘SINGARS Upgrades Moving to Full Battlefield Communications, ' *Defense Electronics, vol. 25, No.* 1, January 1993, pp. 29-32.

Figure 5-2—A Ground-based Communications Net for Exchange of Location and Identification Information



SOURCE: Office of Technology Assessment, 1993.

IFF Through Exchange of Location Information

Navigation and communication systems can be used as a type of IFF device, one in which identification is based not on vehicle characteristics or the exchange of codes, but on location information. Take as an example a direct-fire weapon like a tank. A navigation system could provide each tank with an accurate position, and a communication system could provide the positions of all friendly tanks within range. As part of the current firing sequence, the tank gunner uses a laser range-finder to determine the target's range. While current standard equipment on tanks does not provide gun bearing, that is, the direction in which it is shooting, the navigation system could provide that information as well.

The tank gun's computer or free-control system, knowing its own location and the range and bearing of the target, can quickly calculate the exact location of the target. This location can be compared to the locations currently reported by friendly vehicles and, if there is no match, the target could be assumed hostile. (One might want further conflation in case it is a friend with malfunctioning equipment.)

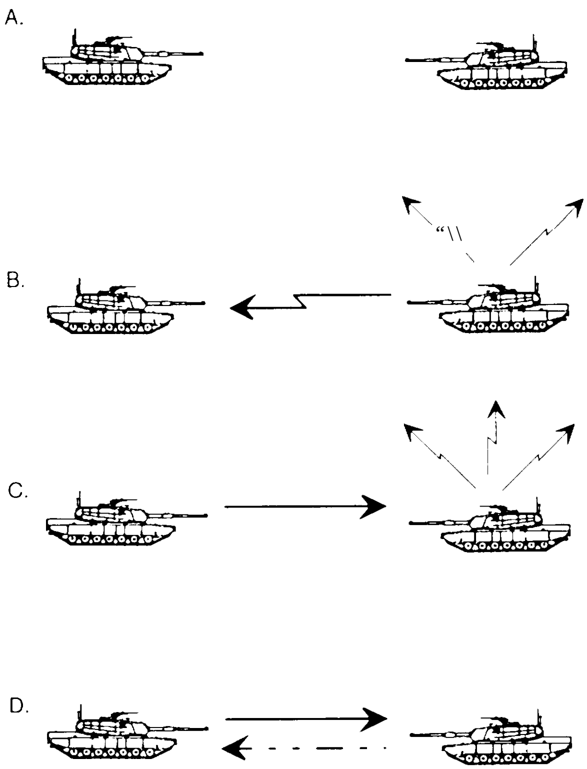
If the current register of locations shows a match, the answer is somewhat ambiguous. A match only means that a friendly vehicle is at the same location, *within the accuracy of the system,* not that the target in the gun sights is a friend. The accuracy may be dozens of meters and the true friend may be obscured behind a clump of trees.

Other approaches following this general theme are possible. For example, just before the gun frees, a radio or laser signal could be sent out containing the message: "Attention! I am about to shoot at a target at the following coordinates, if you are sitting on that spot, you should tell me now." Obviously, the message, and reply, would have to be encrypted to keep the enemy from exploiting the system. The speed of the system is also important. Tank crews are trained to get a round off within ten seconds of first detecting a target; good crews can do it within six seconds. Any IFF procedure that takes "only" a second significantly increases engagement time.

IDENTIFICATION SYSTEMS

Even a very effective navigation-communication system probably will be unable to offer perfect friend and foe identification; an additional system devoted to IFF may also be needed. The simplest cooperative IFF system allows the observer to remain passive, as illustrated in figure 5-3a. The target vehicle might use characteristic markings to identify itself as friendly. In the Persian Gulf War, the vehicles were marked with an inverted 'V' made with an infrared-reflective

Figure 5-3-Approaches to Identification of Friend and Foe



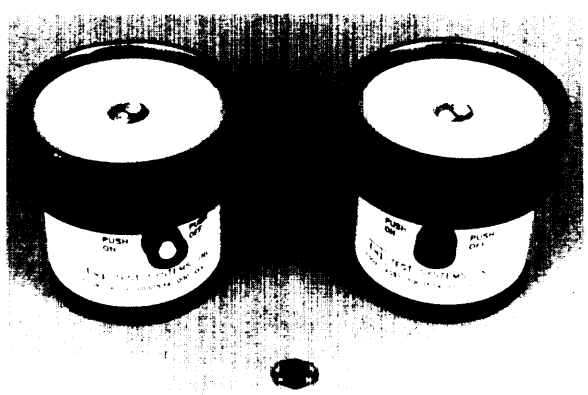
SOURCE: U.S. Army.

tape or paint that showed up on infrared imaging devices while being fairly unobtrusive visually.

▮ Beacons

The target vehicle might instead *broadcast* a signal in all directions, identifying itself as friendly, as illustrated in figure 5-3b. This is the principle of the so-called "DARPA Lights" and "Budd Lights."[4] Attaching flashing lights to combat vehicles may seem unwise, since they reveal the vehicles' position to the enemy as well, but these particular lights are only visible in the near-infrared. In the Gulf War, the Allied forces were widely equipped with infrared image-intensifiers and the Iraqis were not. In addition, the DARPA Light is fitted with an adjustable shroud that blocks ground observers' views of the light while keeping it visible from aircraft. This simple security measure was useful, again, because of limitations of the enemy: the Allies had total air dominance leaving no Iraqi airborne platforms to observe DARPA Lights from above. (DARPA Lights were acquired and ready to deliver to the Gulf, but the conflict ended just before shipment.)

The Thermal Identification Device, or TID, is another beacon system in limited current production. The TID is a simple bent metal sheet in the shape of a roof. The sheet is heated electrically on one side to generate a thermal signal. The other side reflects the cool thermal image of the sky. The sheet is mounted on a short mast and an electric motor rotates the sheet. Thus an observer seeing the TID through an infrared image will see an alternating bright and dark spot.[5] See figure 5-4. The disadvantages of the TID include lack of



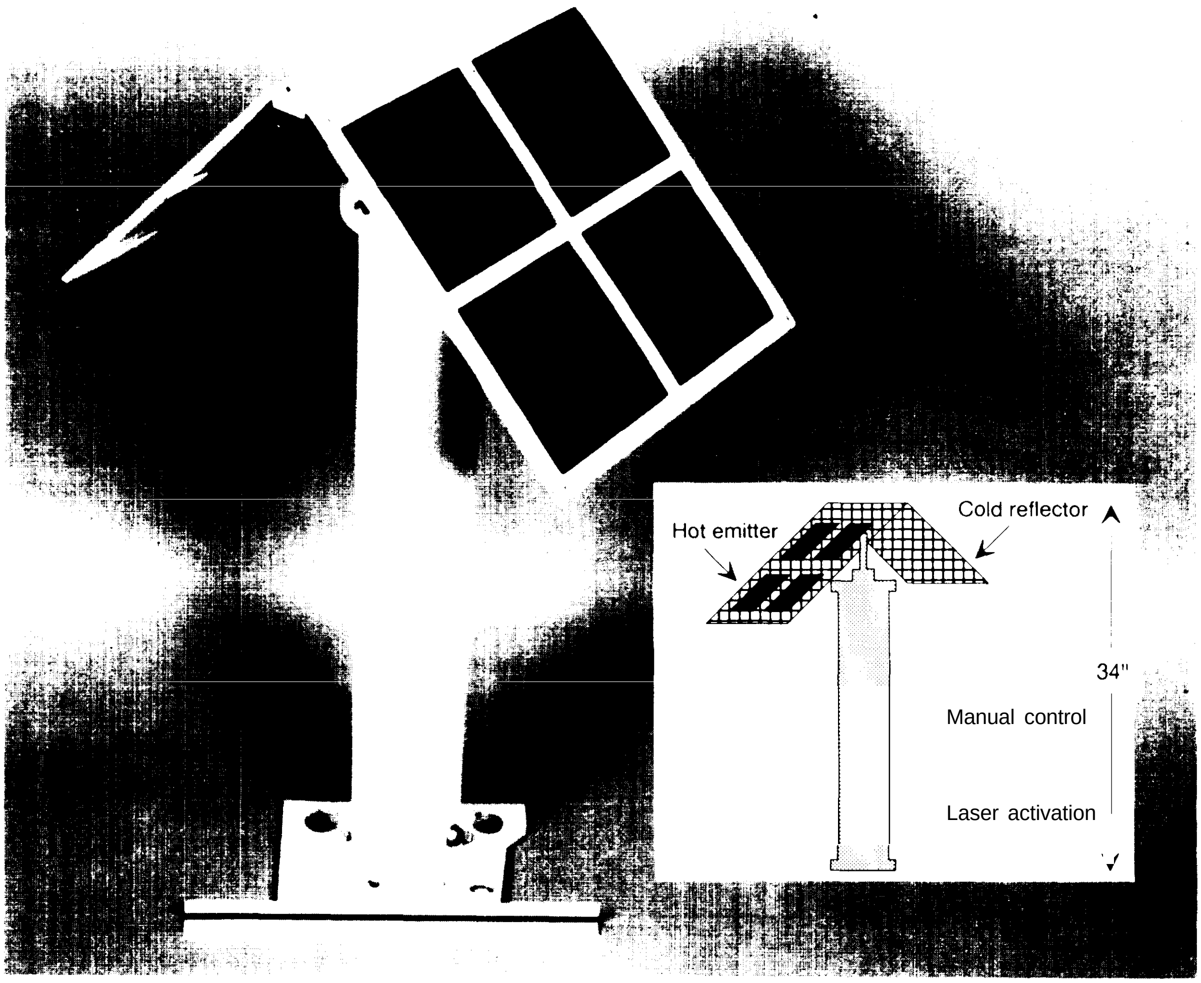
U.S. ARMY

The ''DARPA Light' is a simple infrared beacon visible only through night-vision goggles.

4 The name @@t have stuck because of its similarity t. that of a popular malt beverage, but the transmitter was originally so named after its inventor, Henry ''Bud' Croley at the U.S. Army Night Vision Laboratory who, along with Wayne Antesberger, holds U.S. patent number 4862164 on the device.

5 Briefing entitled, ''Thermal Identification Device (TID) for Combat Identification,'' John R. Gresham, Night Vision and Electro-optics, Night Vision Laboratory, Ft. Belvoir, Virginia (undated).

Figure **5-4-The Thermal Identification Device (TID)**



SOURCE: U.S. Army.

security (any enemy with the proper thermal sights can see it as well as other friends can) and unreliability (apparently the exhaust plume from the engine of the M-1 tank can obscure the TID from certain angles).

Near-infrared blinking lights, such as the DARPA and Budd Lights, have two related drawbacks. First they are visible to anyone, friend or foe, with near-infrared night-vision image-intensifiers, which are cheap and widely available through the mail for about a thousand dollars. Thus, any enemy might have at least a few devices that could detect the beacons. Second, they are *not* visible to the far-infrared imaging devices used to aim the guns and other weapons on U.S. armored vehicles. The TID avoids these short-comings. Whereas the near-timed image intensifiers are relatively inexpensive, far-infrared viewers are a hundred thousand dollars or more, and correspondingly fewer countries have the devices widely deployed. The TID also radiates at the wavelengths at which the far-infrared targeting viewer is most sensitive.

Future systems operating on the same principle could use continuous omnidirectional *radio transmissions*. Signals sent by radio would have longer range than visible or infrared light, especially in fog, rain, dust, or smoke. Of course, special provisions must be made to keep an enemy from intercepting and exploiting the signals. Possibilities include spread-spectrum signals-described in the previous chapter--or time-synchronized signals. Either approach forces an enemy to listen to radio noise over a wide range-of frequency bandwidth or time-and filter out a signal, while friendly forces, knowing the waveforms or the time sequence pattern, can listen only for the signal.

Question-and-Answer Systems

Having friendly targets broadcast only when interrogated by another friendly shooter provides additional security against enemy intercept and exploitation of identification signals. This approach is illustrated schematically in figures 5-3c and 5-3d.

Queries

The query signal could be a laser or some radio pulse. The query pulse should be directional, otherwise on a complex battlefield each tank's query would set off all tanks' responses and matching up queries and responses would be hopelessly complicated.

The queries should also be encrypted to authenticate them as coming from friends. This keeps the enemy from exploiting the system. The enemy might, for example, suspect that U.S. vehicles lie camouflaged along a tree line but not know where. If sweeping the whole treeline with a laser or radio pulse caused all the U.S. weapons to send out IFF replies, they would reveal their positions, so the response must come only after receipt of a valid, encrypted query.

A potentially cheap IFF approach would be adapting the existing laser range-finders now fitted on U.S. tanks. A danger of this approach is that the laser signal will not reliably penetrate smoke, fog, and dust. This may not cause a problem for the laser's range-finder function—after all, ranging the target, the dust cloud around it, or the tree next to it is good enough to get a hit with a flat trajectory weapon like a tank gun. But if the laser did not penetrate intervening dust, then the target would never get the query and would never send off a friendly response.

The query signal would be sent through a simple directional antenna aligned with the weapon. It could be, for example, fixed to the barrel of the tank gun or to the turret much as the laser range-finder is now. The same simple directional antenna would then naturally be lined up to pick up the signal from the particular target in question and not any other.

The Army's current near-term solution will use a millimeter wave radio beam as the query signal. Millimeter waves can penetrate obscurants, like dust, and they can be fairly narrowly focused.[6]

Replies

The reply signal could be any of those described above for a passive observer with much the same advantages and disadvantages. Like the query, the reply signal would have to be encrypted in some way that the enemy could not reproduce,

Since the reply would be sent out only when the system is properly queried, somewhat less attention could be given to avoiding intercept by the enemy. For example, some proposed systems would determine the general, but not exact, direction of the query and return a bright, broad laser beacon to show that the target is friendly, accepting that the beacon would sometimes be

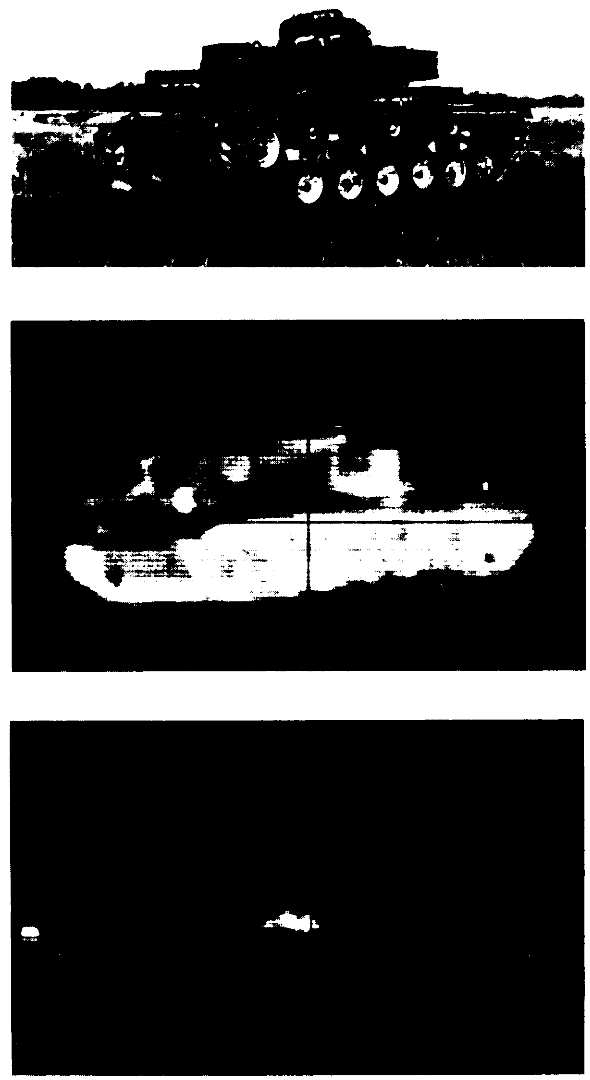
[6] U.S. Army, Combat Identification System Program Office, Ft. Meade, MD, ''Report to the Committees of the United States Senate and House of Representatives on the Combat Identification Program, " January 1993.

seen by enemies. Alternately, omnidirectional radio beacons, illustrated in figure 5-3c, could announce that the target is friendly. Omnidirectional broadcast is much simpler because it removes any requirement for steering an antenna—very quickly!—in a particular direction.

A directional reply, shown schematically in figure 5-3d, would provide additional security by making enemy intercept less likely. One clever approach would use the interrogating laser as its own reply signal by reflecting the laser back to its origin using a comer reflector. (A corner reflector is just a set of reflective surfaces in the shape of the inside of the comer of a cube. The geometry of the surfaces is such that no matter which direction a light beam enters, it is reflected back out in exactly that direction.) The reply would be authenticated by modulating or chopping the query pulse in some way, for example, by turning on and off liquid crystal windows covering the comer reflector. This particular approach, using lasers, would be unreliable in smoke or dust. Radio frequencies could penetrate better and could use the same principle with the authentication provided by vibration of the reflective surfaces to produce a detectable Doppler shift in the return signal or by rapidly changing the impedance of the reflecting antenna-similar to the pre-World War II proposals for varying dipoles on aircraft.[7]

DISMOUNTED INFANTRY

Most of the effort for IFF devices has centered on the identification of *vehicles,* not people. At present, programs examining exclusively the problem of identification of dismounted infantry are in the planning stage. The Army intends to fund dismounted infantry IFF programs in the coming and subsequent fiscal years. Infantry almost always work closely with vehicles of some sort and any vehicle-mounted system will also help prevent mistaken attacks on friendly infan-



U.S. ARMY NIGHT VISION LABORATORY

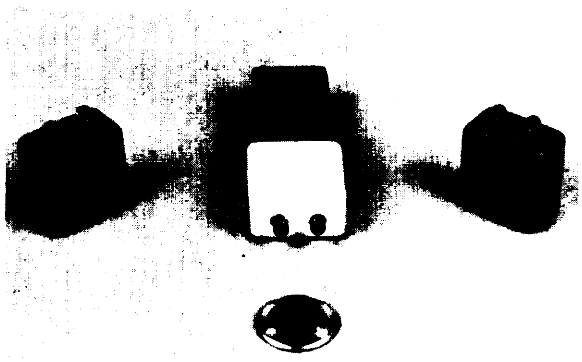
These three images are of the same tank on a test range. The top is a close-up taken in visible light at midday. The tank as seen at night through infrared ''image intensifiers' at a range of 500 meters is shown in the middle image. The bottom image is the tank seen through the same device but at 1500 meters. Modern optics and electronics allows the detection of vehicles beyond the range at which they can be reliably identified.

[7] Briefing entitled, "Achieving Covert Communications and Ground-Combat Identification Using Modulated Scatterers,' E.K. Miller and D.M. Metzger, Mechanical and Electronic Engineering, Los Alamos National Laboratory (Mar. 11, 1992).

try. Moreover, navigational and communications improvements that increase tactical knowledge will reduce fratricide of infantry as well as vehicles, even without specific new IFF capabilities.

One of the quick fixes used in the Persian Gulf and mentioned already was the small, battery-powered blinking infrared light called the Budd Light. Its flashing is invisible to the unaided human eye but shows up clearly at night through night-vision goggles or other near-infrared image-intensifiers. The device is cheap and easily produced by components from retail electronics stores. Being so widely available, it hardly counts as an IFF device but it can be a useful command and control device. For example, one combat unit may know that another unit is somewhere in front of it in a group of trees but not know exactly where. Getting the two units coordinated by describing features at night over the radio is difficult, but a request to turn on the infrared blinkers for five seconds could make relative positions clear in an instant, and thus help avoid fratricide.

Future research will include work on techniques specifically directed toward infantry identification. Some of these ideas are modern incarnations of World War I infantry identification efforts that included sewing mirrors on the backs of trench coats to aid identification by friendly aircraft overhead. Notional proposals include: fabrics that reflect millimeter waves or fabrics and dyes that reflect only very specific wavelengths chosen to match up with the wavelengths detected by targeting sensors; fabrics and **dyes** that luminesce under specific laser illumination; retro-reflectors on combat uniforms; and active infrared displays on the uniforms.[8]



U.S. ARMY NIGHT VISION LABORATORY

''BuddLights' are invisible to the naked eye but show up clearly through night-vision goggles.

NONCOOPERATIVE IDENTIFICATION

Development of noncooperative identification of ground targets is perhaps at an even earlier stage than it is for air targets, but some ideas have surfaced. Just as for air targets, the simplest identification technique is based on the outward appearance of the vehicle. Again, as for air targets, this simple approach is made very complex by the proliferation of U. S., British, French, Russian, and other weapons throughout the world.

A straightforward improvement in identification capability would come from improvement in imaging devices, for example, higher resolution for infrared detectors, laser radars that provide three dimensional images, and so on.

More subtle clues to identity might be provided by, for example, vibrations of the surface of the vehicle, detectable by Doppler radar. Doppler radar shows some promise for the identification of helicopter because of the characteristic Doppler shifts caused by the rotating blades.[9]

Sensors might be able to pick up characteristics of the vehicle exhaust, even detecting differences in fuel type,[10] or sensors could look at the

8 ''Information Paper: Identification Friend or Foe for the Individual soldier, ' Robin St. Pere, U.S. Army, Natick RD&E Center, Oct. 6, 1992.

9 Briefing entitled, "Radar Helicopter Identification, " Gerardo Melendez, EW/RSTA Directorate, Us. Army Communications and Electronics Command (undated).

10 Briefing entitled, ' 'Laser Radar Effluent Sensor," Guil Hutcheson, Los Alamos National Laboratory (undated).

reflectivity of the vehicle in several spectral ranges.[11] For ground combat application, each of these techniques that depend on detection of subtle spectral differences should be approached with a healthy skepticism, since transmission of radiation through the dirty, dusty, smoky, foggy air of the battlefield will often be the fundamental limit to their performance. In addition, one must consider the effects of trees, buildings, and intervening terrain.

Some sensor systems have been developed to detect enemy vehicles on the battlefield. For example, the Remotely Monitored Battlefield Sensor System, or REMBASS, uses a combination of acoustic, seismic vibration, magnetic, and infrared sensors to detect vehicles. With some added sensitivity, each of these techniques might be able not just to detect, but identify, vehicles. These sensors are typically short range and fixed so they are probably better at providing tactical intelligence about enemy vehicles to a communications network than at providing the information directly to a shooter.

CURRENT PROGRAMS

A quick review is worthwhile to repeat what is hypothetical and what is under active consideration or development. The Army divides its development efforts into four time categories. The "Quick Fix" was intended to get something into the hands of troops immediately. Quick fixes include the Budd and DARPA Lights, receivers for satellite transmissions of global positioning data, and the infrared-reflective "thermal" tape that were rushed into service during the Persian Gulf War. The Thermal Identification Device described above is another quick fix.

After the Persian Gulf War, the Army acquired 20,000 Budd lights, which are to become logistic stock items, and contracted for 120,000 square feet of thermal tape. The Army also has the 8,000 DARPA Lights acquired during the Persian Gulf War. The Army will acquire 300 TIDs, or the parts required for rapid assembly. Production will beat Tobyhanna Army Arsenal. This will provide enough TIDs for an armored brigade. (Note also that the extreme simplicity of the TID should allow rapid surge production.) The Army also has bought, or is in the process of buying, over 10,000 global position receivers called Small Lightweight Global Positioning Receivers, or SLGRs (pronounced "slugger").

The near-term program aims to get something in the field in five years or so. The ideal near-term system should require little or no additional research and development. A request for proposals sent to industry solicited numerous responses. A test at Ft. Bliss, Texas examined many of the proposed systems using actual combat vehicles under realistic desert conditions.[12] The result of that test was selection of a millimeter wave question-and-answer system for near-term development and deployment. One of the disadvantages of a millimeter wave system is that it will be difficult to incorporate into airplanes, but compatibility between aircraft and surface vehicles is only a desirable characteristic for near-term solutions and a *requirement only* for far-term solutions. The Army has set a limit of $100 million for total costs to produce approximately enough identification devices for 1,500 vehicles, not enough to outfit the whole army but enough for a substantial contingency force.

Mid- and far-term solutions are intended to provide a more permanent solution in seven or more years. These programs are now in the exploratory stage.

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11 These notional approaches are taken for a briefing presented by Wayne Grant, "Electro-Optics (E-O) Technology for Positive Target Identification%" United States Arrny, Night Vision and Elecro-Optics Directorate, Fort Belvoir, VA (undated).

12 Training and Doctrine Coremand, *Combat ID Tech Demo,* June 9, 1992. Because of limitations of the desert test sites, performance in fog, rain, or forest could not be tested.

TACTICS, DOCTRINE, AND TRAINING

The Army has not given as much explicit attention to avoiding fratricide in the past as might be expected, but this is because troop safety was a natural, integral part of coordination and planning. The Army now believes, however, that friendly fire requires special treatment in tactics, doctrine, and training.

Some changes in tactics are possible. For example, most of the Persian Gulf fratricides occurred under conditions of reduced visibility, either darkness or dust and haze. If the goal were to reduce fratricide, then one easy solution would be to never attack except under clear daylight conditions. Remember, though, that low visibility for U.S. forces often translates into no visibility for enemy forces not equipped with infrared or image-intensifying viewers. Night attacks reduce the enemy's effectiveness, including his ability to inflict casualties, and thus reduce casualties overall.

Nevertheless, technical advantages enjoyed by the United States, compared to a wide spectrum of potential adversaries, could allow changes in tactics. For example, in the Persian Gulf, U.S. forces could often see, hit, and kill Iraqi targets that could not even see the forces shooting at them. Under these conditions, more cautious, deliberate attacks might be able to keep both fratricidal and enemy-inflicted casualties down.

Training is extremely important to avoiding fratricide in future conflicts. The Army's training centers now pay special attention to fratricide incidents and collect the information for an on-going "lessons-learned' study. Firing ranges are now equipped with both enemy and friendly targets to practice ' 'Don't Fire! situations.

Simulation is an important part of modern training. In the past, simulators have been much better at depicting the day-lit world than the night world seen through infra-red viewers. Yet most of the fratricide in the Persian Gulf occurred under some sort of reduced visibility. Simulation for training is a rapidly progressing field and simulation of poor-visibility conditions must be supported in future programs.

CONCLUSIONS

Ground combat illustrates most clearly the vital importance of tactical knowledge of the battlefield to avoiding fratricide. Indeed, by some estimates, the majority of fratricide could be avoided by improvements in navigation and communication without a dedicated IFF system. For the foreseeable future, however, IFF devices will probably also be desired to compensate for gaps in tactical knowledge.

Navigation-communication systems and IFF systems will be pursued in parallel but, when comparing costs, one should keep in mind that avoiding fratricide is just one advantage of improved knowledge of the battlefield. Better information will increase maneuverability, flexibility, control and coordination of units and fire, and, hence, overall combat capability.

The Army's preferred near-term solutions will be difficult and expensive to incorporate into fixed-wing aircraft, This alone might make it unacceptable as a permanent solution if fixed-wing aircraft are expected to continue to provide close air support. One of the important policy questions is how to allocate resources between solutions that provide quick, but limited, results and more permanent solutions, which admittedly will take longer to implement.

The Army's technology and equipment to avoid ground combat friendly fire is primitive compared to Navy and Air Force equivalents. Army programs may need preferential funding for several years just to catch up to the level enjoyed by its sister Services today. The distribution of fratricides in the Persian Gulf argues for this relative shift in effort, at least until imbalances are less pronounced.